DRAFT

Forest Landscape Restoration Opportunities Assessment

Multi-Criteria Spatial Analysis

Transboundary Report

IUCN PACO is implementing a regional project, named "Ecosystem Conservation and Management of International Water Resources of the Mano River Union ", in four African countries: Côte d’Ivoire, Guinea, Liberia and Sierra Leone.

Contents

1. Background

The Mano River Ecosystem Conservation and International Water Resources Management Project hereinafter referred to as Manu River Project is a project funded by the GEF implemented in four member countries of the Mano River Union, namely Côte d'Ivoire, Guinea, Liberia and Sierra Leone.

The Manu River Project aims "to strengthen transboundary natural resource management for sustainable ecological benefits and improved livelihoods for adjacent forest communities", through supporting local communities in developing alternative sources of income to facilitate sustainable management and related benefits of natural resources at local, national, regional and global levels (ecosystem services, biodiversity, carbon sinks).

The project has two components: Component 1: Integrated Forest Ecosystem Management and Component 2: Sustainable Management of Transboundary Waters.

Under the Component 1 the project selected the Restoration Opportunities Assessment Methodology (ROAM), in order to restore forest ecosystem services, conserve biodiversity and increase the resilience of the local livelihoods. This methodology aims to identify, analyse and locate specific areas of Forest Landscape Restoration opportunities based in a spatial multi-criteria analysis. The process is based in the stakeholder engagement and is driven by the context in analyse.

This report focus in the spatial mapping, one of the key components of the ROAM. Under this project this component is named Activity 1.9 and focus on the spatial analysis of degradation and restoration opportunities at the watershed level. This approach allows carry out the assessment at the landscape level, what will generate a more general information, that could guide more broad decisions in terms of biodiversity and social benefits. The landscape approach is considered very important to global restoration efforts (Laestadius et al., 2015), but also to address drivers of degradation (Weatherley-Singh & Gupta, 2017).

This activity was developed by each country for each forest block. This report should be based in the information provided by these individual maps, however some issues related with the methodologies applied and incompatibilities in the information prevented its use, so this report was developed with information available in the global datasets. The standardisation of the methodology and data used across all the landscape allows the comparison between the different transboundary blocks, as well as a prioritisation based in the same criteria. Indeed the spatial analysis provide useful information More detailed information is needed to complement this assessment and to identify

1.1 Project Area Description

The Mano River project targets the conservation and sustainable use of the transboundary water basins and their biodiversity resources within the four member states of the Mano River Union, namely Côte d'Ivoire, Guinea, Liberia and Sierra Leone.

The transboundary protected area complexes (Table 1, Figure 1) will be the four target landscapes of the Mano River project as outlined below:

- the Diecke National Forest Area Complex in Guinea, the Mount Nimba Strict Nature Reserve in Guinea and Ivory Coast and the East Nimba National Park in Liberia designed hereinafter
- the Wonegisi Ziama National Forest Protected Area Complex between Liberia and Guinea,
- the Gola Rain Forest National Park Protected Area Complex in Sierra Leone and The Gola National Forest in Liberia,
- The Sapo National Park Protected Area Complex and the Grebo National Park in Liberia.

Table 1. Forest block's areas

TARGET LANDSCAPE (DESIGNED HEREINAFTER)	FOREST BLOCK	COUNTRY	AREA (SQ KM)	AREA (HA)
SITE 1 DIECKE AND NIMBA	Diecke National Forest Area Complex	Guinea	592,31	59 231
	Mount Nimba Strict Nature Reserve	Guinea and Ivory Coast	192,55	19 255
	East Nimba National Park	Liberia	135,79	13 579
SITE 2 WONEGISI AND ZIAMA	Wonegisi Ziama National Forest Protected Area Complex	Liberia	380,05	38 005
		Guinea	914,80	91 480
SITE 3 GOLA	Gola Rain Forest National Park Protected Area Complex	Sierra Leone	710,41	71 041
	The Gola National Forest	Liberia	979,54	97 954
SITE 4 SAPO AND GREBO	Sapo National Park Protected Area Complex	Liberia	1550,86	155 086
	Grebo National Park	Liberia	971,45	97 145
TOTAL			**6427,76**	**642 776**

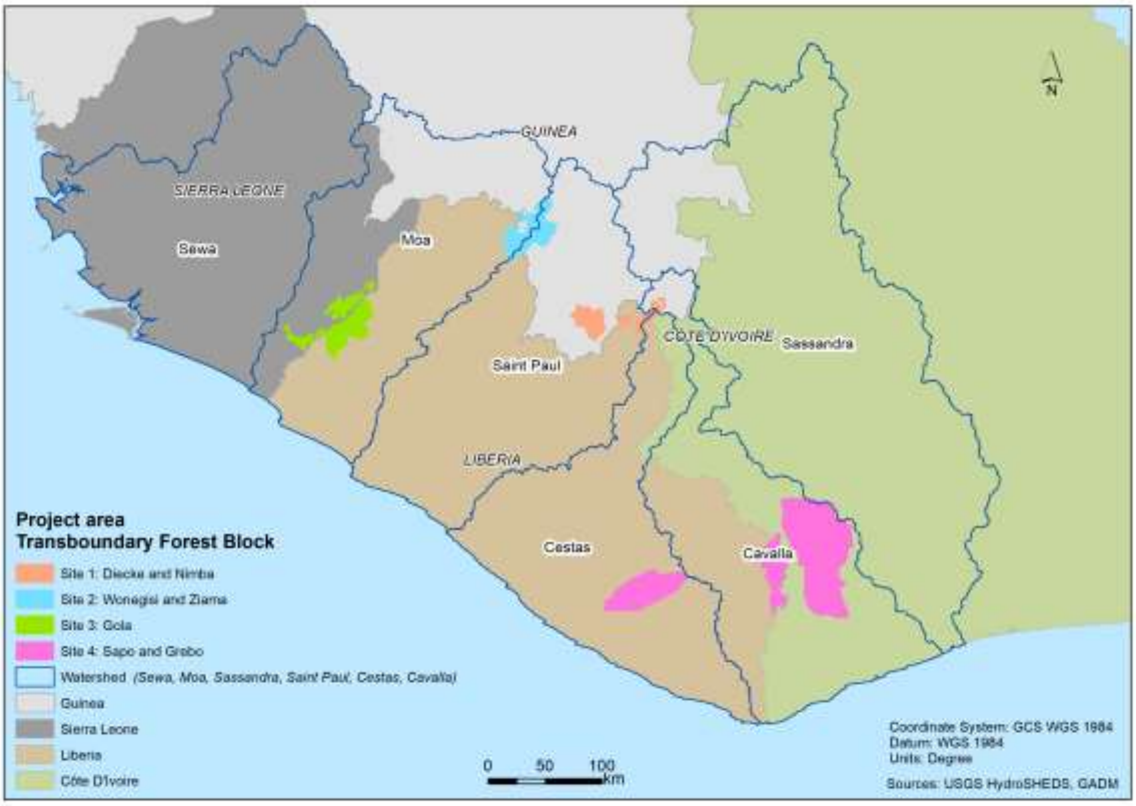

Figure 1. Location of the 4 transboundary forest blocks

The four sites occupied an area of more than 640 000 hectares and contain the last large blocks of intact and semi-intact forest mosaics left in the entire Upper Guinean Forest ecosystem (Figure 2). The Mano River project represent an opportunity to launch an integrated forest ecosystem management in the whole area to conserve and improve the Upper Guinean Forest ecosystem and the livelihoods for adjacent communities.

The Guinean Forest of West Africa is a biodiversity hotspot that supports impressive levels of biodiversity, having high levels of species richness and endemism (IUCN, 2015).

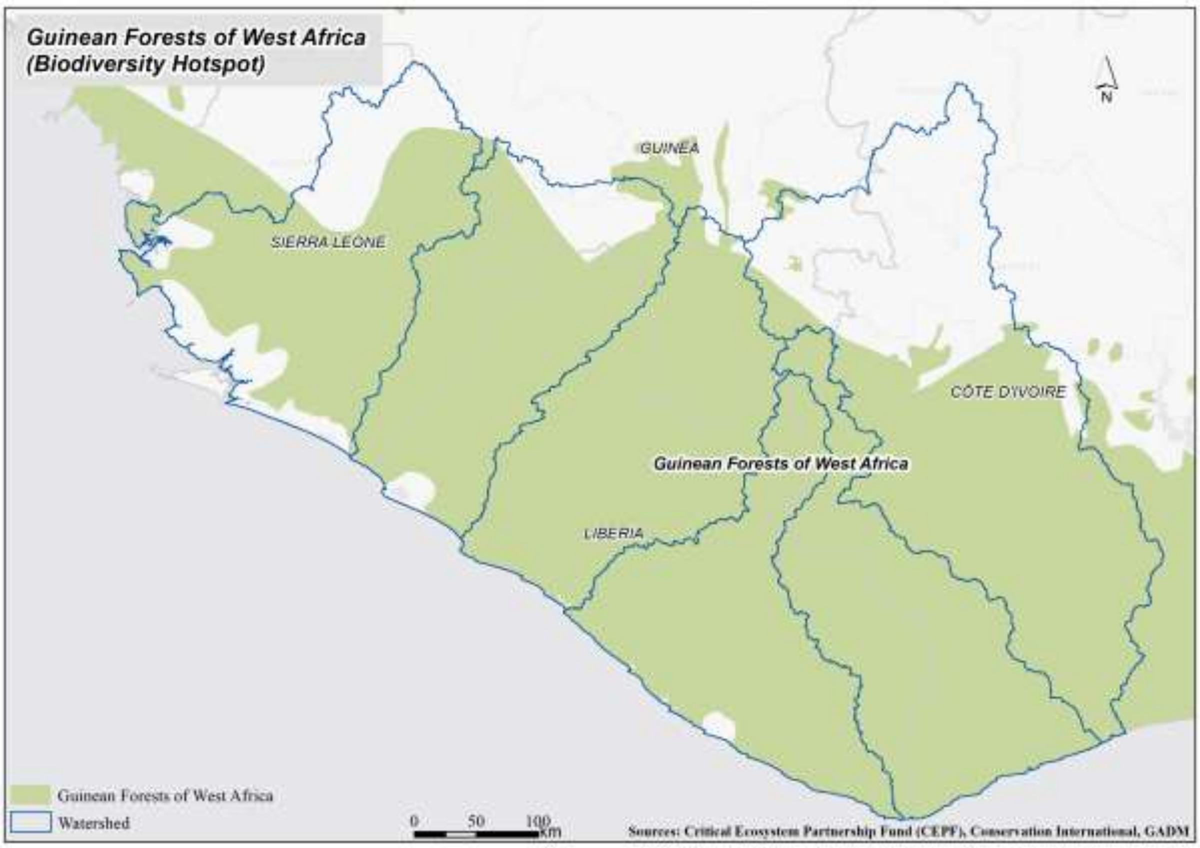

Figure 2. Extension of the Guinean Forests of West Africa (Biodiversity hotspot)

In addition to their biological richness, a number of ongoing threats to biodiversity in the Guinean Forests have resulted in the loss of more than 85 percent of the native vegetation cover (Mittermeier et al. 2004). Major threats include agricultural expansion to provide for the needs of an expanding population in rural and urban areas, unsustainable logging and fishing, hunting and trade of bushmeat, industrial and artisanal mining, industrial development, climate change and pollution, among numerous others (IUCN, 2015). Many of the threats to biodiversity occurring in the region are linked, either directly or indirectly, to a high incidence of poverty, political instability and/or civil conflict (IUCN, 2015).

The Mano River project intends to address the conservation issues of these relicts of the Upper Guinean Forest ecosystem through sustainable management of transboundary ecosystems. The Mano River project will support local communities in developing alternative means of income generation, which will lead to an increase in forest coverage and its related benefits both at the local (ecosystem services) and global (biodiversity and enhanced carbon sinks) levels

1.2. Situation analysis

a. Context

The four countries of the Mano River Union cover approximately 735 000 km^2. Sierra Leone cover an area of 72 600 km^2, Liberia 92 900 km^2, Guinea 244 800 km^2 and Côte d'Ivoire 321 600 km^2. According to the World Bank[1], in 2018 the population is estimated to 49 952 million inhabitants (4 819 million in Liberia, 7 650 million in Sierra Leone, 12 414 in Guinea and 25 069 million in Côte d'Ivoire).

