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Simulation of forest cover losses: case study of the East and South Regions of Cameroon

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Abstract

The Congo Basin forest, the second-largest rainforest in the world, has been the subject of worldwide scientific debate and continuous monitoring for the last two decades. Cameroon, which has nearly 10% of the forests of the Congo Basin, is observing an accelerated and poorly controlled disappearance of its core forest in the eastern and southern regions, and a difficulty in setting up systems to restore degraded forests and create new ones. It is, therefore, imperative to examine the loss of forest cover in these regions. This article measures and quantify the gains and losses of forest cover disaggregated to the scale of the districts of the eastern and southern regions to evaluate the integrity of forest landscapes with respect to anthropogenic pressures, to forecast the forest cover of these regions for the year 2050, and to present and quantify in terms of area the potential sites of forest restoration. The primary data for our article are time series of satellite images, coupled with the Cameroon Forest Atlas. The results obtained indicate that the forest core of Cameroon is disappearing at an exponential rate and presents alarming integrity recoveries with respect to anthropic pressures. 46% of the study area has a high level of integrity, 37% a medium level, and 17% a low level. For the year 2050, forecasts of forest cover change obtained by implementing the RCP8.5 scenario indicate systematic losses of 13% in the East and 8% in the South compared to the current state. The Eastern region, having lost 2.96% over the period 2001-2020 of its forest cover of the year 2000 can restore up to 1.18%. On the other hand, in the South region, the 6.29% of losses over the same period, can be restored by 0.92%. This descriptive, predictive and prescriptive study of forest cover contributes to the monitoring of Cameroon's forest core and would serve as a guide for forest managers, to orientate and accentuate in these regions, the efforts of reforestation and afforestation.

Keywords: Deforestation; forest cover; forest degradation; natural resources; REDD+

1. Introduction

Forests are an essential link for life on earth. They participate in the recycling of air, and the fight against climate change and are at the same time one of the main sources of carbon sink in the world, a living environment for great biodiversity, and a feeder of humankind. However, and particularly in the case of Cameroon, they present alarming environmental, economic destruction and immense social challenges. The present study arises from the observation of an accelerated and poorly controlled disappearance of Cameroon's forest core, and the difficulty to set up systems of restoration and creation of new forests. Cameroon's forests are monitored by MINFOF (Ministry of Forests and Wildlife), MINEPDED (Ministry of Environment, Nature Protection, and Sustainable Development), WRI (World Resources Institute), and CIFOR (Center for International Forestry Research), among others, whose work reports on national and regional changes in forest cover, as well as the drivers of these change. This work suffers from the limitations and problems of spatial data aggregation, which result in the disappearance of details as one moves up in geographical levels. This makes the results less meaningful. Prime, this article highlights the issue of the partial absence of information on the quantification of forest cover losses disaggregated to the scale of the districts of the regions of East and South Cameroon, and the total absence of forecasts of the state of the forests of the said regions. Segundo, the curious and astonishing situation of everyone in observation of the anthropogenic pressures on the forest landscapes of these regions and the great delay in the policies for the restoration of these forests. This raises the question: how can we contribute to filling these knowledge gaps and thus participate in the development of this declining forest potential? More precisely, how can we respond to the dynamics of changes in forest cover in the regions of East and South Cameroon at the scales of their administrative subdivisions? How do we assess the integrity of these once lush forests in light of anthropogenic pressures? Assuming the circumstances are maintained, what would be the state of forest cover in these regions in the next thirty years? Where can we act to challenge these existing conditions? In this study, we aim to report on changes and forecasts of forest cover in the East and South Cameroon regions, assess their integrity, and propose potential sites for forest restoration. To execute this, we assume that:

- The loss of forest cover is increasing exponentially, which would lead to a loss of more than 10% of the forest cover of the regions of East and South Cameroon in 2050 if these circumstances are maintained, compared to the reference cover in the year 2000;
- The retreat of the forests weakens their integrity. As such, it makes any action of forest restoration difficult.

This will lead us to:

- Measure and quantify the gains and losses of forest cover disaggregated to the scale of the districts, through the interpretation of time series of satellite images via Google Earth Engine;
- Assess the integrity of forest landscapes with respect to anthropogenic pressures, through the globally consistent and continuous index of forest landscape integrity;
- Forecast forest cover for the year 2050 by implementing the RCP8.5 scenario coupled with the CESM1 BGC, CESM1 CAM5, and HadGEM2 models;
- Present and quantify in terms of area, the potential forest restoration sites will be obtained by subtracting the current forest cover and areas of human activities, from the current forest potential.

2. Methodology

2.1. Study Area

The study is carried out in Cameroon, in its Eastern and Southern regions, each of which has four departments (**Figure 1, Figure 2**) and 33 districts in the Eastern region (**Figure 3**), and 29 districts in the Southern region (**Figure 4**).