These countries have high proportions of their populations below the income poverty line (USD 1.90 per day in 2011). Côte d'Ivoire in 2015 has 28.2% of the population below this poverty line, in Guinea 63% of population in 2012, Liberia 40.9% of population in 2016 and Sierra Leone 52.2% in 2011[2] .Their Human Development Index[3] are among the lowest in the world, in 2019 their score falls below 0.55. Concerning the Global Hunger Index, in 2019 all the countries fall in the serious category with scores higher than 20.0 (Côte d'Ivoire 24.9, Guinea 27.4, Liberia 39.4 and Sierra Leone 30.4)[4].

These indicators show up the weak economies of the countries characterized by high levels of poverty, whose been exacerbated by the high population growth rate and the internal conflicts that all the countries have experienced over the last 25 years. Liberia has a civil war between 1989 and 2003, and Sierra Leone between 1991 and 2002. Guinea hosted about 3 million refugees from both countries. These civil war led to a series of direct and indirect impacts on conservation, for instance rebel groups destroyed or damaged park facilities as well as urban, water and agricultural infrastructure in rural areas and towns in the east of the country (UNEP 2010). Although environmental conditions declined in general as a consequence of the overall state of lawlessness, the illegal exploitation of natural resources was particularly damaging (Tigani and Brandolini 2006).

Another important factor is the Ebola outbreak in the region in 2014 with an important socio-economic impact particularly in Guinea, Liberia and Sierra Leone, the mainly consequence was an important drop in the grow rate of the three countries.

The MRU countries share 10 transboundary river basins and also the last remnants of a unique Biodiversity Hotspot area, the Upper Guinea Forest. Both the rivers and the forests have been threatened by the development of agro industrial plantations, mining operations, expansion of slash and burn agriculture and poaching.

These factors associated with observed changes in the regional climate resulted in the decrease of precipitation and drive to problems like water quality and quantity, deforestation and loss of biodiversity. This situation is aggravated due to the high dependency of the population on these forest resources both for timber and non-timber forest products.

The high population increase that is a result from a combination of reproduction and inward migration, leads to a need of agriculture expansion to meet population needs. In this regard,

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[1] World development Indicators database, World Bank, 19.09.2019 (https://databank.worldbank.org/data/download/POP.pdf)

[2] World Bank: http://povertydata.worldbank.org/poverty/region/SSF accessed: 20.10.2019

[3] World Bank: http://worldpopulationreview.com/countries/hdi-by-country/ accessed: 20.10.2019

[4] World Bank : https://www.globalhungerindex.org/results.html accessed: 20.10.2019

agriculture expansion has been the most significant cause of deforestation and 80 percent of original Guinean Forests can now be considered as an agriculture-forest mosaic (Norris et al. 2010). Today, forests have been, and continue to be, cleared or degraded for expanding areas of agriculture, including for commercial crops. However, the forest ecosystems and water resources have an imperative role in meeting the livelihoods needs of their population therefore its conservation is fundamental for a sustainable development.

b. FLR objectives

Forest Landscape Restoration is a collaborative and participatory process, hence the stakeholders must agree on the long-term objectives for their landscapes. They will be important to define the current condition of their landscape and the desired condition that they want to achieve through landscape restoration intervention. In this regard, in the ROAM workshop the objectives to be achieved through Forest Landscape Restoration are:

- poverty alleviation and improving livelihoods through income generation activities,
- biodiversity conservation and restoration of forest ecosystem services.

These objectives will be considered in the analysis to help define opportunity areas where specific forest landscape restoration interventions should be implemented to target these objectives.

c. Drivers of deforestation and land degradation

This Mano River region is one of the poorest in Africa with weak economies, institutions and political systems. The four countries of the Mano River have experienced internal conflicts over the last 25 years. This situation is aggravated by the high population growth and rapid urbanisation. The populations mostly living in fishing, farming or forest communities are very dependent of natural resources, putting a lot of pressure namely on timber and non-timber products, which leads to degradation, particularly to high rates of deforestation.

The degradation in Mano River region has been causing problems in water quality and quantity in their downstream catchments, particularly during the low flows, but also decreasing biodiversity.

The assessment of the drivers of degradation, extent and location is crucial for the assessment of forest landscape restoration opportunities in a country. The drivers of degradation identified by the stakeholders during the inception meeting of the Mano River Project are presented in the Table 2. Agriculture expansion, artisanal mining and exploitation of non-forest timber products are considered by the stakeholders the mainly drivers of degradation across the four landscapes. Between the mainly causes we can also find hunting, forest exploitation and wildfires. The secondary causes are human migration, logging, fire wood extraction and bush burning.

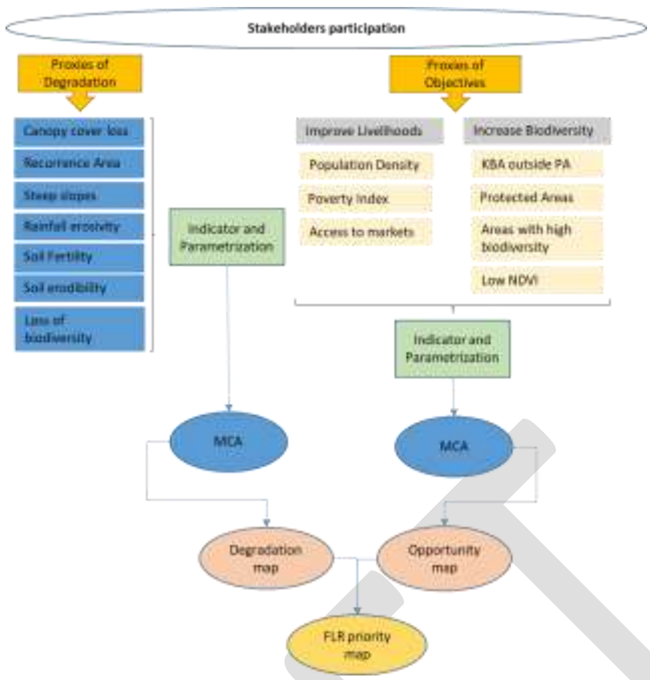
Table 2. Drivers of degradation

#	LANDSCAPE	#	DRIVERS OF DEGRADATION
1	**MONT NIMBA**	*I*	Agriculture
		Ii	Loss species
		Iii	Wildfire
		Iv	Artisanal mining
		V	Sedimentation of running water
		Vi	Human migration
		Vii	Water pollution
		Viii	Forest exploitation
2	**Ziama-Wonegizi**	*I*	Agriculture
		Ii	Non-timber forest products
		Iii	Forest exploitation
		Iv	Braconnage
		V	Cutting down of trees (wind)
		Vi	Loss of species
		Vii	Artisanal mining
		Viii	Reduction of water quality
		Ix	Water pollution
		X	Human migration
3	**GOLA**	*I*	Slash and burn
		Ii	Artisanal mining
		Iii	Hunting
		Iv	Logging
		V	Water pollution
		Vi	Non Timber Forest Products
		Vii	Charcoal burning
4	**SAPO GREBO TAI**	*I*	Hunting
		Ii	Artisanal mining
		Iii	Harvesting of NTFP
		Iv	Agriculture
		V	Water pollution
		Vi	Fire wood for cooking
		Vii	Charcoal burning
		Viii	Logging of species
		Ix	Human migration
		X	Bush burning

These drivers lead to different types of degradation, which deforestation and loss of biodiversity, soil erosion, sedimentation and water pollution are the most common with a direct impact on human well-being.

1.2.4 Theory of change

Considering the drivers of degradation, the assessment carried out identifies areas where FLR actions should be implemented to generate most social and ecological benefits and revert degradation. A multi-criteria analysis will be implemented to define degradation and opportunity areas to achieve specific objectives through FLR. The output of this assessment is a FLR priority map.



2. Multi-criteria Spatial analysis of Forest Landscape Restoration

2.1 Land Degradation and deforestation

Land degradation has been ranked as a major environmental and social issue for the coming decades (Higginbottom & Symeonakis, 2014). Land degradation affects negatively the livelihoods and food security of global population, so there have been recurring efforts by the international community to identify the global extent and severity of land degradation (Le, Nkonya, & Mirzabaev, 2016).

Although the existing demand for land degradation information, there is no global agreement on its definition neither a standardized methodology for its assessment at different scales (Dubovyk, 2017). In the case of Mano River Project the degradation was assessed based in a multi-criteria analysis (MCA) since this approach allows the integration of the several driving factors behind the degradation problem. As land degradation is a composite issue, an exact measure of it is not possible this MCA will identify the most degraded areas based in a combination of proxies of degradation. These proxies are used as indirect measures to estimate the extent and severity of degradation. These proxies (described in the next sections) were defined based on the drivers of degradation identified for this specific landscape and based on input by stakeholders.

In the context of the Mano River Union, the expansion of agriculture and mining areas as well as exploitation of timber and non-timber forest products have been the mainly drivers that have threaten the last remnants of a unique biodiversity hotspot area, the Upper Guinean Forest. The reasons beyond these drivers are associated with the population increase combine with high levels of poverty and a high reliance on agriculture and forest resources to sustain their livelihoods.

Considering these drivers, proxies such as loss of canopy cover, fire recurrence area, steep slopes, rainfall erosivity, soil erodibility, soil fertility and loss of biodiversity are used in the analysis to assess degradation. Effectively, the combination of this information will identify areas where the biophysical predisposition to degradation is being aggravated by human disturbances.

The output of this analysis is a degradation map (Figure 3) that will be used in all subsequent MCAs for each FLR objective to help identify where the intensity of degradation may overlap with restoration opportunities for improve livelihoods and increase biodiversity.

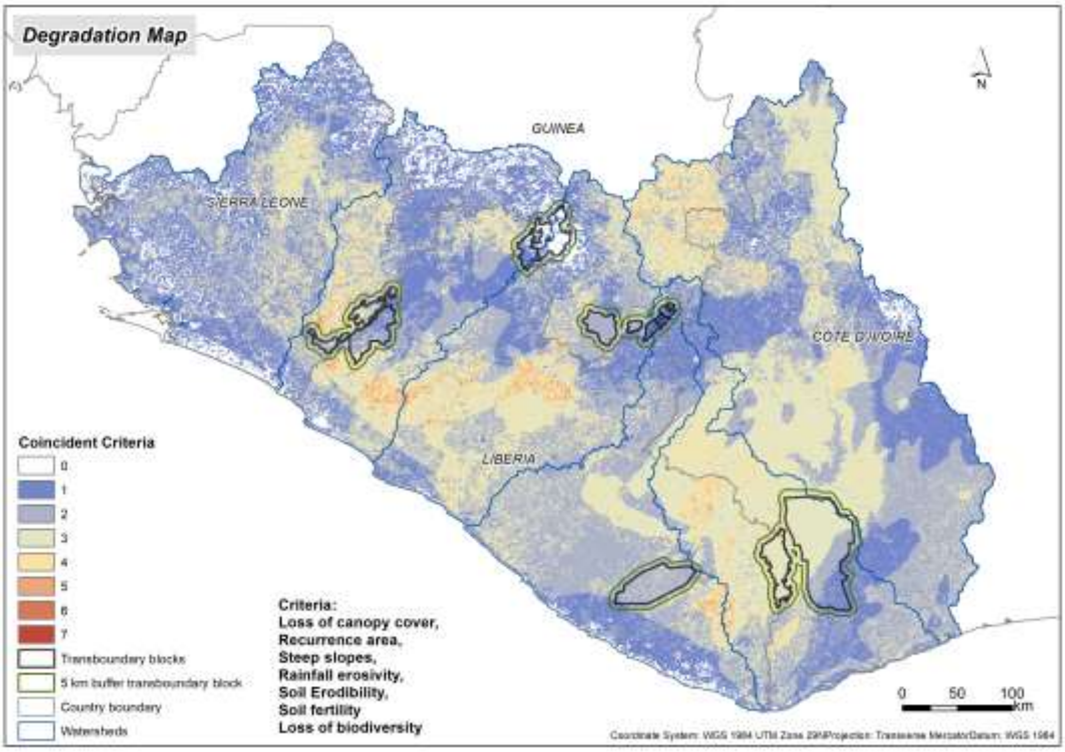


Figure 3. Degradation map. Sept input criteria were used as proxies for the multi-criteria degradation map. Red indicates a larger number of coincident criteria in a specific area, which, based on the input criteria, form a measure of landscape degradation severity.

The map and table below shows the combination of degradation criteria present in the landscape, in areas above 30,000 ha.