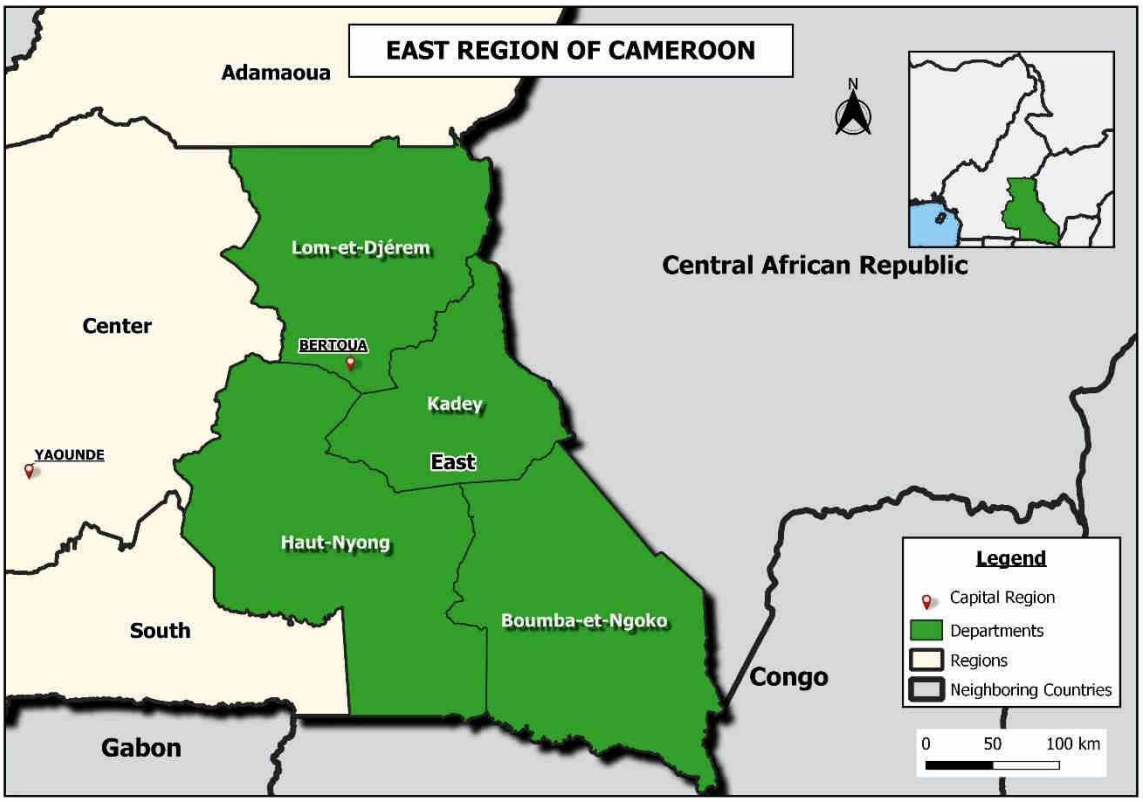

Figure 1: East Region

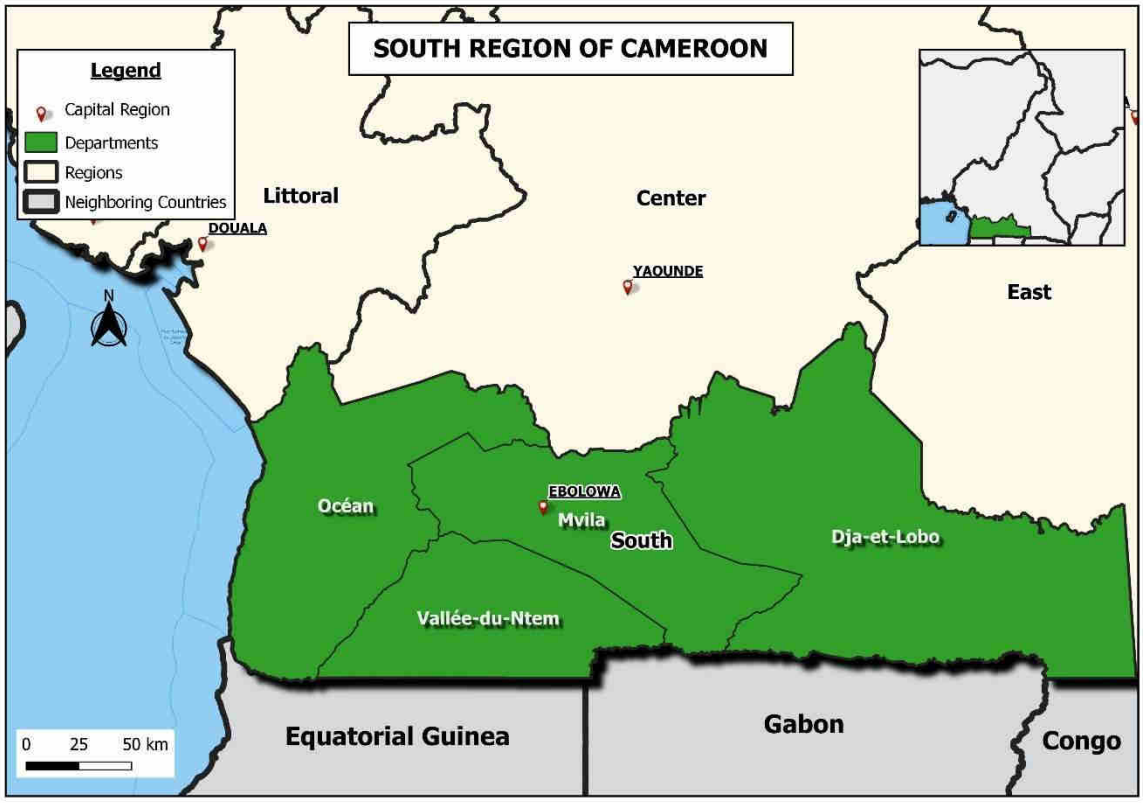

Figure 2: South Region

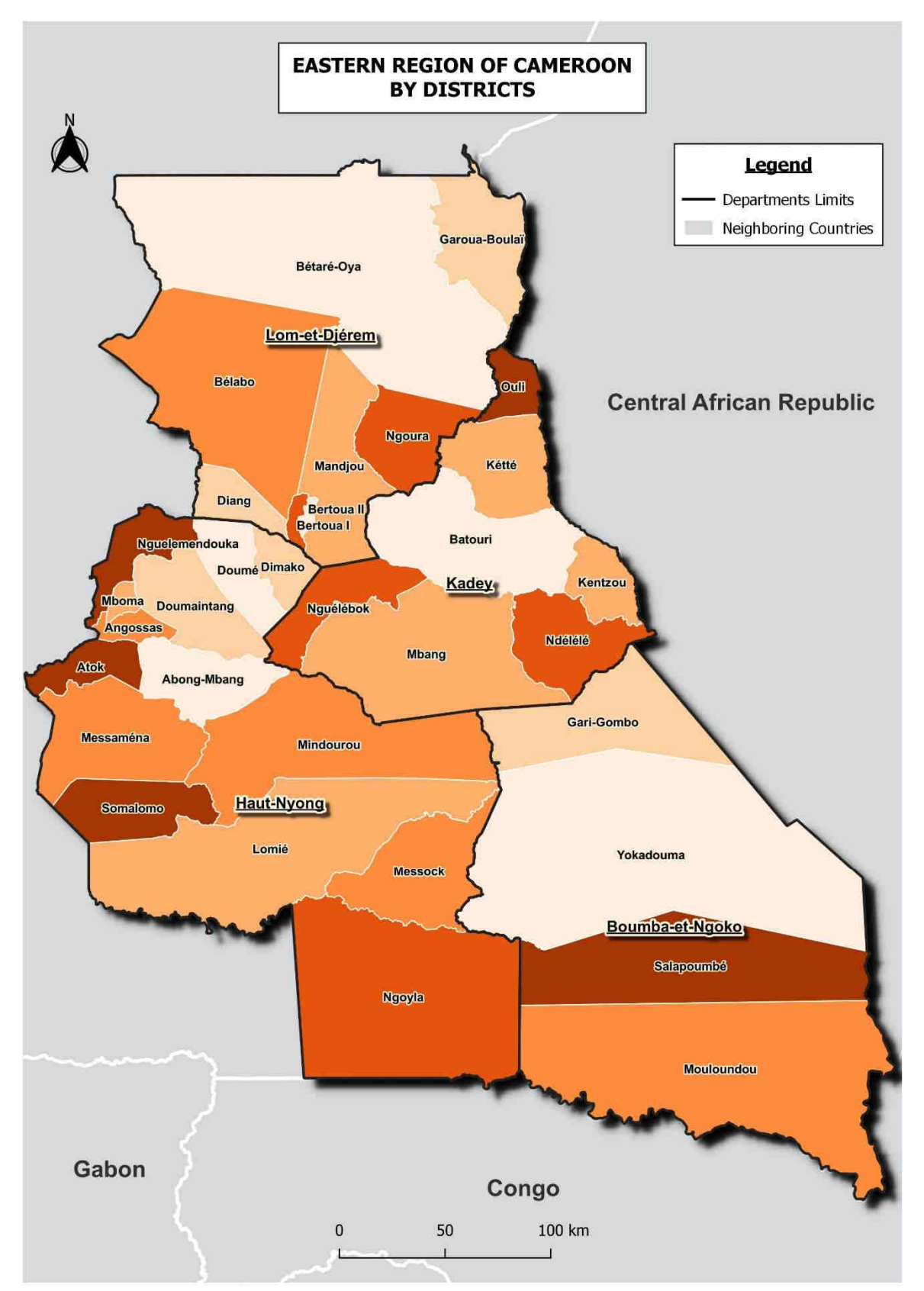

Figure 3: Districts of the Eastern Region

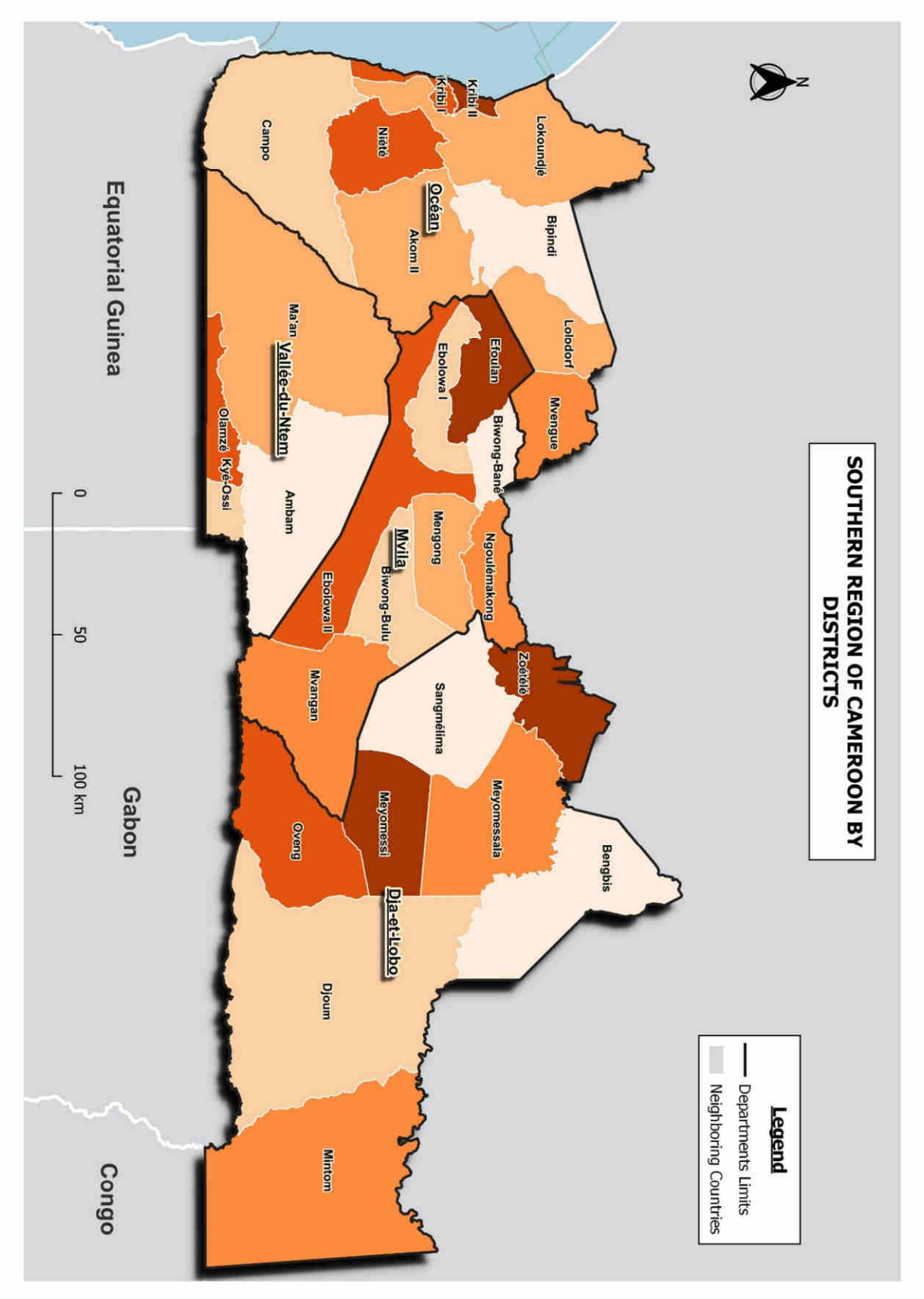

Figure 4: Districts of the Southern Region

2.1.1. Eastern region: general socio-economic and physical parameters

The Eastern Region made of a mosaic of indigenous, Bantu, and Sudanese people has an economy strongly supported by the forestry and mining sectors (INS 2020a). The region has two types of climate: one equatorial in the southern part, particularly in Yokadouma, and the other equatorial and tropical transition in the northern part, particularly in Bertoua, Bétaré-Oya, and Garoua-Boulaï. The hydrographic network of the region is composed of eight rivers: the Nyong, Djerem, Doumé, Kadey, Ngoko, Dja, Pangar, and Lom. The region, which presents different physical faces, is rich in tourist potential. Its relief is characterised by a vast plain whose highest altitudes vary between 800 and 900 meters in the west and the lowest around 400 meters in the southwest (**Figure 5**). The vegetation of the region consists mainly of forests that cover the entire Haut-Nyong and Boumba-Ngoko departments, and parts of the Lom-Djerem and Kadey departments. The transition zone includes the towns and communes of Bertoua and Ndélélélé. It is also of the savanna, which covers the entire northern part and extends over the rest of its area.

2.1.1. Southern region: general socio-economic and physical parameters

The Southern Region is one of the most cosmopolitan regions in Cameroon, populated by at least fifteen ethnic groups, all of them Bantu. The region’s economy is sustained by the forestry and mining sectors, agriculture, and tourism (INS 2020b). It has an equatorial Guinean climate characterised by abundant rainfall. The region's hydrographic network is composed of the main rivers: the So'o, the Ntemlong, the Lokoundje, the Dja, the Lobé, and the Kienké. The relief dominates the southern Cameroonian plateau, with an altitude varying between 0 and 1,000 m. There is a plateau in the east that rises to 1,000 m; an Atlantic coastal plain 150 km long south of Kribi; and a monotonous succession of convex hills that vary in altitude from 650 to 1,000 m (**Figure 6**). The vegetation of the region is mainly made up of dense rainforest characterized by abundant rainfall and found at low altitudes along the coast, dense evergreen rainforest (temperate) found in the Dja-et-Lobo, and dense swamp forest found mainly in the coastal zone.

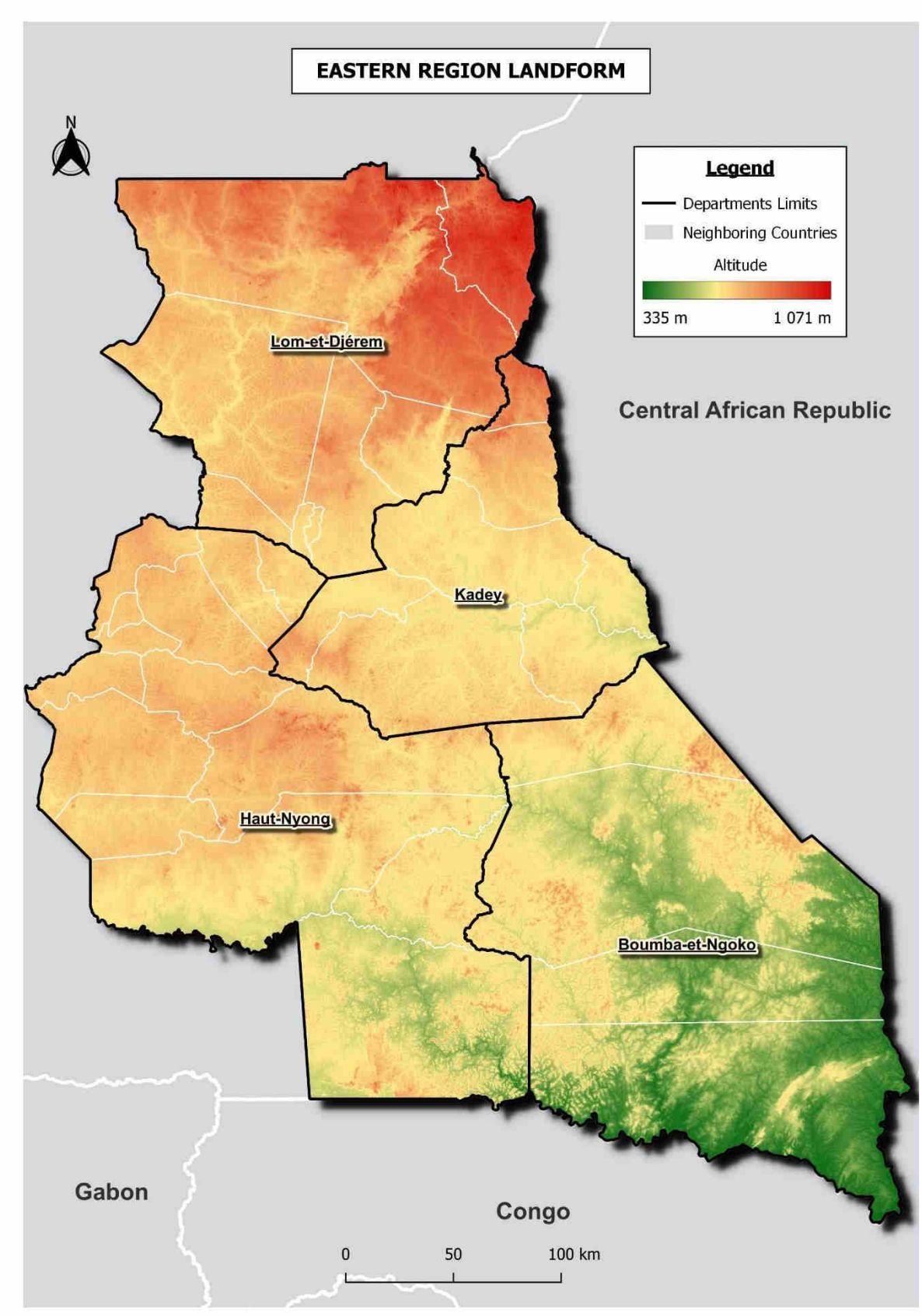

Figure 5: Map of the relief of the Eastern Region

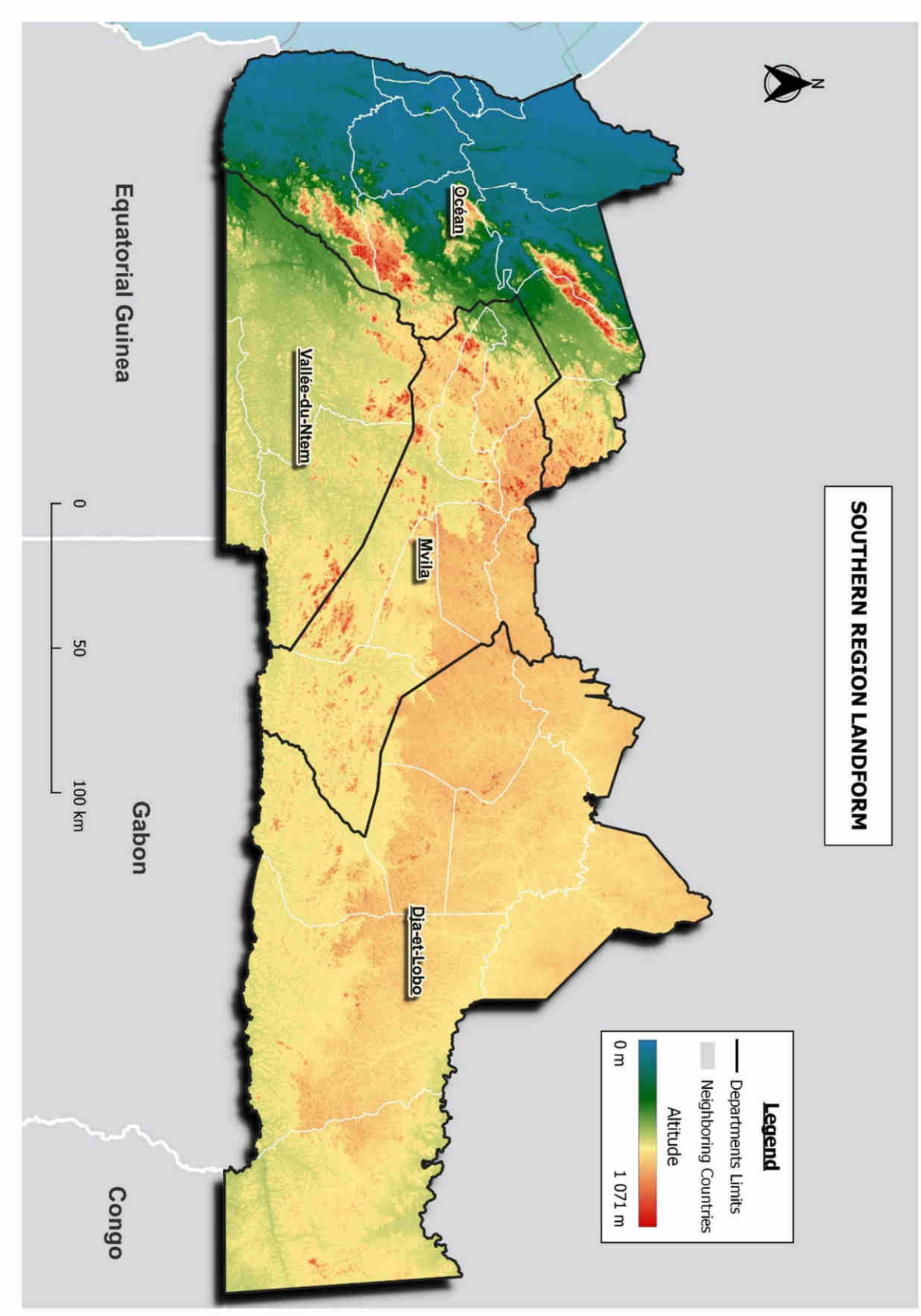

Figure 6: Map of the relief of the Southern Region

2.2. Local quantification of forest cover change

To evaluate the losses and gains of forest cover in our study area, and thus to put these losses and gains on the same scale, we relied on the work of Hansen et al. (2013). The objective here is to combine in a single map the baseline forest cover in the year 2000, with the forest cover gains recorded from 2001 to 2012, and the forest cover losses recorded from 2001 to 2020. This study is the result of the analysis of the Landsat image time series characterising forest extent and change. Trees are defined as vegetation greater than 5 m in height and expressed as a percentage per pixel. Forest cover loss is a change from forest to non-forest over the period 2001-2020. Forest cover gain is the inverse of loss or a change from non-forest to a full forest state during 2001-2012. Losses were disaggregated to the annual scale. In addition, gains do not account for tree regrowth initially recognized as forest (Hansen et al. 2013).

2.3. Assessment of forest landscape integrity

To assess the impact of anthropogenic factors on forest cover conditions, the Index of Forest Landscape Integrity (FLII) was calculated for the study area. This assessment focuses on the work of Grantham et al. (2020). To execute this, integrated with the forest extent data defined as all woody vegetation greater than 5m tall (Hansen et al., 2013), the following data; observed human pressures (e.g., infrastructure, agriculture, tree cover loss) that can be directly mapped using current datasets; Inferred pressures modeled based on proximity to observed pressures (e.g., collection of forest materials) occurring in association with those that are observed, but cannot be directly mapped; and changes in forest connectivity.

FLII scores range from 0 (lowest integrity) to 10 (highest integrity). This range is discretized to define three broad illustrative categories: low (<6.5), medium (≥6.5 and <9.5), and high integrity (≥9.5) by comparison with reference locations worldwide.

2.4. Prediction of gain and loss risks in 2050

Predictions of change were obtained by differencing the expected 2050 total potential tree cover from the current total potential tree cover and draws on the work of Jean-Francois Bastin and Devin Routh. The current total potential tree cover was obtained by extrapolating the forest through a random regression model of machine learning of forests (Breiman 2001), based on the environmental covariates that best predict the training samples in protected areas of the world, namely:

Five climate variables (mean annual temperature, annual precipitation, precipitation seasonality, mean temperature of the wettest quarter, precipitation of the driest quarter), three soil variables (organic carbon stock 0-15 cm, depth to bedrock, sand content 0-15 cm), and two topographic variables (elevation and hill shading). For future projections, the original model was revisited, keeping the three soil variables and two topographic variables unchanged and updating the five bioclimatic variables from three general circulation models commonly used in ecology (Martin et al. 2011; Hurrell et al. 2013) under an RCP8.5 scenario. Two Community Earth System Models (CESMs) were chosen to investigate a diverse set of land-system interactions: the CESM1 BGC, a carbon-climate model that accounts for carbon feedback from the land, and the CESM1 CAM5, an eighth-generation atmospheric general circulation model (Hurrell et al. 2013). In addition, the Earth system component of the Met Office Hadley Centre HadGEM2 family of models was used as the third and final model (Martin et al. 2011). The risk assessment of changes between current and future forest cover potential was derived by subtracting the “current potential” from the “future potential” so that potential increases were positive and potential decreases were negative. Importantly, the choice of the general circulation model affects less than 5% of the estimated future potential forest cover, showing that all general circulation models consistently predict losses in forest cover by 2050 (Bastin et al. 2019).

2.5. Assessment of forest restoration potential

Inspired by the work of Jean-Francois Bastin and Devin Routh, to have the total area available for forest restoration, the current estimate of forest extent calculated from the forest cover map published by Hansen and colleagues (Hansen et al. 2013), the extent of global potential forests (estimated by converting global potential forest cover into forest/non-forest classes) in respect to the Food and Agricultural Organisation definition of forests taking in account the tree cover threshold greater than or equal to 10% (FAO 2018). For providing realistic figures, all areas with urban settlements or agricultural activities were excluded. Thus, the restoration potential is simply the difference between the current forest cover and areas of human activities, to the current forest potential.

2.6. Spatial sampling: part of the results validation process

Sampling was implemented to validate the results of the dynamic forest cover change over the period 2000-2020. We favored a random stratified sampling design that takes

into account the homogeneity of our study area. The variation in velocity by zone, deforestation, and forest degradation in our study area based on the Cameroon Forest Estate Architecture (**Figure 7**) and the Cameroon Forest Atlas 2018 was also taken into account. There are many possible reasons for stratified sampling (Cochran 1977; Schreuder, Gregoire and Wood 1993).

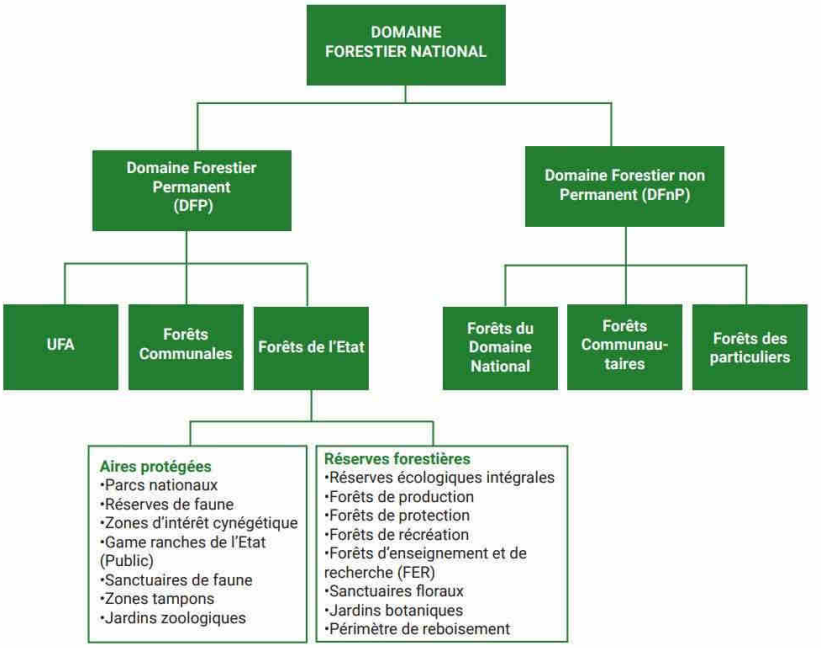

Figure 7 : Architecture of the forest domain of cameroon

It is considered Strata areas where forest cover loss is at the same rate within a stratum and differences between two classes. We have distinguished three main strata: the first includes agro-industrial plantations, planted areas, communal forests, community forests, production forests, FMUs, annual cuttings, sales of cuttings, and mining plots. The second stratum includes protected areas; the third stratum includes parts excluded from the first two strata. Sample plots were placed randomly within each stratum, at points where the multi-date digital image classification approach detected either a change in forest cover (a loss or a gain) or no change over the 2000-2020 study period. Thus, a total of 200 sites were evaluated **(Figure 8**), of which: 80 were classified as sites with canopy loss, 80 as sites with canopy gain, and 40 as sites where land cover change was not detected. Collect Earth Online was used for the validation by an augmented visual interpretation by defining the sample cells in a square with an area equal to 0.5 ha, which is consistent with the minimum area of the forest definition under REDD+ in Cameroon.

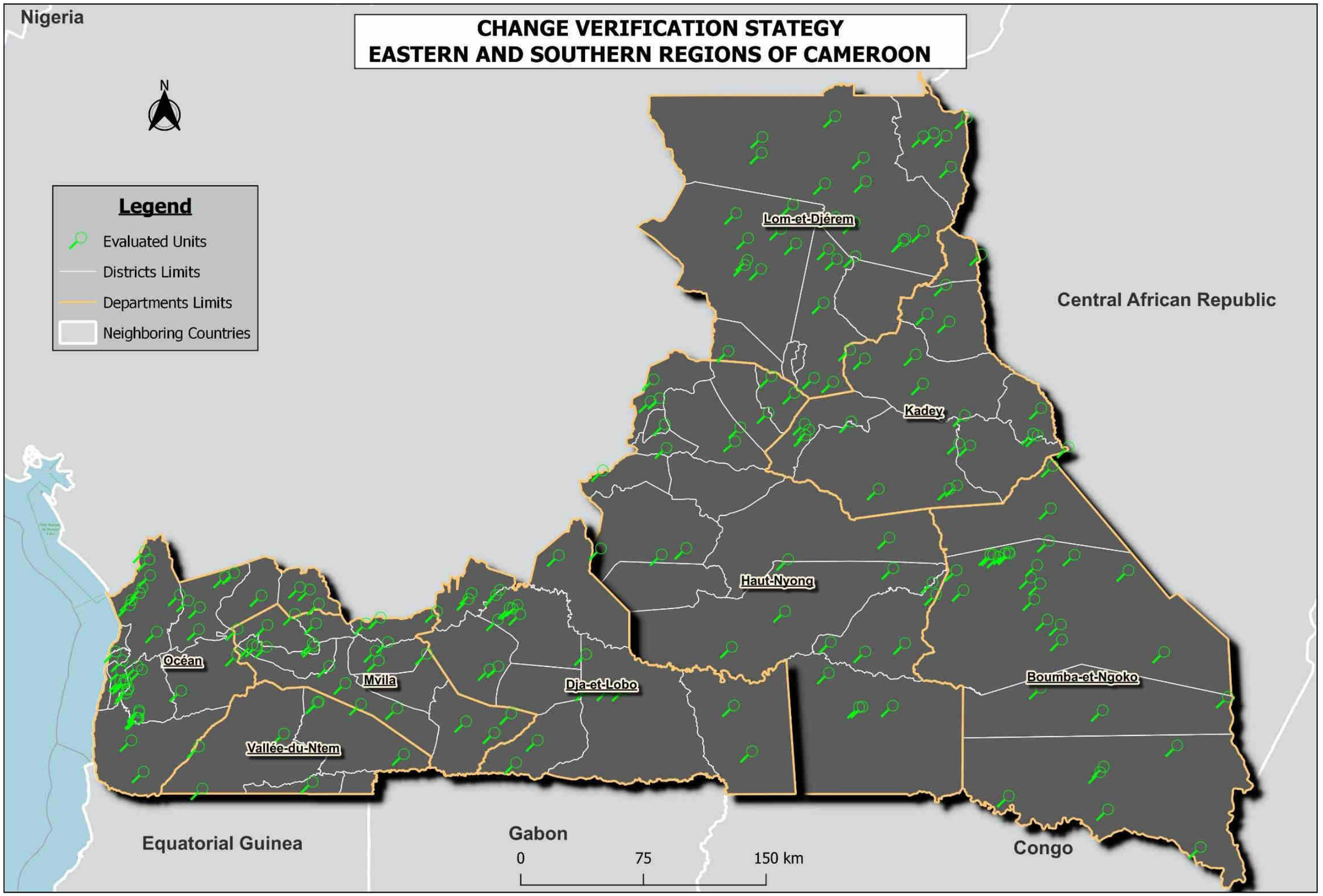

Figure 8 : Sampling plan

3. Results and discussions

3.1. Analysis of changes by region

The analysis of changes in forest cover in the Eastern and Southern regions of Cameroon carries many messages that should be presented.