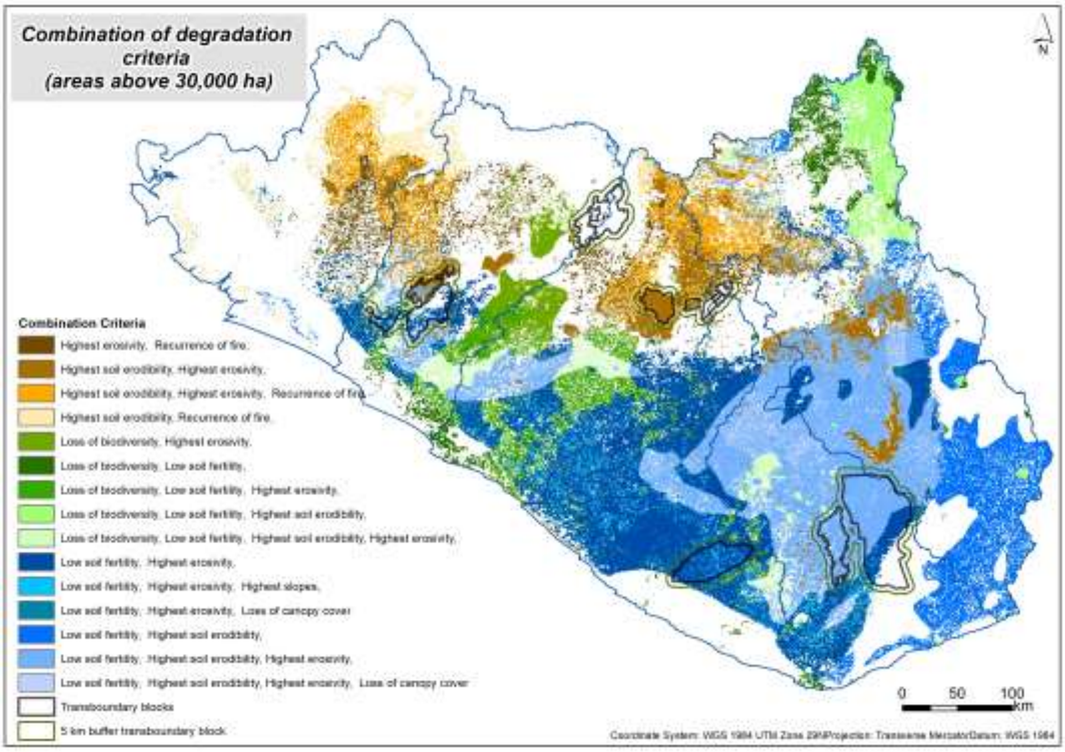


Figure 4. Combination of the 7 input criteria of degradation, considering only areas above 30,000ha

Table 3. Combination of degradation criteria in areas above 30,000 ha

Combination of degradation criteria (areas above 30,000 ha)	**Area_ha**
Low soil fertility, Highest soil erodibility, Highest erosivity	273,021
Low soil fertility, Highest erosivity	265,514
Low soil fertility, Highest soil erodibility	121,174
Highest soil erodibility, Highest erosivity	114,083
Highest soil erodibility, Highest erosivity, Recurrence of fire	63,055
Loss of biodiversity, Low soil fertility, Highest erosivity	54,812
Highest erosivity, Recurrence of fire	41,520
Loss of biodiversity, Low soil fertility, Highest soil erodibility	41,055
Loss of biodiversity, Highest erosivity	40,263
Low soil fertility, Highest erosivity, Highest slopes	39,465
Low soil fertility, Highest erosivity, Loss of canopy cover	37,875
Loss of biodiversity, Low soil fertility	37,611
Low soil fertility, Highest soil erodibility, Highest erosivity, Loss of canopy cover	36,909
Highest soil erodibility, Recurrence of fire	33,409
Loss of biodiversity, Low soil fertility, Highest soil erodibility, Highest erosivity	32,409

The detailed analysis of these proxies and the rationale behind their use as a proxy of degradation is explained below.

a. Loss of canopy cover

Changes in forest cover affect the delivery of important ecosystem services, including biodiversity richness, climate regulation, carbon storage, and water supplies (Foley et al., 2005).

The changes in forest cover is perceived by stakeholders as the mainly evidence of degradation in the Mano River area as a result of agricultural expansion, logging, with particular relevance for the illegal logging, charcoal production and firewood extraction.

The MCA analysis performed to assess degradation, considered the loss of canopy cover as a proxy of degradation. The loss of canopy cover between 2010 and 2018 was extracted from the Global Forest Change dataset (Hansen et al., 2013). Hansen et al., 2013 mapped the annual global tree cover loss at a spatial resolution of 30m based on Landsat data. Forest loss was defined as a stand-replacement disturbance or the complete removal of tree cover canopy (Hansen et al., 2013).

Burivalova et al, 2015, in a study conducted in Masoala National Park in Northeastern Madagascar, about forest loss and degradation considered this dataset as particularly useful for detecting small-scale forest loss and degradation. These authors considered this dataset very valuable in situations where diffuse slash-and-burn agriculture is the principal proximate cause of forest degradation or small scale deforestation. Effectively, in the region of Mano River region the slash and burn agriculture is, according to the stakeholders, a very common practice.

The criteria considered in the MCA is the perimeter of the canopy cover loss between 2010 and 2018 (Figure 4). This criteria pretends to highlight areas where several drivers of degradation such as logging or wildfires has been occurring and could be addressed by FLR interventions.

Proxy	***Criteria***	***Source***
Loss of canopy cover	Perimeter of canopy cover loss (2010-2018)	Hansen/UMD/Google/USGS/NASA https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.6.html

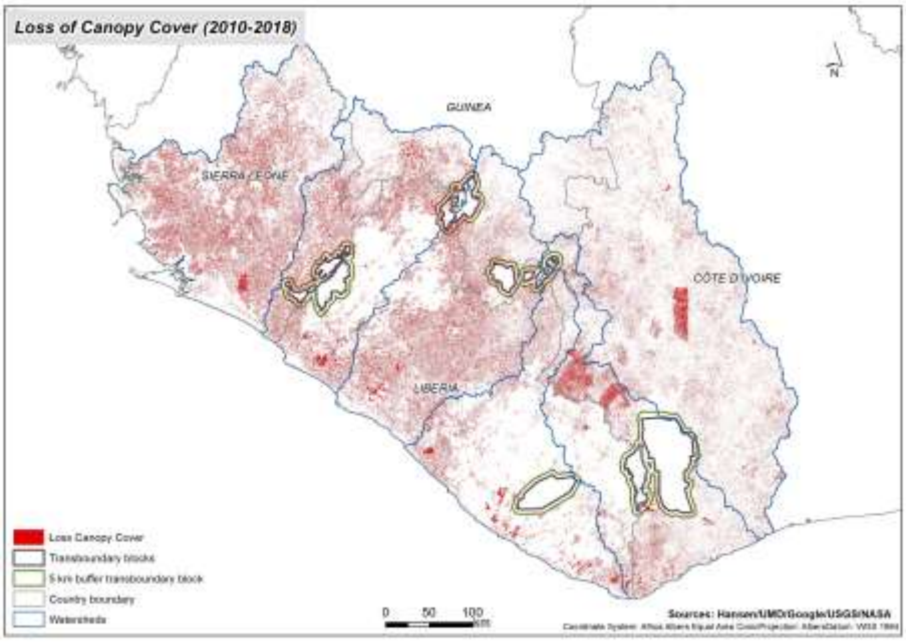


Figure 5. Loss of canopy cover 2010-2018

b. Recurrence of fires

According with the stakeholders in the Mano River the fire is recurrent in these landscapes, mainly associated with the slash and burn agriculture, bush burning or wildfires. Even, recognizing the immediate benefits of the fire mainly for agricultural purposes, the stakeholders refer that the frequency and intensity of fire could have devastating impacts in the environment leading to land degradation.

Considering this, the recurrence of fire is used as a proxy of degradation. To create this proxy, firstly the burned area by year was mapped based in the MODIS (MCD45) burned area product at 500 m resolution collected from the Land Processes Distributed Active Archive Center (LP DAAC) of USGS. Secondly, the annual burned area was combined to identify the number of times each pixel burned between 2010 and 2018. The pixels that burned more than 5 times are considered our criteria to be integrated in the MCA and express areas with the potential of degradation is higher (Figure 4).

Indicator	***Criteria***	***Source***
Recurrence of fire	Perimeter burned more than 5 times	Land Processes Distributed Active Archive Center (LP DAAC) https://lpdaacsvc.cr.usgs.gov/appeears/``

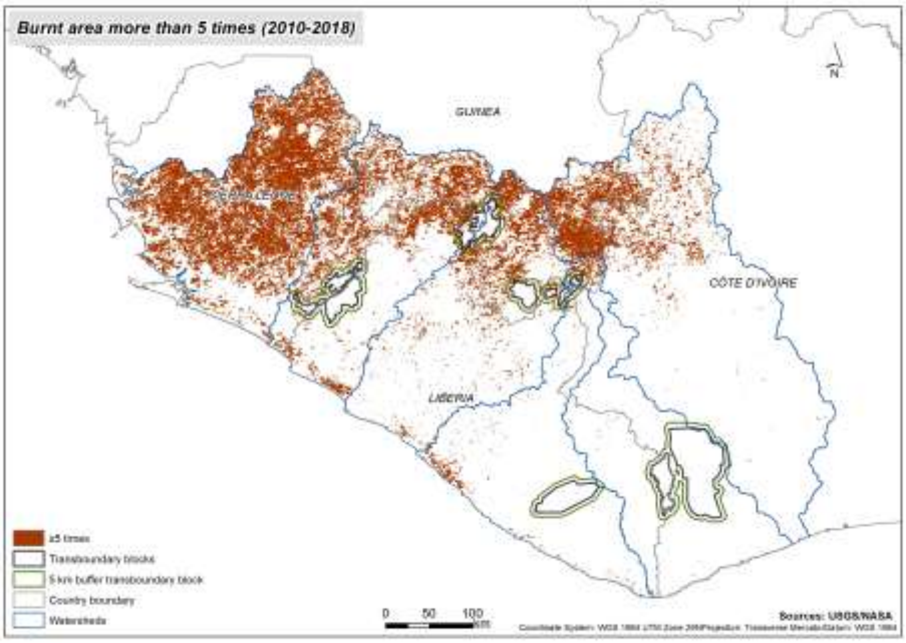


Figure 6. Recurrence of fire - Area burned more than 5 times (2010-2018)

c. Steep slopes

Slope is not necessarily a measurement of degradation, however areas of high slope have greater potential for degradation and represent a reasonable proxy within a multi-criteria analysis. Steeper slopes have a high risk of erosion.

Nevertheless, defining what constitutes “steep” slope is a complex issue and no consensus was found in the literature review. Depending on the nature of the soils, rainfall regimes, and land cover but also on the purpose of this definition the threshold for steep slopes may vary from 5° (Nabiolli et al., 2018) to 22° Koulouri and Giourga (2007).

In the Mano River region the threshold considered in the MCA analysis will be 5° as suggested Nabiolli et al., 2018. We selected the lowest cut off because the slope average in the area is about 2°, however the importance of rainfall and increase changes in land use land cover highlight the importance of this criteria. The slope map was produced based on the CGIAR-CSI SRTM data.

Proxy of degradation	***Criteria***	***Source***
Steep Slopes	Slopes greater than 5°	CGIAR-CSI SRTM http://srtm.csi.cgiar.org/srtmdata/

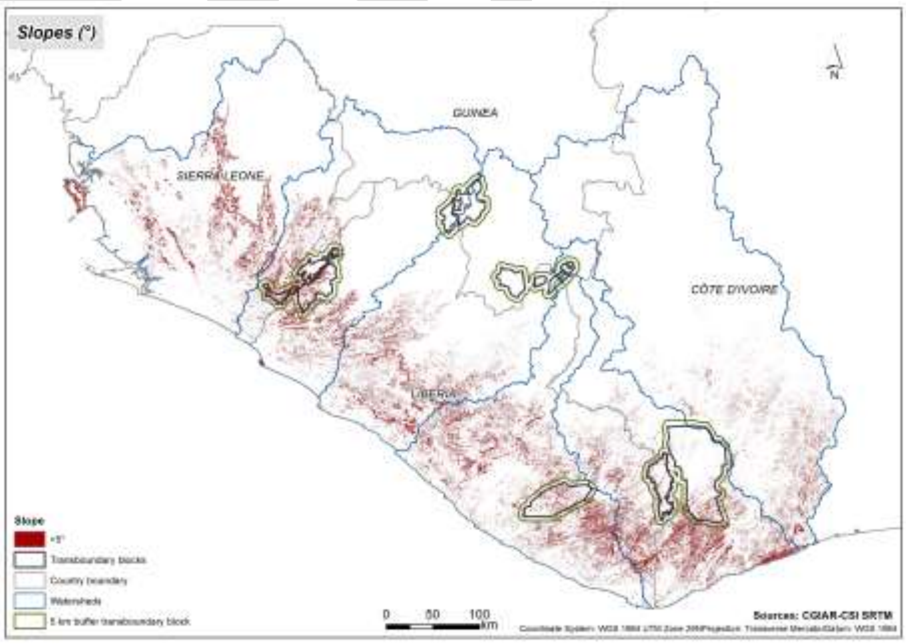


Figure 7. Slopes higher than 5°

d. Rainfall Erosivity

Heavy rainfall and extreme events are of major importance for climate change, economy and society (Alexander et al., 2006). The rainfall erosivity factor (R) is an indicator of potential water erosion which combines the effects of the duration, magnitude, and intensity of rainfall events (Panagos et al., 2017).