The East region, which in 2000 had a forest cover rate estimated at 99.33% of the region, observed an increase in this rate of 0.11% over the period 2001-2012, against a decrease of 0.75% over the same period. That is to say, a loss/gain ratio of 694.61%. After the year 2012, this loss rate saw an increase of 2.22% over the period 2013-2020 or a total loss of 2.96% compared to its coverage rate in the base year 2000. At the scale of its departments, we observe loss/gain ratios over the period 2001-2012. Forest cover loss rates over the period 2001-2020, of 370.82% in ratio and 1.62% in losses in Boumba-et-Ngoko, 832.58% in ratio and 2.88% in losses in Haut-Nyong, 428.86% in ratio and 3.26% in losses in Kadey, 1878.83% in ratio and 4.54% in losses in Lom-et-Djérem (**Figure 9, Table 1**).

The Southern region, which in 2000 had a forest cover rate estimated at 99.38% of the region, observed an increase in this rate of 0.19% over the period 2001-2012, against a decrease of 1.26% over the same period. That is to say, a loss/gain ratio of 645.00%. After the year 2012, this loss rate saw an increase of 5.03% over the period 2013-2020 or a total loss of 6.29% compared to its coverage rate in the base year 2000. At the scale of its departments, we observe loss/gain ratios over the period 2001-2012. Forest cover loss rates over the period 2001-2020, of 1141.61% in ratio and 5.13% in losses in Dja-et-Lobo, 1688.88% in ratio and 7.93% in losses in Mvila, 371.02% in ratio and 7.67% in losses in Océan, 1076.13% in ratio and 5.35% in losses in Vallée-du-Ntem **(Figure 10, Table 2**).

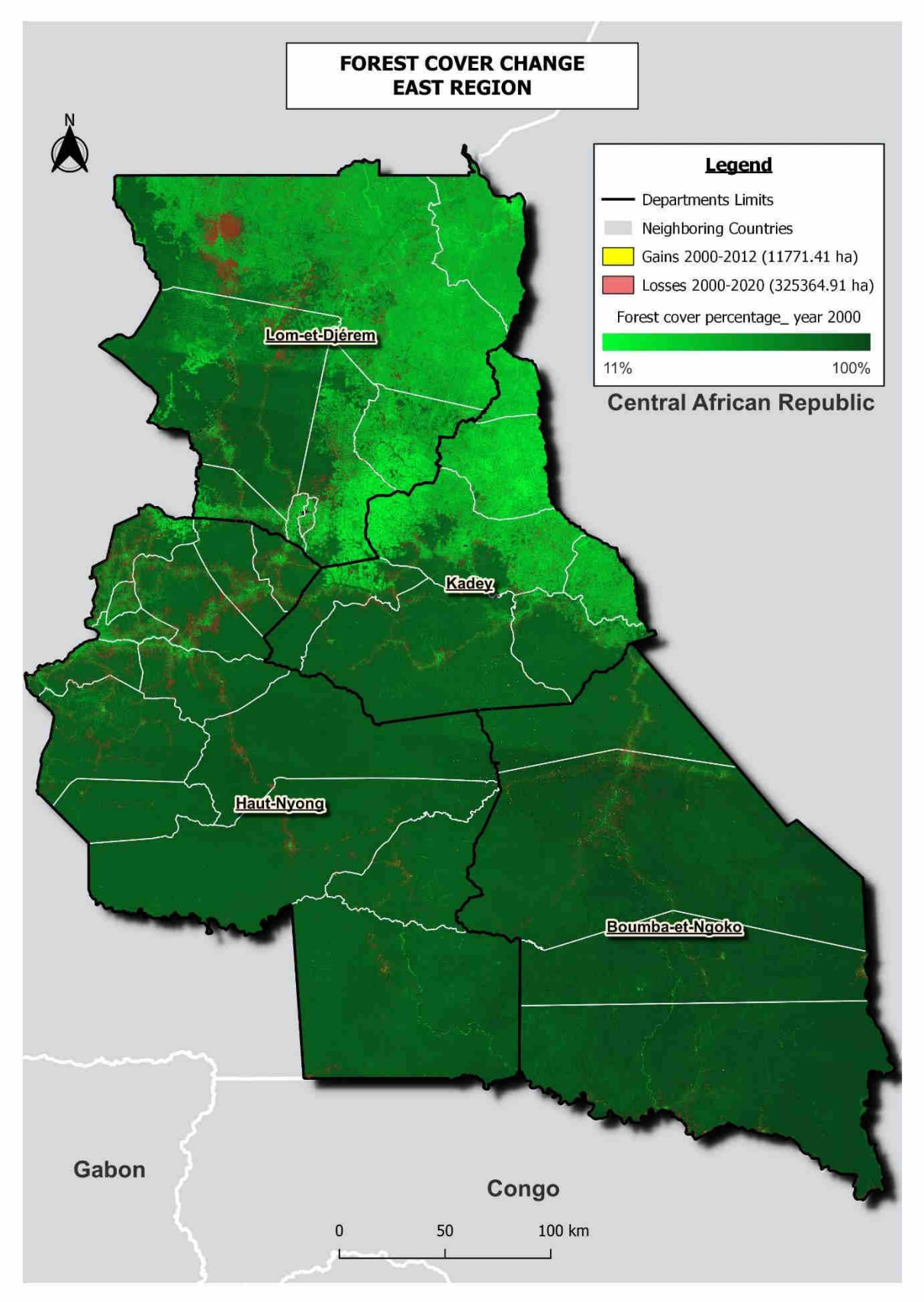

Figure 9: Map of Changes, Eastern Region

Region	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
East	3134	7412	5108	4946	6125	5405	10895	3250	13334	6709	2632	12814	19911	20693	20397	33777	45795	18745	30676	53605	11047753.53	10973988.23	99.33%	0.75%	0.11%	694.61%	2.96%	2.22%

Departments	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
Boumba-et-Ngoko	1263	1037	690	616	1422	679	1875	1439	5143	1723	696	1658	3514	3951	2584	4809	4571	3168	4334	6000	3189488.89	3167473.84	99.31%	0.58%	0.16%	370.82%	1.62%	1.04%
Haut-Nyong	746	2050	1744	1282	2031	1167	3482	1033	2315	1464	768	3599	6819	8178	6539	8901	10774	6977	10140	23886	3621043.62	3601406.01	99.46%	0.60%	0.07%	832.58%	2.88%	2.28%
Kadey	458	1584	425	260	918	214	1099	229	2510	1526	565	1445	2410	2979	2060	9308	4919	4054	5706	9733	1619419.71	1609190.89	99.37%	0.70%	0.16%	428.86%	3.26%	2.56%
Lom-et-Djérem	667	2742	2249	2789	1754	3346	4440	550	3366	1995	603	6112	7168	5584	9214	10759	25531	4546	10496	13986	2617801.31	2595912.57	99.16%	1.18%	0.06%	1878.83%	4.54%	3.36%

Districts	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
Abong-Mbang	28	73	220	154	284	71	256	35	186	107	103	313	596	807	931	942	1251	834	963	1865	170349.40	169428.64	99.46%	1.08%	0.07%	1570.84%	5.91%	4.83%
Angossas	40	37	17	83	107	50	79	36	49	85	79	134	465	251	231	340	431	234	377	1678	40661.86	40406.26	99.37%	1.97%	0.17%	1192.20%	11.88%	9.92%
Atok	55	22	85	91	137	130	69	85	69	115	80	136	480	757	503	666	1047	626	994	2247	89310.70	88882.30	99.52%	1.21%	0.16%	742.38%	9.44%	8.24%
Batouri	71	323	119	75	217	38	280	52	112	862	137	504	807	1024	673	4126	1596	1313	1978	3714	372662.08	370201.47	99.34%	0.75%	0.16%	471.75%	4.87%	4.11%
Bélabo	117	534	290	358	131	189	382	75	187	363	71	851	835	938	667	3412	6491	858	1623	3424	667028.05	658442.26	98.71%	0.54%	0.06%	869.73%	3.31%	2.77%
Bertoua I	0	58	36	66	17	19	81	5	17	27	31	92	136	65	78	106	190	195	78	310	16829.34	16326.17	97.01%	2.74%	0.13%	2040.57%	9.23%	6.49%
Bertoua II	0	57	65	75	9	15	71	6	8	109	13	80	52	37	42	54	121	64	42	270	9154.23	8688.97	94.92%	5.83%	0.16%	3685.59%	13.68%	7.85%
Bétaré-Oya	405	934	1304	929	1354	2650	2988	358	2512	694	322	4054	5024	2899	7192	3942	15768	1627	6343	2585	1180556.07	1172776.25	99.34%	1.58%	0.04%	3524.21%	5.45%	3.87%
Diang	12	291	122	86	97	45	171	19	22	199	24	221	242	266	235	541	610	267	254	1360	83009.63	82552.57	99.45%	1.59%	0.13%	1248.95%	6.16%	4.57%
Dimako	22	246	92	81	17	91	129	4	61	36	26	488	283	284	194	934	654	379	377	2297	72459.05	72048.54	99.43%	1.79%	0.10%	1846.07%	9.29%	7.50%
Doumaintang	132	413	279	314	450	140	919	87	175	298	142	700	1047	1091	1035	1219	1247	1180	1505	5051	191941.75	191032.90	99.53%	2.12%	0.12%	1782.21%	9.12%	7.00%
Doumé	78	410	200	132	165	93	327	88	63	69	30	355	498	483	336	1018	613	491	542	2275	120871.09	120266.68	99.50%	1.67%	0.10%	1658.77%	6.87%	5.20%
Gari-Gombo	99	115	49	5	360	54	249	202	2306	149	185	109	345	475	351	735	505	408	580	911	346845.13	345238.35	99.54%	1.12%	0.41%	274.14%	2.37%	1.25%
Garoua-Boulaï	120	404	159	132	85	295	261	38	509	194	57	256	162	311	189	611	818	445	687	607	223085.74	221121.96	99.12%	1.13%	0.03%	3508.32%	2.87%	1.73%
Kentzou	47	52	7	8	89	0	137	15	45	39	26	53	164	232	151	572	458	677	839	716	101851.07	100849.04	99.02%	0.51%	0.09%	553.29%	4.29%	3.78%
Kétté	61	71	58	48	48	43	62	17	42	260	35	77	177	331	240	1272	594	493	690	730	195157.76	194124.36	99.47%	0.42%	0.08%	499.39%	2.75%	2.33%
Lomié	45	196	170	70	131	51	315	194	430	43	33	258	735	839	646	729	830	443	638	1022	734430.24	730843.81	99.51%	0.27%	0.06%	454.73%	1.07%	0.80%
Mandjou	0	405	239	735	40	97	400	37	87	320	73	468	585	729	556	1340	1122	739	902	4073	265478.40	264174.54	99.51%	1.10%	0.13%	858.13%	4.90%	3.81%
Mbang	122	509	124	55	207	61	290	44	729	169	124	317	435	580	493	1505	1058	588	875	2078	534809.14	532127.32	99.50%	0.52%	0.16%	329.72%	1.95%	1.43%
Mboma	13	22	15	18	28	21	41	36	29	43	41	62	215	192	167	156	316	118	287	718	19569.31	19458.44	99.43%	1.90%	0.09%	2021.91%	13.05%	11.15%
Messaména	18	75	98	124	166	77	329	74	102	72	86	271	742	1111	598	835	1410	1035	1947	1985	311681.95	310255.42	99.54%	0.48%	0.05%	1044.60%	3.60%	3.11%
Messock	120	62	118	26	76	26	140	81	309	55	7	127	389	548	401	322	472	436	484	520	264735.15	263420.49	99.50%	0.44%	0.15%	285.42%	1.79%	1.36%
Mindourou	51	113	73	125	199	68	435	62	635	67	35	138	333	555	305	355	507	244	289	626	536236.33	533814.76	99.55%	0.37%	0.10%	384.50%	0.98%	0.60%
Mouloundou	316	242	146	177	323	207	250	251	178	671	190	328	673	704	418	1196	816	482	707	1467	999536.35	989210.44	98.97%	0.33%	0.05%	702.33%	0.98%	0.65%
Ndélélé	96	200	14	4	237	6	122	78	1445	120	180	168	324	399	247	728	459	580	910	658	199233.01	197212.25	98.99%	1.35%	0.40%	339.95%	3.54%	2.18%
Ngoura	0	60	35	408	22	37	86	12	25	91	12	90	132	339	256	754	413	451	569	1358	172658.86	171826.17	99.52%	0.51%	0.09%	597.67%	3.00%	2.49%
Ngoyla	59	100	123	12	58	38	118	134	124	71	14	104	390	429	390	313	409	337	528	704	785483.17	779535.30	99.24%	0.12%	0.02%	510.62%	0.57%	0.45%
Nguélébok	51	413	102	69	74	52	203	8	116	49	52	318	494	391	243	1086	696	362	311	1775	149510.15	148813.80	99.53%	1.01%	0.09%	1160.48%	4.61%	3.60%
Nguelemendouka	83	270	236	38	209	310	284	117	74	400	88	499	573	724	726	1000	1493	557	1097	2751	106253.30	105742.42	99.52%	2.46%	0.14%	1782.72%	10.90%	8.44%
Ouli	11	14	3	0	46	10	5	15	21	27	12	8	9	22	14	20	58	41	103	63	66196.50	65859.96	99.49%	0.26%	0.03%	864.59%	0.76%	0.50%
Salapoumbé	163	205	77	137	147	139	159	149	164	224	85	174	423	466	256	375	353	176	347	530	552649.88	549075.90	99.35%	0.33%	0.06%	571.21%	0.86%	0.53%
Somalomo	2	13	19	14	6	0	38	0	11	4	6	14	72	108	77	73	94	64	111	148	177060.32	176263.19	99.55%	0.07%	0.01%	808.47%	0.50%	0.42%
Yokadouma	685	474	418	296	593	278	1218	837	2494	680	236	1048	2072	2306	1558	2503	2898	2102	2700	3093	1290457.54	1283946.73	99.50%	0.72%	0.21%	340.70%	2.22%	1.50%

Table 1 : Changes by administrative subdivision, Eastern Region

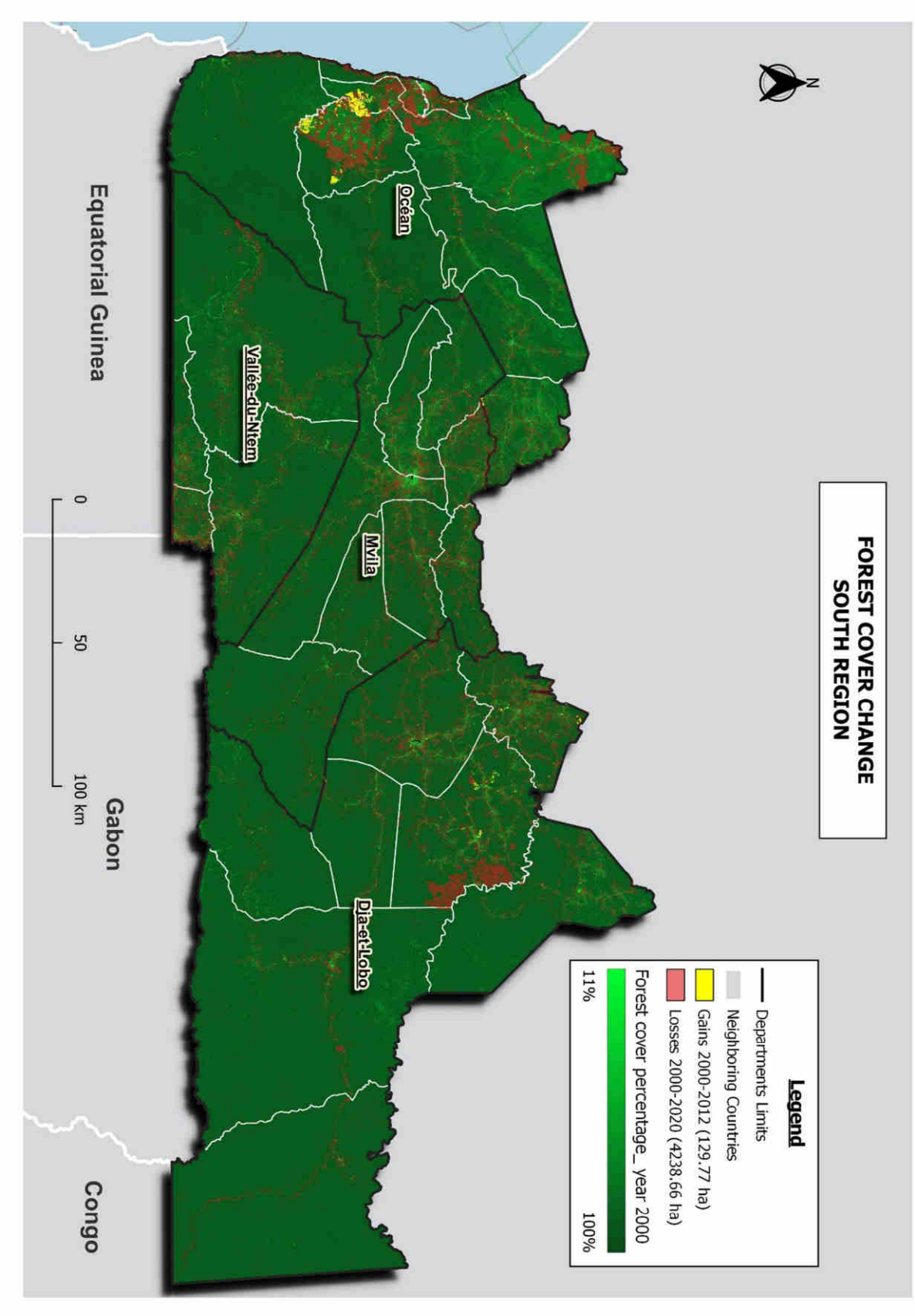

Figure 10 : Map of changes, Southern Region

Region	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
South	8048	2988	3261	1947	2804	4339	5455	6238	4973	3761	7505	7889	15672	47921	19215	26390	27899	33067	21043	45757	4738392.12	4709167.35	99.38%	1.26%	0.19%	645.00%	6.29%	5.03%

Departments	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
Dja-et-Lobo	2851	806	686	343	536	1955	946	1609	1767	422	1942	1882	7085	14476	7000	8415	11319	11191	7568	19206	2001152.19	1990265.92	99.46%	0.79%	0.07%	1141.61%	5.13%	4.33%
Mvila	948	995	204	519	501	981	629	2778	698	771	1220	1189	2346	13910	2613	7203	3854	9023	3868	14478	871645.41	867102.18	99.48%	1.32%	0.08%	1688.88%	7.93%	6.61%
Océan	3501	385	1780	738	907	868	3273	1204	1674	2354	3127	3671	3741	13216	6768	8329	9830	8570	6562	6590	1143889.48	1135297.25	99.25%	2.07%	0.56%	371.02%	7.67%	5.60%
Vallée-du-Ntem	748	803	590	346	860	535	607	648	834	213	1215	1146	2499	6319	2834	2444	2896	4283	3045	5482	721705.04	716498.47	99.28%	1.19%	0.11%	1076.13%	5.35%	4.16%

Districts	Losses (ha) 2001	Losses (ha) 2002	Losses (ha) 2003	Losses (ha) 2004	Losses (ha) 2005	Losses (ha) 2006	Losses (ha) 2007	Losses (ha) 2008	Losses (ha) 2009	Losses (ha) 2010	Losses (ha) 2011	Losses (ha) 2012	Losses (ha) 2013	Losses (ha) 2014	Losses (ha) 2015	Losses (ha) 2016	Losses (ha) 2017	Losses (ha) 2018	Losses (ha) 2019	Losses (ha) 2020	Area (ha)	Forest cover 2000 (ha)	Forest cover year 2000	Losses from 2001 to 2012 compared to the year 2000	Gain from 2001 to 2012 compared to 2000	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	Increased losses since 2013 to 2020
Akom II	194	19	100	49	23	24	167	72	125	155	86	207	235	656	203	364	538	351	454	217	193994.28	193118.02	99.55%	0.63%	0.07%	941.76%	2.19%	1.56%
Ambam	120	302	162	121	391	239	76	368	352	40	404	323	807	2562	1561	724	577	1994	999	2809	246335.65	244720.42	99.34%	1.18%	0.11%	1088.64%	6.10%	4.92%
Bengbis	116	16	56	35	28	150	49	216	44	61	75	99	509	1363	358	705	1117	1014	514	1969	226425.42	225250.61	99.48%	0.42%	0.03%	1211.17%	3.77%	3.35%
Bipindi	187	14	102	31	28	44	218	30	123	150	110	251	128	505	277	426	542	374	673	342	132550.45	131893.17	99.50%	0.98%	0.10%	998.61%	3.45%	2.48%
Biwong-Bané	89	158	10	121	33	82	64	281	42	134	95	144	161	1730	163	1026	360	979	321	1546	46045.21	45808.54	99.49%	2.73%	0.20%	1373.43%	16.46%	13.72%
Biwong-Bulu	51	94	10	37	50	123	17	305	99	26	96	73	274	1589	202	646	285	888	240	1899	98201.04	97732.3	99.52%	1.00%	0.05%	1959.35%	7.17%	6.16%
Campo	129	3	63	36	25	73	73	22	134	54	178	128	228	497	238	252	309	135	217	107	276804.72	274087.96	99.02%	0.34%	0.05%	644.52%	1.06%	0.72%
Djoum	61	145	109	30	56	24	104	49	243	55	84	228	943	1471	635	811	1364	1018	894	1405	546607.26	543862.94	99.50%	0.22%	0.02%	1328.05%	1.79%	1.57%
Ebolowa I	145	124	29	63	57	121	119	325	53	156	120	207	217	1361	283	823	320	1001	359	1249	73799.03	73400.30	99.46%	2.07%	0.15%	1413.49%	9.72%	7.65%
Ebolowa II	167	149	37	99	147	223	118	454	141	114	213	135	474	2617	779	1365	718	2042	801	2808	200376.42	199122.09	99.37%	1.00%	0.05%	1981.97%	6.83%	5.83%
Efoulan	154	76	42	102	38	61	192	226	101	245	164	336	190	1256	170	1130	394	701	295	825	86023.06	85618.54	99.53%	2.03%	0.12%	1628.11%	7.83%	5.79%
Kribi I	81	4	86	31	14	17	92	46	89	80	409	373	293	584	532	343	856	692	207	699	20422.53	20145.89	98.65%	6.56%	0.66%	993.70%	27.43%	20.87%
Kribi II	161	5	21	48	44	9	124	20	142	75	183	200	121	375	206	230	512	222	276	166	10536.69	10261.30	97.39%	10.06%	0.92%	1088.20%	30.62%	20.55%
Kyé-Ossi	62	196	173	3	97	134	63	148	164	16	267	245	372	829	282	209	414	509	472	1056	26958.7	26728.38	99.15%	5.86%	0.72%	810.59%	21.36%	15.50%
Lokoundjé	1057	141	587	182	215	161	766	246	437	808	930	1118	1423	4252	2841	2895	3592	3610	2683	1951	229970.26	227556.19	98.95%	2.92%	1.35%	216.39%	13.14%	10.22%
Lolodorf	224	7	8	58	23	28	191	13	41	81	150	251	162	611	257	604	458	316	373	391	96828.73	96361.64	99.52%	1.12%	0.06%	1829.15%	4.41%	3.29%
Ma'an	513	173	152	221	299	115	431	85	214	149	434	426	962	2093	870	1178	1655	1286	1188	1073	400487.43	397614.30	99.28%	0.81%	0.07%	1240.66%	3.40%	2.59%
Mengong	96	186	34	51	67	209	47	604	112	23	215	77	463	2101	498	930	782	1415	576	2658	89033.07	88595.76	99.51%	1.94%	0.10%	1938.79%	12.58%	10.64%
Meyomessala	677	193	157	83	126	885	320	412	448	134	624	820	2638	3263	3909	2947	4153	4817	1445	5192	212833.48	211670.16	99.45%	2.30%	0.26%	878.18%	15.70%	13.40%
Meyomessi	125	21	11	11	34	107	73	43	77	28	95	131	287	918	203	580	480	509	426	1086	124613.54	124029.9	99.53%	0.61%	0.03%	1809.52%	4.23%	3.62%
Mintom	6	82	62	43	26	6	56	35	180	9	18	35	531	589	376	290	668	541	735	582	408208.51	405619.78	99.37%	0.14%	0.02%	883.19%	1.20%	1.06%
Mvangan	123	83	7	21	77	91	30	173	77	33	187	166	319	1571	256	540	449	921	498	1731	208825	207818.63	99.52%	0.51%	0.03%	1509.77%	3.54%	3.02%
Mvengue	242	136	31	151	70	59	156	195	42	168	111	371	214	2100	274	1475	579	1039	439	1590	82273.81	81860.49	99.50%	2.12%	0.25%	852.14%	11.54%	9.42%
Ngoulémakong	124	125	35	25	33	71	41	411	73	41	130	51	248	1687	262	744	546	1075	777	1761	69342.58	69003.09	99.51%	1.68%	0.09%	1888.39%	11.97%	10.29%
Niété	1227	54	783	152	464	454	1486	560	541	784	971	770	938	3638	1939	1740	2445	1831	1239	1127	100508.03	100009.25	99.50%	8.24%	2.37%	348.48%	23.14%	14.90%
Olamzé	53	131	103	1	73	48	37	47	104	7	111	152	358	835	121	333	250	493	385	544	47923.27	47434.25	98.98%	1.83%	0.16%	1147.23%	8.83%	7.00%
Oveng	106	35	11	6	20	44	36	28	15	12	58	53	159	447	128	196	135	169	185	499	178955.73	178137.14	99.54%	0.24%	0.02%	1335.45%	1.32%	1.08%
Sangmélima	947	147	63	80	113	460	177	460	371	52	632	353	1010	3753	590	1792	1877	1894	1660	4459	194424.34	193201.84	99.37%	1.99%	0.08%	2532.60%	10.81%	8.82%
Zoétélé	813	166	220	56	133	280	130	367	389	72	358	161	1008	2671	802	1093	1524	1229	1709	4014	109083.91	108490.16	99.46%	2.90%	0.34%	855.42%	15.85%	12.95%