Although rainfall erosivity was not a direct measure of degradation, it is one of the most important input parameters for describing erosive processes (Panagos et al., 2017), which in turn may increase land degradation.

The erosivity is considered in this analysis a proxy of degradation, because in the humid tropics, the large amount and high intensity of rainfall can potential reach dramatic levels of soil erosion in this region (Labrière et al., 2015). This biophysical factor when combined with other factors such as loss of canopy cover, or burned areas could intensify its own impact.

To assess rainfall erosivity in the Mano River Union, was used the Global Rainfall Erosivity Database, which contains erosivity values (with a spatial resolution of 1 km) calculated based on precipitation time series ranged from a minimum of 5 years to maximum of 52 years, from 3,625 stations distributed in 63 countries worldwide.

The criteria selected was based in the average of the rainfall erosivity value for the area, which is about 8,000 Mj mm ha-1 h-1 yr-1.

Proxy of degradation	***Criteria***	***Source***
Rainfall erosivity	Erosivity higher than 8000 Mj mm ha-1 h-1 yr-1	https://esdac.jrc.ec.europa.eu/content/global-rainfall-erosivity, Panagos et al., 2017

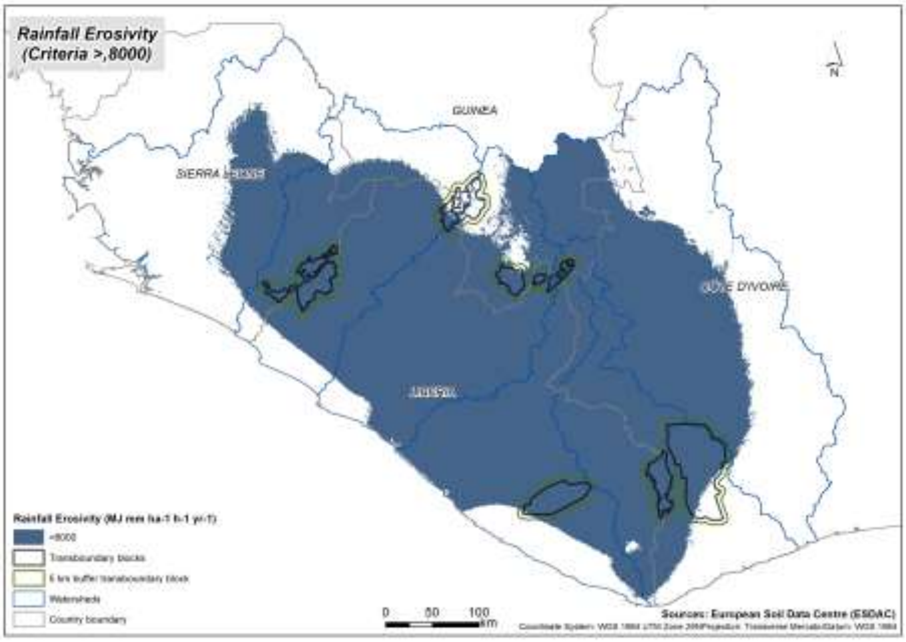


Figure 8. Area with highest rainfall erosivity values

e. Erodibility (K factor)

Erodibility (K factor) is the measure of susceptibility of soil particles to detachment and transportation by rain and runoff. Areas with low vegetation cover and with erodible soils are likely to have degradation.

Digital soil map of the world developed by FAO/UNESCO, 1995 and the Williams (Williams, 1995; Neitsch et al., 2000) equation were used to calculate the erodibility factor for the area of Mano River region.

In this analysis was decided to extract all cells that have factors of more than 0.015 (the average in the watershed) as areas with high erodibility.

Proxy of degradation	***Criteria***	***Source***
Soil Erodibility	Erodibility higher than 0.015 t ha h ha-1MJ-1mm-1	https://esdac.jrc.ec.europa.eu/content/global-rainfall-erosivity Panagos et al., 2017

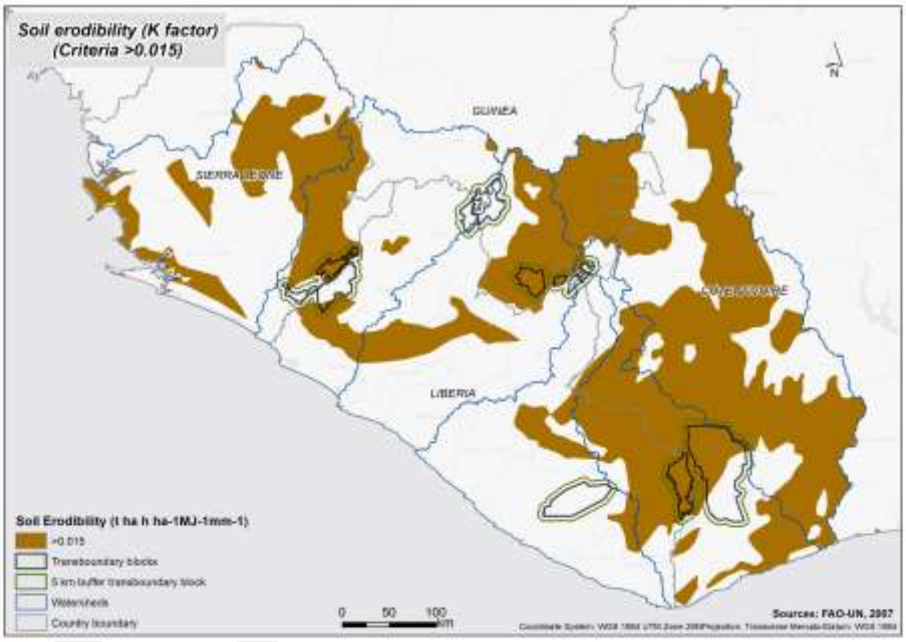


Figure 9. Area with highest soil erodibility values

f. Soil fertility

Soil information will help identify areas at risk of soil degradation (Hengl et al., 2015). The Alliance for a Green Revolution in Africa (AGRA, 2014) has estimated that up to 80% of arable land in sub-Saharan Africa has low soil fertility and suffers from physical soil problems. The principal reason for the poor soil characteristics in West Africa, is that the major soils in that area are derived from coarse-textured and acidic parent rocks (mainly granite) and have weathered under a tropical climate (Abe et al., 2010). In addition, anthropogenic disturbances such as hastened deforestation and subsequent exploitive farming practices have been critically affecting soil fertility (Sanchez et al., 1997, Sanchez, 2002).

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions (Hazleton and Murphy 2007). Plants use these cations such as calcium, magnesium and potassium in large amounts (CUCE, 2007). Cation exchange capacity is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants (Hazleton and Murphy 2007).

Soils with a low CEC are more likely to develop deficiencies in potassium (K^+), magnesium (Mg^{2+}) and other cations (CUCE 2007). The lower the CEC, the lower organic matter present in the soil and lower water holding capacity (CUCE, 2007). Olorunfemi et al., 2016 also demonstrated that there is a strong correlation between CEC value and amount of organic matter present in the soil.

Considering this, in this analysis, the cation exchange capacity is used as a proxy for fertility. The areas with low cation exchange capacity are considered as low fertility soils, which could be synonymous of land degradation.

Using the information from ISRIC, the areas with CEC lower than 10 cmolc/kg were extracted to indicate areas degraded or more prone to degradation (Figure 5). This value represent the average of CEC in the study area, so the areas with values lower than 10 cmolc/kg, will be considered areas more prone to degradation, being that land degradation is defined as the long-term loss of ecosystem function and productivity (Bai et al., 2008).

Proxy of degradation	***Criteria***	***Source***
Soil Fertility	Cation Exchange Capacity CEC <10cmolc/kg	https://soilgrids.org/#!/?layer=ORCDRC_M_sl2_250m&vector=1

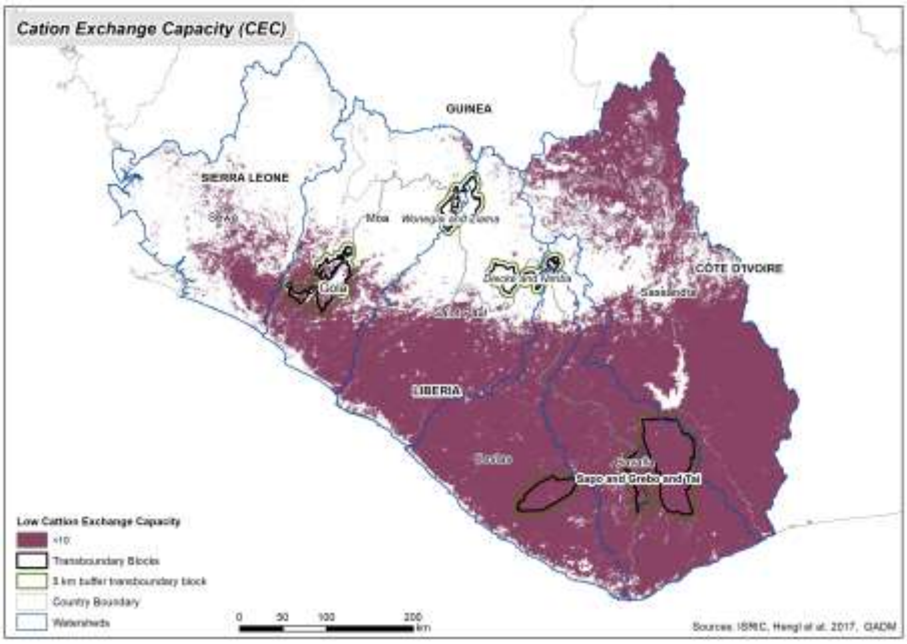


Figure 10. Area with cation exchange capacity lower than 10cmolc/kg

g. Loss of biodiversity

Biodiversity has already experienced large net losses in Mano River region, according with the stakeholders. These losses have potentially compromising its contribution to provision of ecosystem functions and services such as biomass production and pollination, that underpin human wellbeing (Armbrecht et al, 2006).

The Biodiversity Intactness Index (BII) estimates how the average abundance of native terrestrial species in a region compares with their abundances before pronounced human impacts.

The Biodiversity Intactness Index (BII) was initially proposed by Scholes & Biggs (2005) and only tested the effects of land use - among the main drivers of biodiversity loss (Maxwell et al. 2016; Brummitt et al. 2015). Recently Newbold et al., 2016 under the PREDICTS (Projecting Responses of Ecological Diversity in Changing Terrestrial Systems) project produced global BII estimates considering four pressure variables as fixed effects (land use, land use intensity, human population density and proximity to the nearest road). This BII as defined as: the average abundance of originally present species across a broad range of species, relative to abundance in undisturbed habitat (Newbold et al., 2016). The BII estimate how land-use pressures have affected the numbers of species and individuals in the landscape. The dataset has a spatial resolution of 1km and the BII values are shown in a 0 to 1 scale (1= 100% intactness).

This dataset was used in the MCA as a proxy of degradation in the sense that the loss of biodiversity compromise will compromise its contribution to provide ecosystem functions, which leads to land degradation. The criteria established was considered the average of loss of species in the watershed (<0.9). The area with lower values is considered to have with higher losses in biodiversity consequently more degraded or prone to degradation.