Table 2 : Changes by administrative subdivision, Southern Region

These assessments at the regional and departmental levels suggest trends that could wrongly be qualified as good. At the district level, some districts show extreme and alarming rates of forest cover loss. In the East region, the districts of Bertoua II, Mboma, Nguelemendouka, among others, show respectively rates of loss of forest cover over the period 2001-2020 in relation to its reference coverage in the year 2000 and ratio of losses/gains over the period 2001/2012 of 13.68% in losses for a ratio of 3685.59%, 13.05% in losses for a ratio of 2021.91% and 10.90% in losses for a ratio of 1782.72%. The southern region is no exception. The districts of Kribi II, Kribi I, Sangmélima, among others, respectively show rates of loss of forest cover over the period 2001-2020 in relation to its reference coverage in the year 2000, and the ratio of losses/gains over the period 2001/2012 of 30.62% in losses for a ratio of 1088.20%, 27.43% in losses for a ratio of 993.70% and 10.81% in losses for a ratio of 2532.60%. These indicators convey three main messages: the first one, obtained by comparing the forest cover disaggregated loss rates at the borough level over the periods 2001-2012 and 2013-2020, underlines the fact that forest cover losses evolve exponentially from year to year. This implies a high share of LFPs in the Cameroonian economy and the conquest of more and more agricultural land to meet the needs of the population. This observation is unmistakable if we associate these figures with their geolocation, where we for example, in the districts of Niété and Meyomessala in the South, observe the presence of large rubber plantations, or communal and community forests in operation in the districts of Bétaré-Oya and Angossas in the East region. The second message is that in terms of loss/gain ratios are poorly implemented forest restoration policies in some districts, such as Bertoua II, where losses are 3,685.59 percent of gains, and Sangmélima, where the loss/gain ratio is 2,532.60 percent, due to the expansion of towns. The third message is the following: If we look at the districts with the lowest rates of forest cover loss and associate land use in these places, we see the presence of protected areas such as the national parks of Campo-Ma'an in the district of Campo in the South, Boumba Bek, Nki and Lobéké in the districts of Salapoumbé, Ngoyla, Mouloundou and Yokadouma in the East region, and on the other hand, like the wildlife reserves of Dja and Ngoyla in the districts of Somalomo, Lomié and Ngoyla in the East region.

3.2. Residual forest integrity in 2020

The Eastern Region has 54% of its area with high forest integrity, 35% with medium integrity, and 11% with low integrity. At the departmental level, the following proportions of areas are classified as high integrity, medium integrity, and low integrity with respect to the FLII: 70%, 25%, and 5% for Boumba-et-Ngoko; 60%, 29%, and 11% for Haut-Nyong; 37%, 48% and 15% for Kadey; 36%, 47% and 17% for Lom-et-Djérem (**Figure 11, Figure 12**).

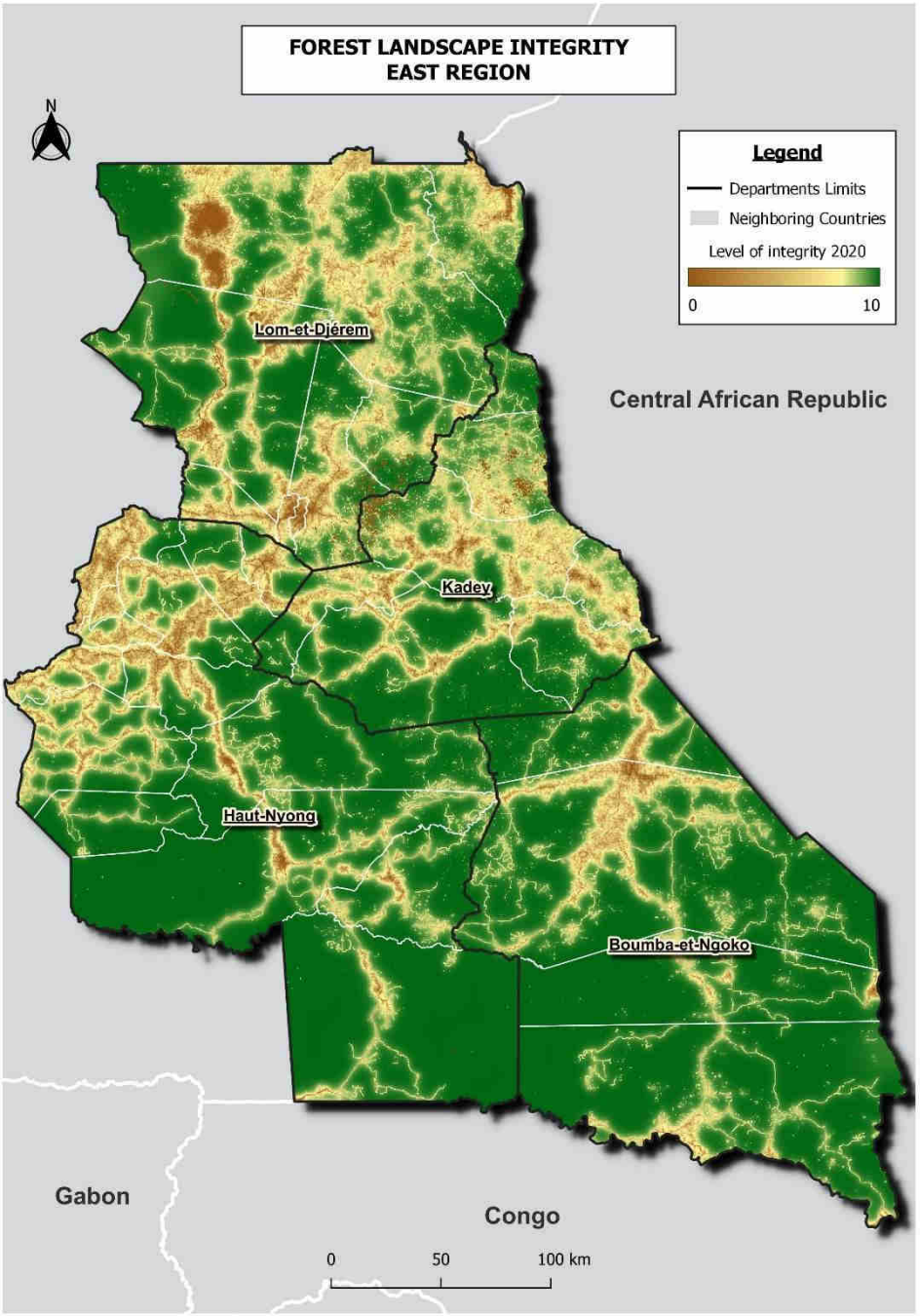

Figure 11: Integrity of forest landscapes in the Eastern Region

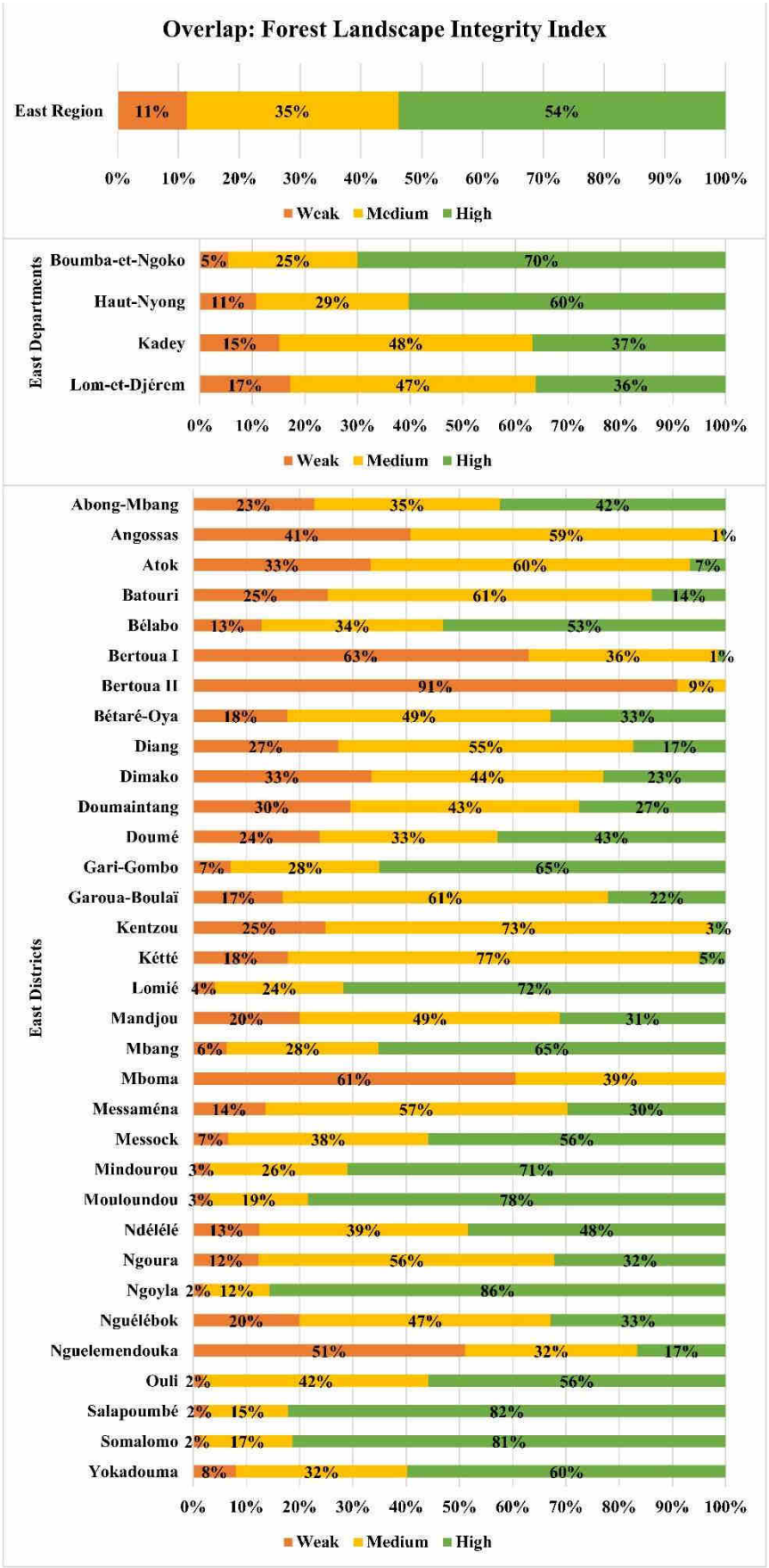

Figure 12: Recovery of The Eastern Region's Integrity Indices

In the southern region, 38% of the region is classified as a high forest integrity zone, 39% as a medium integrity zone, and 23% as a low integrity zone. At the level of its departments, the following proportions of areas qualify as high integrity, medium integrity, and low integrity for the FLII: 48%, 34%, and 18% for Dja-et-Lobo; 19%, 48%, and 33% for Mvila; 38%, 37% and 25% for Océan; 32%, 47% and 21% for Vallée-du-Ntem (**Figure 13, Figure 14**).