Proxy of degradation	***Criteria***	***Source***
Loss of biodiversity	Biodiversity Intactness Index <0.9	https://data.nhm.ac.uk/dataset/global-map-of-the-biodiversity-intactness-index-from-newbold-et-al-2016-science (Newbold et al. 2016)

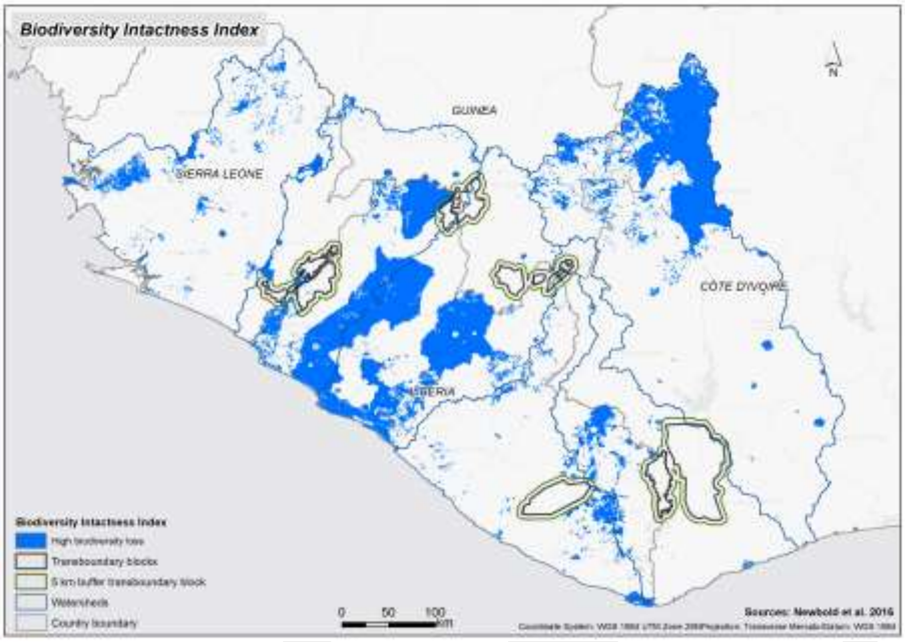


Figure 11. Areas with highest loss of biodiversity

2.2 Forest landscape restoration opportunities

The implementation of FLR in Mano River intends to achieve two mainly objectives, firstly improve livelihoods and second increase biodiversity. To define the opportunity areas for improving livelihoods the following criteria were used: high poverty rate, high population density, low access to markets. To increase the biodiversity the opportunity areas are: key biodiversity areas outside protected, protected areas, areas with low NDVI inside protected areas and areas with high biodiversity intactness.

a. improve livelihoods

The high population density means more pressure on the natural resources. In the case of Mano River, the stakeholders highlighted the fact that communities rely on natural resources for their livelihoods, namely firewood, bushmeat and other non-timber forest products both for subsistence, but also for trade.

Then, the areas with high population density[5] are opportunity areas to implement FLR. These interventions will provide intensification and diversification of natural resources to ensure that livelihood needs are meet and improved.

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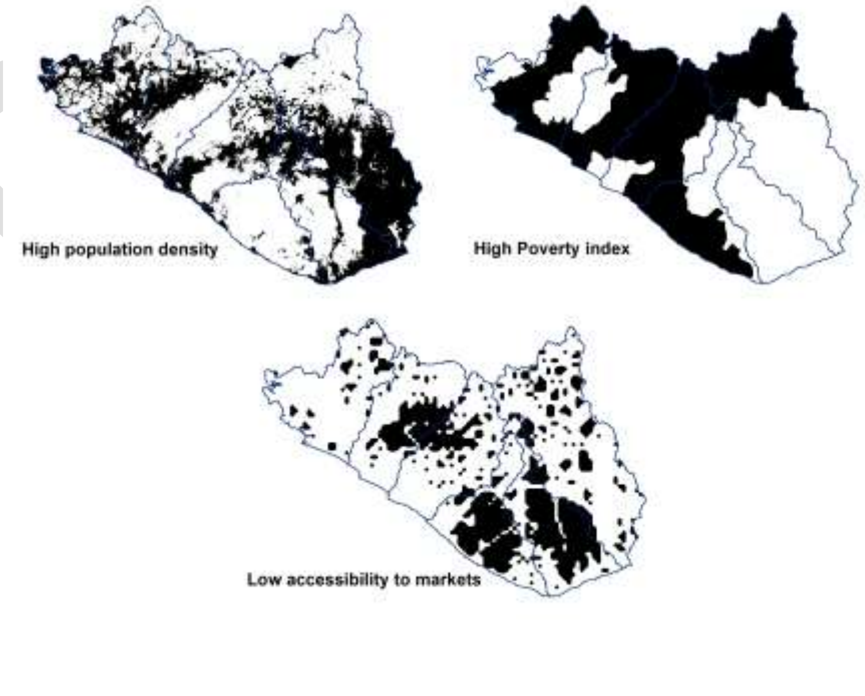
[5] The higher population density was calculated based on the average of population density that was 0.33/pixel (90m) for the watershed, so the values higher were considered areas with higher population density. The source of the dataset is: WorldPop - School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur) and Center for International Earth Science Information Network (CIESIN), Columbia University

In terms of poverty, restoration can provide many benefits that help alleviate poverty and provide alternative livelihoods to subsistence farming. What is important in this analysis is to determine where the alleviation of poverty through FLR interventions might be a priority.

With the purpose of define input criteria for the MCA was used the multidimensional poverty index[6] and were selected areas greater than 40% poverty represent areas of high risk and higher opportunity for FLR. FLR interventions in these areas have the potential to drastically improve the lives of people living in poverty.

A lack of accessible markets reflects that people are both increasingly dependent on ecosystem services and have fewer opportunities to generate market-based income sources. The travel time is the indicator used as a proxy of accessibility to markets, which in turn is considered in this MCA as a proxy for improving livelihoods. Travel time[7] is used in this analysis as a proxy for accessibility to markets and shows how likely farming households are to be physically integrated with or isolated from markets.

The highest travel time means areas where people is more dependent of the natural resources or of their own capacity to diversify production and livelihood strategies and for enhancing food security. In the analysis the areas with a travel time, to major settlements with populations of 20,000 or more, higher than 4 hours are considered areas where FLR strategies should target the risk of food insecurity and diversify production (Figure 12).



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[6] Source: Alkire, S., Kanagaratnam, U. and Suppa, N. (2019). 'The Global Multidimensional Poverty Index (MPI) 2019', OPHI MPI Methodological Notes 47, Oxford Poverty and Human Development Initiative, University of Oxford.
[7] Source: HarvestChoice/International Food Policy Research Institute (IFPRI) (http://agatlas.org/contents/market-access/)

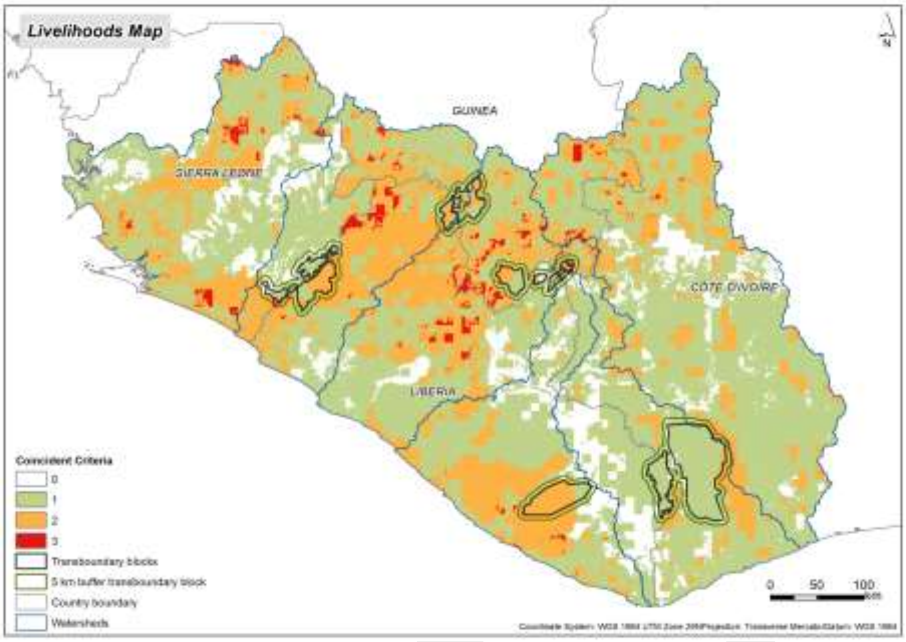

Figure 12. Improve livelihoods objective map (coloured map) result from the combination of three proxies (dark map). In the coloured map light green indicates areas where landscape restoration for improving livelihoods may be lower, while red areas indicate potential priority areas for addressing biodiversity.

The livelihoods opportunity map presented in the Figure 13, identify areas where degradation overlaps with opportunity areas for biodiversity.

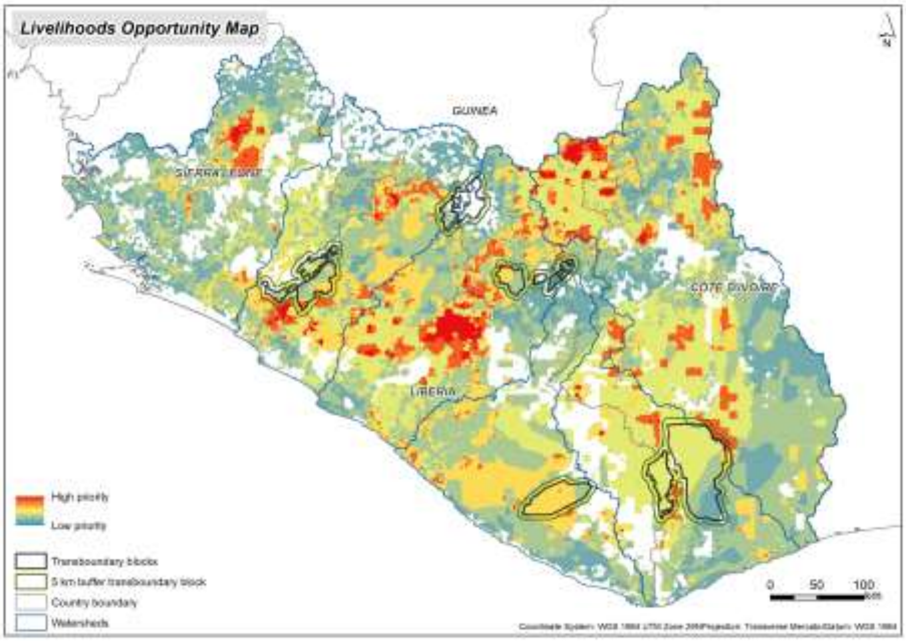

Figure 13. The livelihoods opportunity map is a product of multiplying the results of the degradation map with the results of the livelihoods objective map . This indicates areas where high degradation may overlap with areas of livelihoods opportunity.

Table 4. Input criteria combinations accounting for more than 30,000 ha between degradation and improve livelihoods

Improve livelihoods and Degradation criteria combinations (above 30,000 ha)	Area (ha)
Low fertility, High erodibility, High rainfall erosivity, Low access to markets,	178,815
Low fertility, High erodibility, High population density,	165,393
Low fertility, High erodibility, High rainfall erosivity, High population density,	160,219
Low fertility, High population density,	114,458
Low fertility, High rainfall erosivity, Low access to markets,High multi-poverty index,	114,138
Recurrente fires, High multi-poverty index,	94,697
Low fertility, High rainfall erosivity, High multi-poverty index,	93,454
Low fertility, High rainfall erosivity, Low access to markets,	85,975
High rainfall erosivity, Low access to markets,High multi-poverty index,	85,450
Low fertility, High rainfall erosivity, High population density,	83,388
High rainfall erosivity, High population density,	82,927
Low fertility, High rainfall erosivity,	67,609
Low fertility, High erodibility, High rainfall erosivity,	65,483
High erodibility, High rainfall erosivity, High population density,	58,132
Low fertility, High multi-poverty index,	55,814
High loss of biodiversity, Low fertility, High erodibility, High multi-poverty index,	49,193
Low fertility, High erodibility, High rainfall erosivity, Low access to markets, High population density,	48,565
High erodibility, High rainfall erosivity, Recurrente fires, High multi-poverty index,	47,938
High multi-poverty index, High population density,	47,925
High loss of biodiversity, High rainfall erosivity, Low access to markets, High multi-poverty index,	44,287
High erodibility, High rainfall erosivity, High multi-poverty index,	43,224
Low fertility, Low access to markets, High multi-poverty index,	42,161
High loss of biodiversity, Low fertility, High rainfall erosivity, High multi-poverty index,	38,499
High loss of biodiversity, Low fertility, High multi-poverty index,	37,077
High rainfall erosivity, High multi-poverty index,	33,965
Recurrente fires, High multi-poverty index, High population density,	32,902
Low fertility, Low access to markets,High population density,	31,519
High erodibility, High multi-poverty index,	31,467
High erodibility, High rainfall erosivity,	30,994

b. Increase biodiversity

Biodiversity underpins ecosystem functioning and the provision of ecosystem services is essential for human well-being (CBD, 2010). Protecting biodiversity and improving the supply of—and equitable access to—ecosystem services is a vital global interest to sustain a healthy planet and deliver benefits essential for all people (Zhang et al., 2019).

In the case of Mano River, several communities are heavily dependent of natural resources for their livelihoods so protecting and improving biodiversity is a priority. Landscape restoration that identifies and integrates interventions that are sympathetic to biodiversity have a higher chance of success and can provide significant contributions to long-term resilience (Lamb et al. 2005) but also generate immediate livelihood benefits.

The opportunity areas for improving biodiversity were selected based in 4 input criteria presented in the map below: protected areas, key biodiversity areas outside protected areas, areas with high biodiversity intactness and areas with low NDVI (Figure 14).

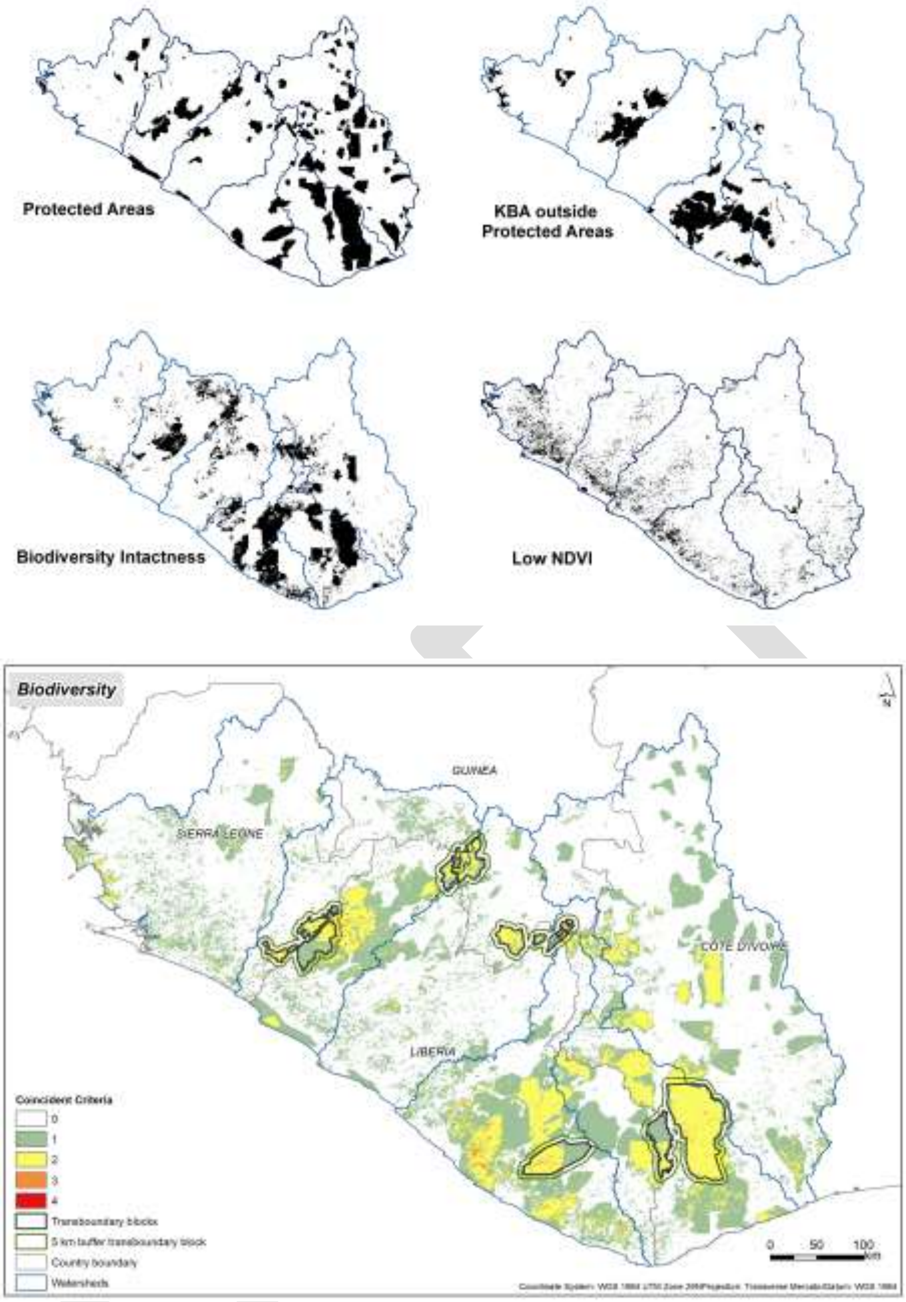

Figure 14. Biodiversity objective map (coloured map) result from the combination of 4 proxies (dark image). In the coloured map light green indicates areas where landscape restoration for biodiversity potential may be lower, while the red areas indicate potential priority areas for addressing biodiversity.

The biodiversity opportunity map presented in the Figure 15, identify areas where degradation overlaps with opportunity areas for biodiversity.

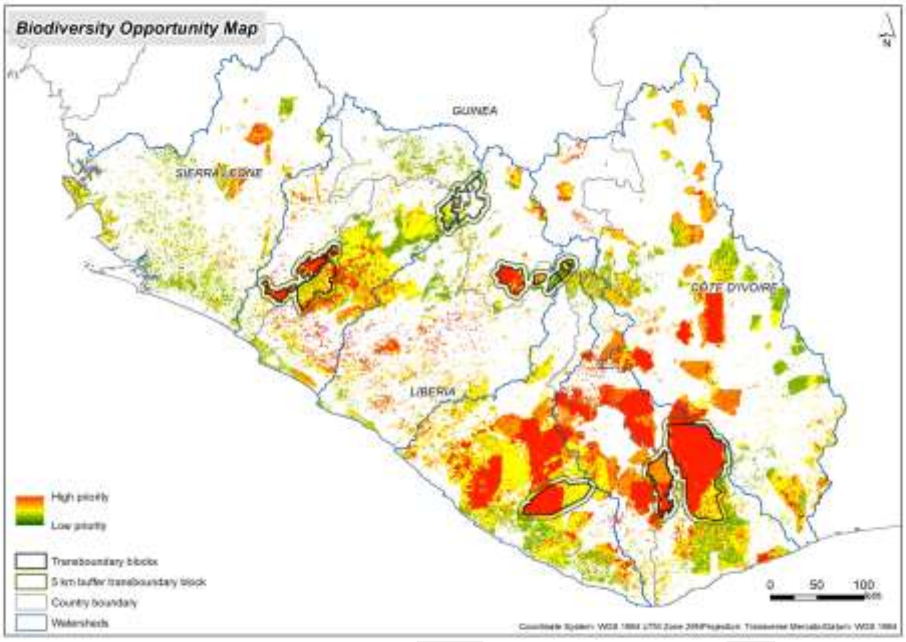

Figure 15. The biodiversity opportunity map is a product of multiplying the results of the degradation map with the results of the biodiversity objectives map . This indicates areas where high degradation may overlap with areas of biodiversity opportunity.

Table 5. Input criteria combinations accounting for more than 200,000 ha between degradation and biodiversity

Biodiversity and Degradation criteria combinations (above 200,000 ha)	Area (ha)
High rainfall erosivity, Loss of Canopy Cover	212,900
Recurrente fires, Loss of Canopy Cover	221,500
High Biodiversity Intactness, KBA outside PA, Low fertility, High rainfall erosivity	222,800
Protected Area, Low fertility, High erodibility	223,500
Low fertility, High rainfall erosivity, Steep slopes	232,500
High loss of biodiversity, High rainfall erosivity	237,500
KBA outside PA, Low fertility, High erodibility, High rainfall erosivity	239,200
High Biodiversity Intactness, Low fertility, High rainfall erosivity	240,800
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover	248,000
High Biodiversity Intactness, Protected Area, Low fertility, High rainfall erosivity	257,000
Protected Area, Low fertility	300,500
High loss of biodiversity, Low fertility, High erodibility, High rainfall erosivity	344,000
Low fertility, High rainfall erosivity, Loss of Canopy Cover	344,600
High erodibility, Recurrente fires	360,800
Protected Area, Low fertility, High erodibility, High rainfall erosivity	364,100
High loss of biodiversity, Low fertility	386,700
High loss of biodiversity, Low fertility, High erodibility	389,900
High rainfall erosivity, Recurrente fires	444,800
KBA outside PA, Low fertility, High rainfall erosivity	471,700
High loss of biodiversity, Low fertility, High rainfall erosivity	494,300
High Biodiversity Intactness, Protected Area, Low fertility, High erodibility, High rainfall erosivity	530,400
High erodibility, High rainfall erosivity, Recurrente fires	651,600
High erodibility, High rainfall erosivity	947,700
Low fertility, High erodibility	1,132,400
Low fertility, High rainfall erosivity	1,606,500
Low fertility, High erodibility, High rainfall erosivity	1,762,800

3. Forest landscape restoration priorities

The final output of the FLR assessment is the FLR priority map (Figure 16), which is a combination of the opportunity map for biodiversity and the opportunity map for livelihoods. This map can provide a guide to define the FLR strategies to be implemented, which should address simultaneously the drivers of degradation as well as the objectives related with restoring biodiversity and improve livelihoods.

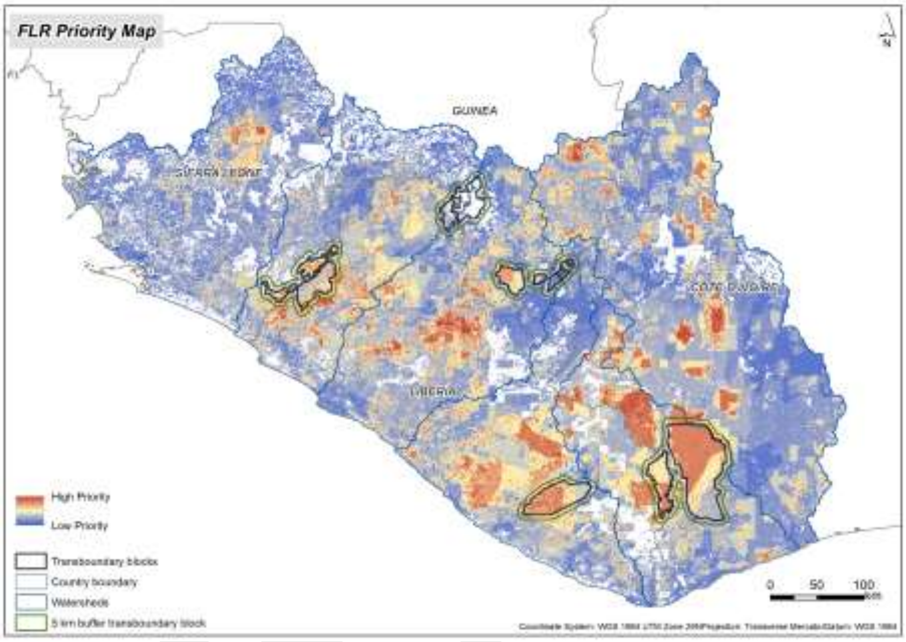

Figure 16. FLR priority areas defined through MCA. This map is a sum of the priority map for biodiversity and the priority map for improved livelihoods

The highest FLR priority occupies more than 430,000 ha, from which 87% occurred in land uses with tree cover (Figure 17), 5% in grassland and about 6% in cropland, according with the 2016[8] land use land cover map.

[8] ESA Climate Change Initiative - Land Cover project 2017 (http://2016africalandcover20m.esrin.esa.int/download.php)

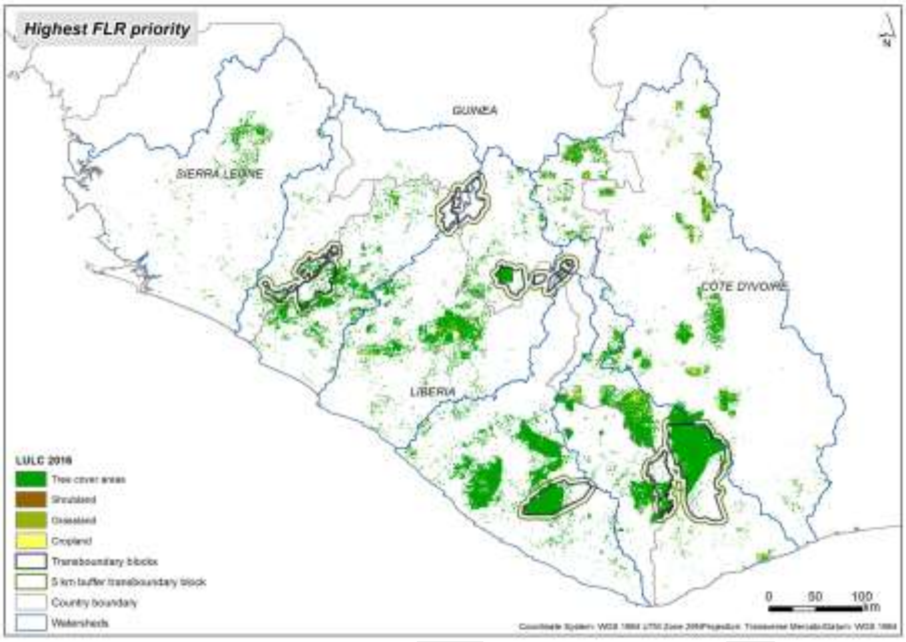

Figure 17. The map indicates areas where highest FLR priority may overlap with the four main land use land cover types.