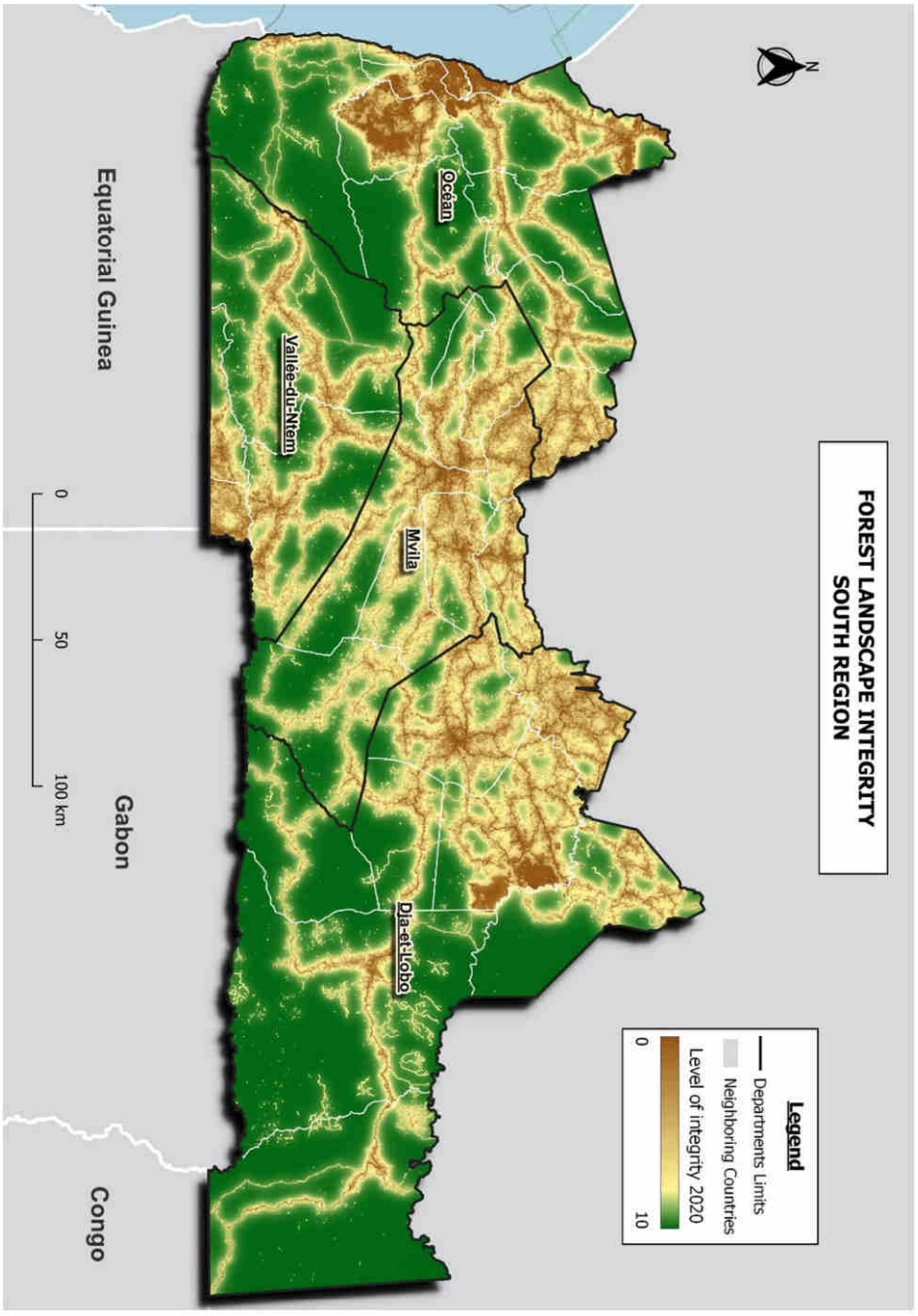

Figure 13: Integrity of forest landscapes in the Southern Region

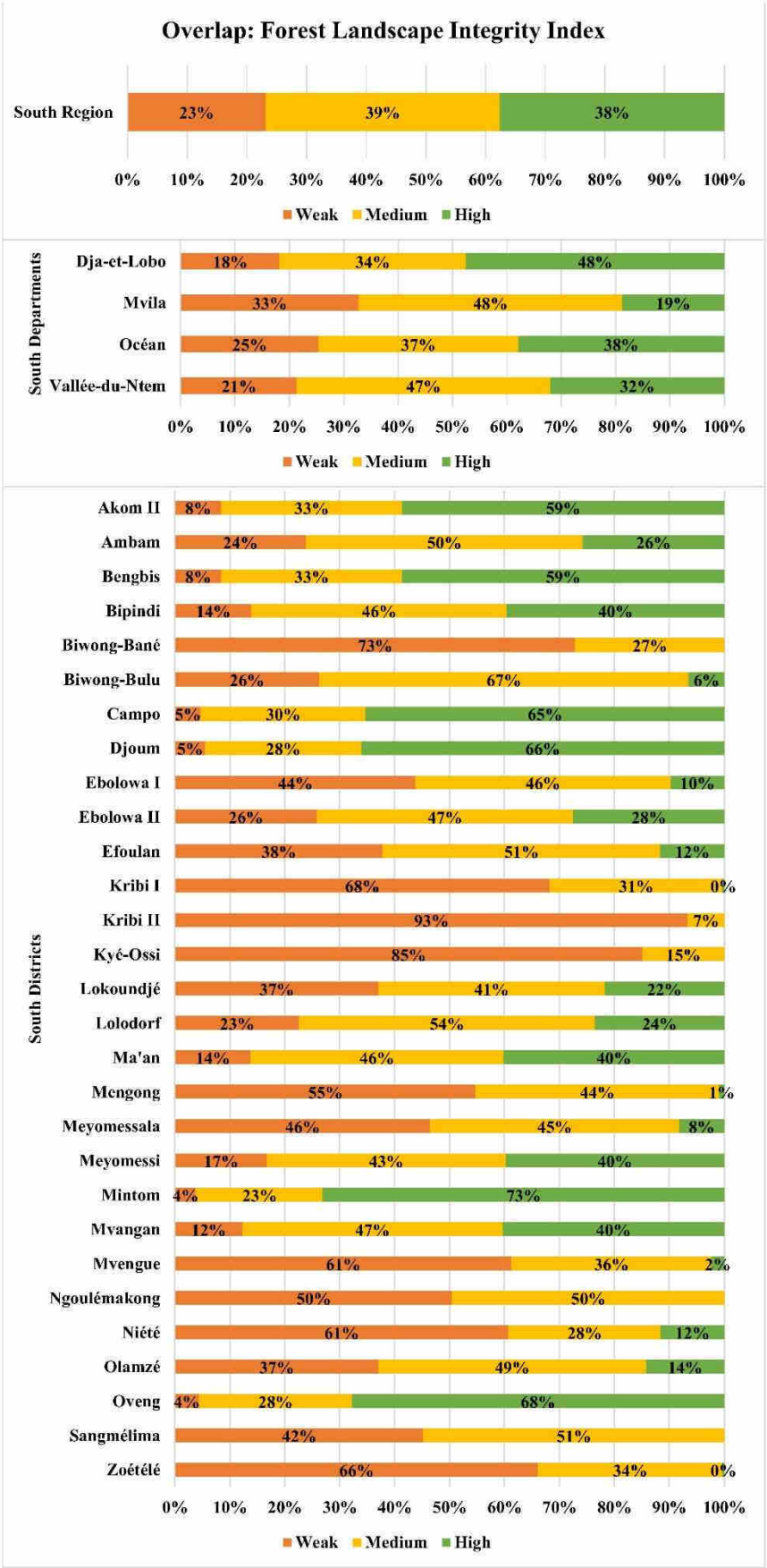

Figure 14: Recovery of integrity indices in the Southern Region

Extreme and opposite situations can be observed at the level of their districts. In the East, the districts of Bertoua II and Mboma show recovery rates of 91% in average integrity and 9% in integrity for Bertoua II, and 61% in average integrity, and 39% in low integrity for Mboma. These recovery rates indicate opposite situations in the districts of Salapoumbé and Ngoyla, which have high, medium, and low integrity recovery rates of 82%, 16%, and 2%, respectively, for Salapoumbé and 86%, 12%, and 2% for Ngoyla (**Figure 12**). In the south, similar recovery rates are observed. The districts of Kribi II and Kyé-Ossi are covered in areas of medium and low integrity respectively in the following proportions: 93%, 7% for the district of Kribi II, and 85%, 15% for the district of Kyé-Ossi. These cover rates indicate opposite situations in the districts of Mintom and Oveng, which respectively show high, medium, and low integrity cover rates of 73%, 23%, 4% for Mintom, and 68%, 28%, 4% for Oveng (**Figure 14**). Forest integrity, the second focus of our study, is closely related to the first focus on forest cover change. Since these two points are related to the drivers of forest cover loss, the landscape of the forest integrity index captures the vulnerability of forests to human activities. Areas of low and medium integrity, therefore, reflect the area is most likely to see a decline in tree cover in the very near future and thus raise the need for special attention. The southern region is the most vulnerable.

3.3. Forecasts of forest cover in 2050

The Eastern region is likely to see its tree cover decreased by 13.32%, with losses in places of 83.78% and gains of 51.28% in places. This means a distribution of values of percent changes with a standard deviation at one sigma of ± 18.30%. Its departments show risks of systematic losses of forests with average statistics and standard deviation at one sigma of -12.75% to ±17.10% in Boumba-et-Ngoko, -13.54% to ±16.25% in Haut-Nyong, -19.14% to ±15.82% in Kadey, -8.44% to ±18.64% in Lom-et-Djérem (**Figure 15, Table 3**).