Some of these FLR higher priority areas are located in the four transboundary landscapes (Figure 18), this information is important to guide in the definition and implementation of the FLR strategies in each landscape to reverse degradation and achieve specific objectives.

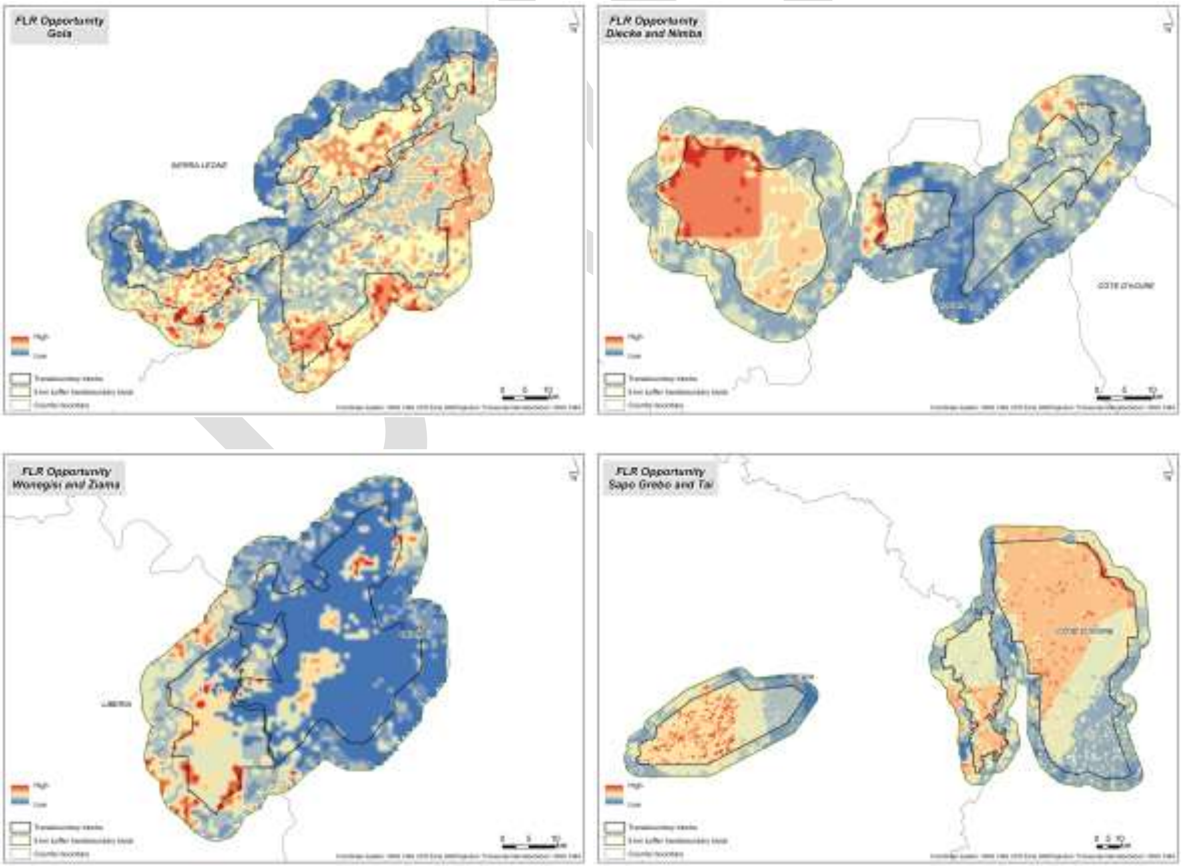

Figure 18. FLR priority map for each transboundary landscape, based in the MCA. The red colours indicate high priority for FLR implementation

The table below represents the percentage of each transboundary landscape occupied by different FLR priority, considering the buffer of 5 km.

Table 6. The table shows the percent area for each transboundary block that was identified as low medium or high priority for forest landscape restoration

FLR PRIORITY	GOLA	DIECKE AND NIMBA	WONEGISI ZIAMA	SAPO, GREBO AND TAÏ
LOW	29%	51%	71%	21%
MEDIUM	49%	36%	25%	36%
HIGH	22%	13%	4%	43%

The tables 7, 8, 9, 10 show each of the input criteria combinations that account for more than 1,000 hectares between the degradation MCA and the livelihoods MCA. These figures show the potential criteria that could be addressed through restoration activities that consider and support livelihoods in the areas where these specific criteria overlaps occur.

Table 7. Input criteria combinations accounting for more than 1,000 ha between degradation and improving livelihoods

Improve livelihoods and Degradation criteria combinations (above 1,000 ha) Gola	**Area (ha)**
High erodibility, High rainfall erosivity, Low access to markets, High population density,	1,015
Low fertility, High rainfall erosivity, Steep slopes, High multi-poverty index, High population density,	1,015
High loss of biodiversity, High rainfall erosivity, Steep slopes, Low access to markets,	1,015
High rainfall erosivity, Low access to markets,High multi-poverty index, High population density,	1,099
High loss of biodiversity, Low fertility, High rainfall erosivity, High multi-poverty index, High population density,	1,099
High loss of biodiversity, High rainfall erosivity,	1,099
High loss of biodiversity, Low fertility, High rainfall erosivity,	1,099
Low fertility, High erodibility, High rainfall erosivity, High population density,	1,184
High erodibility, High rainfall erosivity, Steep slopes, Low access to markets,High multi-poverty index,	1,184
High loss of biodiversity, Low fertility, High erodibility, High rainfall erosivity, High multi-poverty index, High population density,	1,353
High erodibility, High rainfall erosivity, Loss of Canopy Cover, Low access to markets,	1,353
Low fertility, High rainfall erosivity, Loss of Canopy Cover,	1,353
Low fertility, High rainfall erosivity, Steep slopes,	1,353
High erodibility, High rainfall erosivity, High multi-poverty index,	1,438
High loss of biodiversity, Low fertility, High rainfall erosivity, High multi-poverty index,	1,607
High erodibility, High rainfall erosivity, Recurrente fires,	1,691
High erodibility, High rainfall erosivity, Loss of Canopy Cover,	1,691
Low fertility, High rainfall erosivity, Loss of Canopy Cover, High multi-poverty index, High population density,	1,691
Low fertility, High rainfall erosivity, Recurrente fires,	1,691
High erodibility, High rainfall erosivity, Recurrente fires, High population density,	1,860
High loss of biodiversity, Low fertility, High rainfall erosivity, Low access to markets,	1,945
High rainfall erosivity, Steep slopes,	2,030
High rainfall erosivity, High multi-poverty index, High population density,	2,114

High loss of biodiversity, High erodibility, High rainfall erosivity, Low access to markets,	2,114
Low fertility, High rainfall erosivity, Low access to markets,High multi-poverty index, High population density,	2,283
Low fertility, High erodibility, High rainfall erosivity, Steep slopes, Low access to markets,High multi-poverty index,	2,283
High erodibility, High rainfall erosivity, Steep slopes,	2,452
Low fertility, High erodibility, High rainfall erosivity,	3,383
High rainfall erosivity, Steep slopes, High multi-poverty index,	3,383
High erodibility, High rainfall erosivity, Low access to markets,High multi-poverty index,	3,467
High erodibility, High rainfall erosivity, High population density,	3,467
High rainfall erosivity,	3,636
High rainfall erosivity, Steep slopes, Low access to markets,	3,890
Low fertility, High rainfall erosivity, Steep slopes, Low access to markets,High multi-poverty index,	3,975
Low fertility, High rainfall erosivity, Steep slopes, High multi-poverty index,	3,975
Low fertility, High erodibility, High rainfall erosivity, Steep slopes, High multi-poverty index,	5,158
High rainfall erosivity, Low access to markets,	5,412
High rainfall erosivity, High multi-poverty index,	5,497
Low fertility, High rainfall erosivity,	5,835
Low fertility, High rainfall erosivity, Steep slopes, Low access to markets,	6,258
Low fertility, High rainfall erosivity, High multi-poverty index, High population density,	6,681
High erodibility, High rainfall erosivity, Steep slopes, Low access to markets,	7,019
Low fertility, High erodibility, High rainfall erosivity, Low access to markets,High multi-poverty index,	8,541
High rainfall erosivity, Steep slopes, Low access to markets,High multi-poverty index,	9,302
Low fertility, High erodibility, High rainfall erosivity, High multi-poverty index,	11,585
Low fertility, High erodibility, High rainfall erosivity, Low access to markets,	12,008
High erodibility, High rainfall erosivity,	12,177
Low fertility, High rainfall erosivity, Low access to markets,	12,600
Low fertility, High rainfall erosivity, High multi-poverty index,	14,968
High erodibility, High rainfall erosivity, Low access to markets,	34,925
High rainfall erosivity, Low access to markets,High multi-poverty index,	39,069
Low fertility, High rainfall erosivity, Low access to markets,High multi-poverty index,	44,566

Table 8. Input criteria combinations accounting for more than 1,000 ha between degradation and improving livelihoods

Improve livelihoods and Degradation criteria combinations (above 1,000 ha) Diecke and Nimba	Area (ha)
High rainfall erosivity, Recurrente fires, High multi-poverty index, High population density,	1,014
High rainfall erosivity, Loss of Canopy Cover, High multi-poverty index, High population density,	1,014
High erodibility, High rainfall erosivity, Recurrente fires,	1,268
High rainfall erosivity, Low access to markets,High multi-poverty index, High population density,	1,437
High erodibility, High rainfall erosivity, Recurrente fires, High population density,	1,521
High rainfall erosivity, Loss of Canopy Cover,	1,521
High erodibility, High rainfall erosivity, Recurrente fires, Loss of Canopy Cover, Low access to markets,High multi-poverty index,	1,860
High erodibility, High rainfall erosivity, Loss of Canopy Cover, Low access to markets,High multi-poverty index,	1,860

High rainfall erosivity, Recurrente fires,	1,860
High rainfall erosivity, Loss of Canopy Cover, High population density,	2,282
High erodibility, High multi-poverty index, High population density,	2,451
High erodibility, High rainfall erosivity, Recurrente fires, Loss of Canopy Cover, High multi-poverty index,	2,620
High rainfall erosivity, Recurrente fires, High multi-poverty index,	2,958
High erodibility, High rainfall erosivity, Recurrente fires, High multi-poverty index, High population density,	2,958
High rainfall erosivity, Recurrente fires, High population density,	3,297
High erodibility, High rainfall erosivity, High population density,	3,804
High erodibility, High rainfall erosivity, Low access to markets,	3,888
High erodibility, High rainfall erosivity, Recurrente fires, Low access to markets,High multi-poverty index,	4,226
High erodibility, High multi-poverty index,	4,818
High erodibility, High rainfall erosivity, Loss of Canopy Cover, High multi-poverty index,	5,325
High erodibility, High rainfall erosivity,	5,325
High rainfall erosivity, Low access to markets,High multi-poverty index,	5,663
High rainfall erosivity, High multi-poverty index, High population density,	6,678
High erodibility, High rainfall erosivity, Recurrente fires, High multi-poverty index,	6,847
High rainfall erosivity,	7,861
High rainfall erosivity, Low access to markets,High population density,	9,636
High rainfall erosivity, Low access to markets,	10,228
High rainfall erosivity, High multi-poverty index,	11,918
High erodibility, High rainfall erosivity, High multi-poverty index, High population density,	13,524
High rainfall erosivity, High population density,	17,243
High erodibility, High rainfall erosivity, Low access to markets,High multi-poverty index,	29,077
High erodibility, High rainfall erosivity, High multi-poverty index,	54,857

Table 9. Input criteria combinations accounting for more than 1,000 ha between degradation and improving livelihoods

Improve livelihoods and Degradation criteria combinations (above 1,000 ha) Wonegisi Ziama	**Area (ha)**
High loss of biodiversity, High rainfall erosivity, Recurrente fires, Loss of Canopy Cover, High multi-poverty index,	1,099
High rainfall erosivity, Loss of Canopy Cover, Low access to markets,High multi-poverty index,	1,183
Loss of Canopy Cover, High multi-poverty index, High population density,	1,352
High loss of biodiversity, High rainfall erosivity, High multi-poverty index,	1,521
High loss of biodiversity, Recurrente fires, High multi-poverty index, High population density,	1,690
Recurrente fires, High multi-poverty index, High population density,	1,944
High loss of biodiversity, High multi-poverty index,	1,944
High rainfall erosivity, Loss of Canopy Cover, High multi-poverty index,	1,944
Recurrente fires, Loss of Canopy Cover, Low access to markets,High multi-poverty index,	2,113
High loss of biodiversity, High rainfall erosivity, Recurrente fires, High multi-poverty index,	2,113
High loss of biodiversity, Recurrente fires, High multi-poverty index,	3,042
High rainfall erosivity, Recurrente fires, Loss of Canopy Cover, Low access to markets,High multi-poverty index,	3,211
High rainfall erosivity, Recurrente fires, Loss of Canopy Cover, High multi-poverty index,	4,310
Recurrente fires, Low access to markets,High multi-poverty index,	4,732

High rainfall erosivity, Recurrente fires, Low access to markets,High multi-poverty index,	5,070
Loss of Canopy Cover, High multi-poverty index,	5,408
Recurrente fires, Loss of Canopy Cover, High multi-poverty index,	6,338
High rainfall erosivity, Recurrente fires, High multi-poverty index,	8,704
High multi-poverty index, High population density,	10,901
High rainfall erosivity, High multi-poverty index,	16,647
Recurrente fires, High multi-poverty index,	22,816
High rainfall erosivity, Low access to markets,High multi-poverty index,	27,210
Low access to markets,High multi-poverty index,	29,408
High multi-poverty index,	74,955

Table 10. Input criteria combinations accounting for more than 1,000 ha between degradation and improving livelihoods

Improve livelihoods and Degradation criteria combinations (above 1,000 ha) Sapo and Grebo	**Area (ha)**
Low fertility, High rainfall erosivity, Steep slopes, Low access to markets,High population density,	1,022
High rainfall erosivity, Low access to markets,	1,192
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover,	1,192
Low fertility, High erodibility, High rainfall erosivity, Steep slopes, High population density,	1,192
Low fertility, High rainfall erosivity, Steep slopes, High population density,	1,192
Low fertility, High rainfall erosivity, Steep slopes,	1,278
Low fertility, Loss of Canopy Cover, Low access to markets,High population density,	1,363
Low fertility, High rainfall erosivity, High population density,	1,448
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover, Low access to markets,High population density,	1,448
Low fertility, High erodibility, High rainfall erosivity, Steep slopes,	1,533
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover, High population density,	1,618
Low fertility, High erodibility, High rainfall erosivity, Steep slopes, Low access to markets,High population density,	1,874
Low fertility, High population density,	2,385
Low fertility, Steep slopes, Low access to markets,High population density,	2,385
High loss of biodiversity, Low fertility, High erodibility, High rainfall erosivity, Low access to markets,	2,555
Low fertility, High rainfall erosivity, Loss of Canopy Cover, Low access to markets,High population density,	2,981
Low fertility, High rainfall erosivity, Steep slopes, High multi-poverty index,	3,237
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover, Low access to markets,	3,407
Low fertility,	3,748
High erodibility, High rainfall erosivity, Low access to markets,	6,218
Low fertility, High rainfall erosivity,	8,006
Low fertility, Low access to markets,High multi-poverty index,	12,095
Low fertility, High rainfall erosivity, High multi-poverty index,	16,013
Low fertility, High rainfall erosivity, Steep slopes, Low access to markets,	16,864
Low fertility, Low access to markets,High population density,	16,864
Low fertility, High rainfall erosivity, Low access to markets,High population density,	18,653
Low fertility, Steep slopes, Low access to markets,	19,420
Low fertility, High erodibility, High rainfall erosivity, Steep slopes, Low access to markets,	19,846
Low fertility, High erodibility, High rainfall erosivity, High population density,	25,808

Low fertility, High rainfall erosivity, Steep slopes, Low access to markets,High multi-poverty index,	29,044
Low fertility, High erodibility, High rainfall erosivity,	29,726
Low fertility, High erodibility, High rainfall erosivity, Low access to markets,High population density,	40,032
Low fertility, Low access to markets,	82,448
Low fertility, High rainfall erosivity, Low access to markets,	128,357
Low fertility, High rainfall erosivity, Low access to markets,High multi-poverty index,	134,319

The tables 11, 12, 13, 14 show the potential criteria combinations that could be addressed through restoration activities that consider and support biodiversity, that account for more than 1,000 hectares or 5,000 hectares between the degradation MCA and the biodiversity MCA.

Table 11. Input criteria combinations accounting for more than 5,000 ha between degradation and biodiversity

Biodiversity and Degradation criteria combinations (above 5,000 ha) Gola	Area (ha)
Protected Area, Low fertility, High rainfall erosivity, Steep slopes,	5,412
Protected Area, High rainfall erosivity, Steep slopes,	5,920
KBA outside PA, Low fertility, High rainfall erosivity,	6,089
High rainfall erosivity,	6,427
Protected Area, High erodibility, High rainfall erosivity,	6,681
Low fertility, High erodibility, High rainfall erosivity,	6,934
High Biodiversity Intactness, High erodibility, High rainfall erosivity,	6,934
High Biodiversity Intactness, Protected Area, High rainfall erosivity, Steep slopes,	7,780
High Biodiversity Intactness, Protected Area, Low fertility, High erodibility, High rainfall erosivity,	8,034
High Biodiversity Intactness, KBA outside PA, Low fertility, High rainfall erosivity,	8,203
Protected Area, Low fertility, High erodibility, High rainfall erosivity,	8,541
High Biodiversity Intactness, KBA outside PA, High rainfall erosivity,	10,232
KBA outside PA, Low fertility, High erodibility, High rainfall erosivity,	10,655
High Biodiversity Intactness, Protected Area, Low fertility, High rainfall erosivity,	13,615
Protected Area, High rainfall erosivity,	14,376
Low fertility, High rainfall erosivity,	17,251
High Biodiversity Intactness, Protected Area, High erodibility, High rainfall erosivity,	17,420
High erodibility, High rainfall erosivity,	18,858
High Biodiversity Intactness, Protected Area, High rainfall erosivity,	19,196
Protected Area, Low fertility, High rainfall erosivity,	26,976

Table 12. Input criteria combinations accounting for more than 1,000 ha between degradation and biodiversity

Biodiversity and Degradation criteria combinations (above 1,000 ha) Diecke and Nimba	Area (ha)
Protected Area, High erodibility,	1,100
High rainfall erosivity, Recurrente fires, Loss of Canopy Cover,	1,354
Protected Area, High erodibility, High rainfall erosivity, Loss of Canopy Cover,	1,523
Low NDVI in PA and KBA outside PA, High Biodiversity Intactness, Protected Area, High erodibility, High rainfall erosivity,	1,608
Protected Area, High erodibility, High rainfall erosivity, Recurrente fires,	1,861
Low NDVI in PA and KBA outside PA, High Biodiversity Intactness, Protected Area, High rainfall erosivity,	2,031
High Biodiversity Intactness, High erodibility, High rainfall erosivity,	3,131
Low NDVI in PA and KBA outside PA, Protected Area, High rainfall erosivity,	3,131

High Biodiversity Intactness, High rainfall erosivity,	4,061
KBA outside PA, High rainfall erosivity,	4,061
High Biodiversity Intactness, KBA outside PA, High rainfall erosivity,	4,061
High erodibility, High rainfall erosivity, Recurrente fires, Loss of Canopy Cover,	4,654
High rainfall erosivity, Loss of Canopy Cover,	5,077
High erodibility,	5,838
High erodibility, High rainfall erosivity, Loss of Canopy Cover,	8,292
High rainfall erosivity, Recurrente fires,	10,407
High Biodiversity Intactness, Protected Area, High rainfall erosivity,	12,438
Protected Area, High rainfall erosivity,	13,707
High erodibility, High rainfall erosivity, Recurrente fires,	15,569
Protected Area, High erodibility, High rainfall erosivity,	16,922
High rainfall erosivity,	25,299
High Biodiversity Intactness, Protected Area, High erodibility, High rainfall erosivity,	42,560
High erodibility, High rainfall erosivity,	44,845

Table 13. Input criteria combinations accounting for more than 1,000 ha between degradation and biodiversity

Biodiversity and Degradation criteria combinations (above 1,000 ha) Ziama	***Area (ha)***
Protected Area, Loss of Canopy Cover,	*1,017*
Low NDVI in PA and KBA outside PA, High Biodiversity Intactness, Protected Area,	*1,017*
High loss of biodiversity,	*1,441*
High Biodiversity Intactness, Protected Area, Loss of Canopy Cover,	*1,441*
High rainfall erosivity, Loss of Canopy Cover,	*1,526*
High loss of biodiversity, Recurrente fires, Loss of Canopy Cover,	*1,695*
Protected Area, Recurrente fires,	*1,695*
Protected Area, High rainfall erosivity, Recurrente fires,	*1,780*
KBA outside PA, High rainfall erosivity, Recurrente fires,	*1,780*
KBA outside PA, High rainfall erosivity,	*1,780*
High loss of biodiversity, High rainfall erosivity,	*1,950*
High Biodiversity Intactness, Loss of Canopy Cover,	*2,034*
Low NDVI in PA and KBA outside PA, High Biodiversity Intactness, Protected Area, High rainfall erosivity,	*2,034*
Recurrente fires, Loss of Canopy Cover,	*2,713*
High loss of biodiversity, High rainfall erosivity, Recurrente fires,	*2,967*
Loss of Canopy Cover,	*3,391*
High Biodiversity Intactness, Recurrente fires, Loss of Canopy Cover,	*3,391*
High rainfall erosivity,	*4,154*
High rainfall erosivity, Recurrente fires, Loss of Canopy Cover,	*4,662*
High loss of biodiversity, Recurrente fires,	*4,832*
High Biodiversity Intactness, Protected Area, Recurrente fires,	*4,832*
High Biodiversity Intactness, Recurrente fires,	*7,799*
High rainfall erosivity, Recurrente fires,	*9,155*
Protected Area, High rainfall erosivity,	*14,665*
Recurrente fires,	*16,614*
High Biodiversity Intactness,	*16,784*
High Biodiversity Intactness, Protected Area, High rainfall erosivity,	*20,005*
Protected Area,	*23,481*
High Biodiversity Intactness, Protected Area,	*53,319*

Table 14. Input criteria combinations accounting for more than 5,000 ha between degradation and biodiversity

Biodiversity and Degradation criteria combinations (above 5,000 ha) Sapo Grebo and Taï	Area (ha)
High Biodiversity Intactness, KBA outside PA, Low fertility, High rainfall erosivity,	5,441
Low fertility,	5,866
Low fertility, High erodibility, High rainfall erosivity, Loss of Canopy Cover,	5,951
Protected Area, Low fertility, High erodibility, High rainfall erosivity, Steep slopes,	6,631
High Biodiversity Intactness, Protected Area, Low fertility, High erodibility, High rainfall erosivity, Steep slopes,	6,801
Low fertility, High erodibility, High rainfall erosivity, Steep slopes,	7,396
KBA outside PA, Low fertility, High rainfall erosivity,	7,821
Low NDVI in PA and KBA outside PA, High Biodiversity Intactness, Protected Area, Low fertility, High rainfall erosivity,	9,352
High Biodiversity Intactness, Low fertility,	10,032
Protected Area, Low fertility, High rainfall erosivity, Steep slopes,	11,052
Low fertility, High rainfall erosivity, Steep slopes,	12,327
High Biodiversity Intactness, Low fertility, High erodibility, High rainfall erosivity,	12,497
High Biodiversity Intactness, KBA outside PA, Low fertility, High erodibility, High rainfall erosivity,	13,262
Protected Area, Low fertility,	13,772
High Biodiversity Intactness, Protected Area, Low fertility, Steep slopes,	18,958
KBA outside PA, Low fertility, High erodibility, High rainfall erosivity,	19,213
High Biodiversity Intactness, Protected Area, Low fertility, High rainfall erosivity, Steep slopes,	21,254
High Biodiversity Intactness, Low fertility, High rainfall erosivity,	22,954
Low fertility, High rainfall erosivity,	49,309
Protected Area, Low fertility, High rainfall erosivity,	51,859
Protected Area, Low fertility, High erodibility, High rainfall erosivity,	69,542
High Biodiversity Intactness, Protected Area, Low fertility,	77,619
Low fertility, High erodibility, High rainfall erosivity,	91,391
High Biodiversity Intactness, Protected Area, Low fertility, High rainfall erosivity,	155,832
High Biodiversity Intactness, Protected Area, Low fertility, High erodibility, High rainfall erosivity,	267,882

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