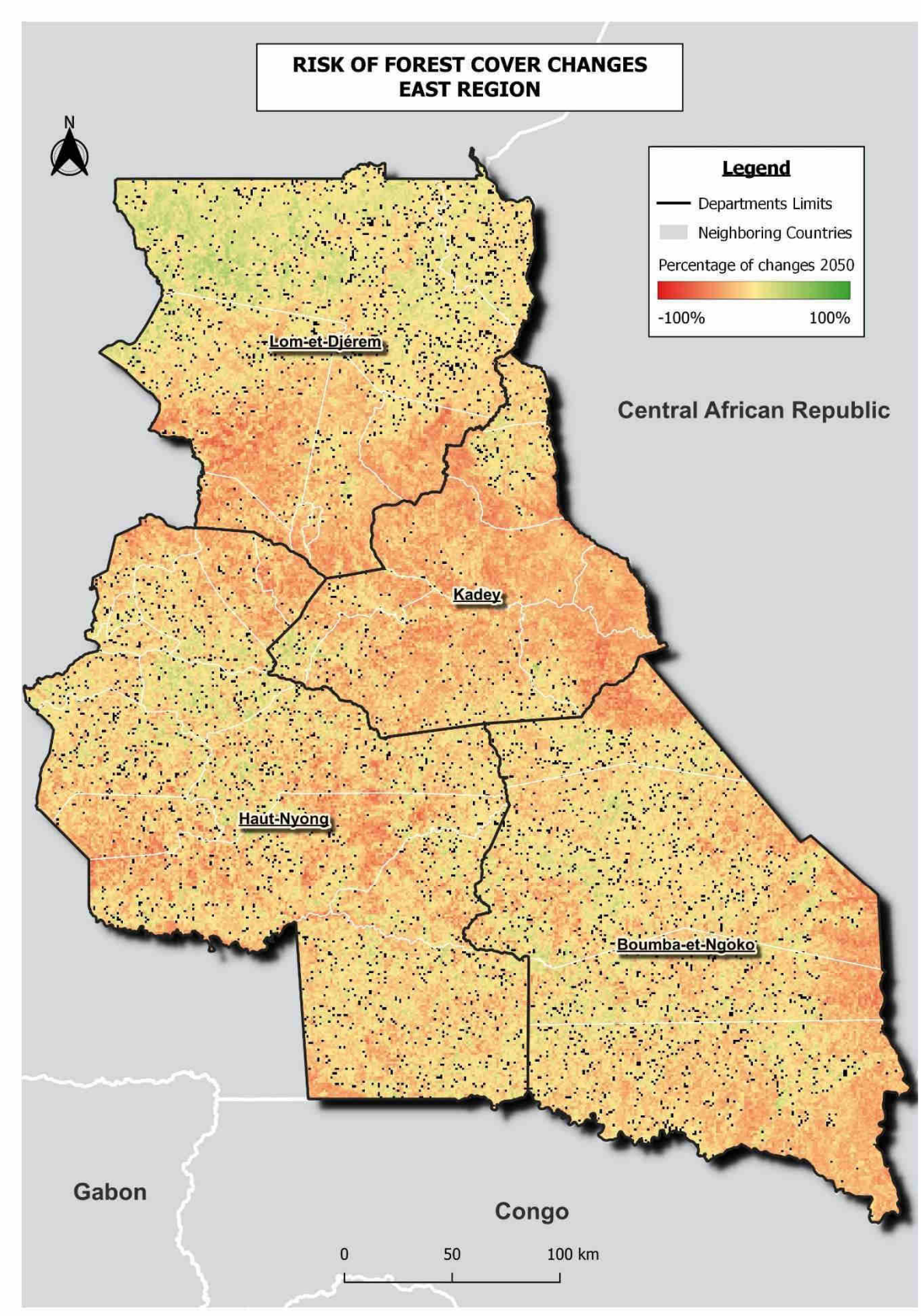

Figure 15: Map of risks of forest cover changes in 2050, East Region

Statistics of percentages of change Forecasts 2050							
Administrative unit	Name		Minimum	Maximum	Mean	Median	Standard deviation
Region	East	↓	-83.78	51.28	-13.32	-12.42	18.30
Departments	Boumba-et-Ngoko	↓	-72.13	51.28	-12.75	-11.92	17.10
	Haut-Nyong	↓	-79.17	47.75	-13.54	-13.55	16.25
	Kadey	↓	-73.70	46.58	-19.14	-19.50	15.82
	Lom-et-Djérem	↓	-80.13	50.53	-8.44	-6.08	18.64
Districts	Abong-Mbang	↓	-49.85	40.73	-0.25	0.00	15.25
	Angossas	↓	-42.98	31.23	-3.93	-3.72	11.97
	Atok	↓	-43.60	29.58	-5.12	-4.85	12.47
	Batouri	↓	-62.47	27.58	-25.70	-26.17	12.61
	Bélabo	↓	-80.13	50.03	-14.95	-14.60	19.42
	Bertoua I	↓	-54.75	21.62	-21.91	-22.65	13.50
	Bertoua II	↓	-54.75	21.62	-20.62	-22.54	12.65
	Bétaré-Oya	↑	-64.00	50.53	1.01	1.68	13.58
	Diang	↓	-64.97	15.10	-25.19	-25.18	13.49
	Dimako	↓	-63.37	20.42	-25.68	-25.56	14.32
	Doumaintang	↓	-63.37	40.73	-10.09	-9.52	16.50
	Doumé	↓	-63.37	38.07	-18.31	-19.14	16.66
	Gari-Gombo	↓	-71.37	46.58	-14.05	-12.67	17.45
	Garoua-Boulaï	↑	-40.77	37.07	1.07	1.13	9.11
	Kentzou	↓	-53.92	10.83	-28.76	-29.20	9.67
	Kétté	↓	-62.47	36.33	-20.84	-22.36	17.27
	Lomié	↓	-79.17	37.65	-12.93	-12.37	16.93
	Mandjou	↓	-56.75	33.02	-16.66	-16.88	14.51
	Mbang	↓	-60.87	46.58	-16.39	-16.87	15.23
	Mboma	↓	-41.17	28.33	-5.02	-4.40	12.19
	Messaména	↓	-60.10	35.03	-7.02	-6.29	15.04
	Messock	↓	-77.87	37.65	-11.36	-10.26	17.31
	Mindourou	↓	-77.87	43.57	-9.79	-9.30	16.66
	Mouloundou	↓	-61.20	50.92	-13.01	-13.82	14.71
	Ndélélé	↓	-68.88	46.58	-24.54	-26.23	15.57
	Ngoura	↓	-69.07	29.25	-20.92	-21.25	15.76
	Ngoyla	↓	-63.87	47.75	-8.79	-8.38	15.12
	Nguélébok	↓	-63.37	43.15	-17.78	-18.67	17.10
	Nguelemendouka	↓	-64.62	32.73	-13.36	-12.93	15.29
	Ouli	↓	-48.28	28.17	-9.03	-9.17	10.80
	Salapoumbé	↓	-62.85	51.28	-9.84	-9.48	16.50
	Somalomo	↓	-65.65	32.20	-17.64	-16.99	16.12
	Yokadouma	↓	-67.97	48.48	-9.42	-8.22	15.75

Table 3: Statistics on the risks of change in 2050, East Region

As for the southern region, it is likely to see its tree cover decrease by 8.63%, with losses in places of 80.93% and gains of 80.00% in places. This means a distribution of values of percent changes with a standard deviation at one sigma of ± 20.02%. Its departments show on the one hand risks of systematic losses of forests with average statistics and standard deviation at 1 sigma of -12.86% to ±15.40% in Dja-et-Lobo, -3.20% to ±25.29% in Océan. On the other hand, risks of forest gains with mean statistics and standard deviation at 1 sigma of 0.74% to ±17.12% in Mvila, 9.75% to ±20.53% in Vallée-du-Ntem (**Figure 16, Table 4**).

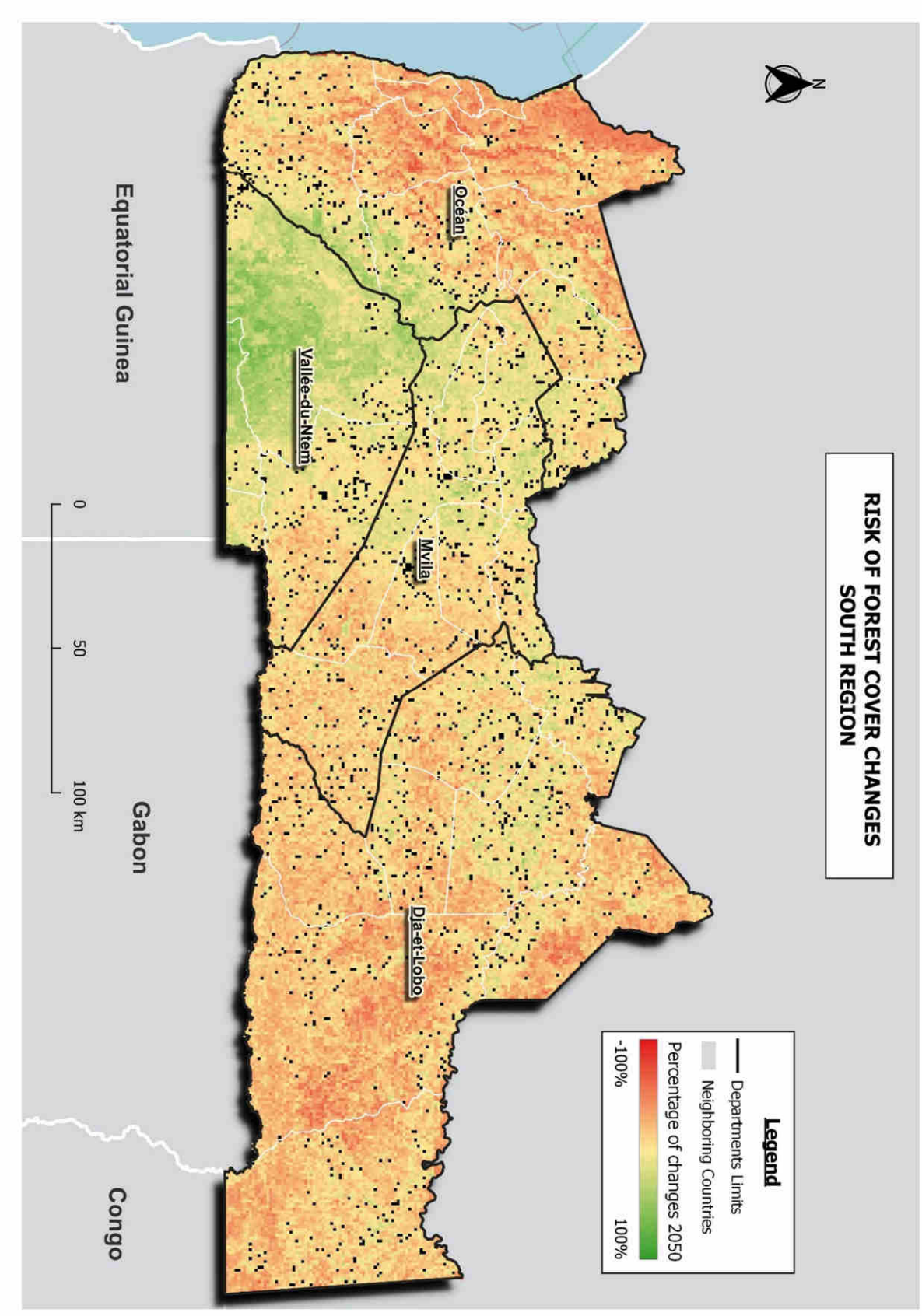

Figure 16: Map of risks of forest cover changes in 2050, Southern Region

Statistics of percentages of change Forecasts 2050							
Administrative unit	Name		Minimum	Maximum	Mean	Median	Standard deviation
Region	South	↓	-80.93	80.00	-8.63	-8.42	20.02
Departments	Dja-et-Lobo	↓	-79.17	47.07	-12.86	-12.80	15.40
	Mvila	↑	-55.40	68.83	0.74	0.00	17.12
	Océan	↓	-80.93	80.00	-3.20	0.00	25.29
	Vallée-du-Ntem	↑	-72.73	80.00	9.75	7.67	20.53
Districts	Akom II	↓	-72.73	58.70	-1.44	0.00	21.68
	Ambam	↓	-51.00	57.73	-1.68	-1.65	14.48
	Bengbis	↓	-64.95	47.07	-13.08	-13.20	16.16
	Bipindi	↓	-66.62	48.57	-14.66	-15.45	18.79
	Biwong-Bané	↑	-29.67	47.78	6.48	5.83	10.44
	Biwong-Bulu	↓	-51.00	36.87	-5.82	-5.63	12.55
	Campo	↑	-75.65	69.50	1.66	0.00	21.11
	Djoum	↓	-65.67	36.12	-18.07	-18.08	14.97
	Ebolowa I	↑	-32.90	46.73	6.84	6.35	11.34
	Ebolowa II	↑	-51.00	62.00	3.55	2.37	16.88
	Efoulan	↑	-44.35	50.87	3.52	4.07	11.79
	Kribi I	↓	-71.50	64.83	-21.62	-22.62	19.32
	Kribi II	↓	-58.62	50.57	-16.15	-20.70	21.04
	Kyé-Ossi	↑	-28.83	39.33	8.91	9.62	10.84
	Lokoundjé	↓	-80.93	64.83	-27.85	-28.07	19.39
	Lolodorf	↓	-62.38	48.57	-7.06	-5.45	18.22
	Ma'an	↑	-72.73	80.00	17.97	17.92	20.01
	Mengong	↓	-44.02	31.37	-4.08	-4.93	12.07
	Meyomessala	↓	-55.37	47.07	-6.32	-6.14	14.77
	Meyomessi	↓	-55.37	28.92	-12.31	-12.02	14.45
	Mintom	↓	-64.42	30.15	-17.61	-17.58	14.57
	Mvangan	↓	-55.40	29.08	-11.29	-11.56	12.04
	Mvengue	↑	-34.27	47.78	2.47	2.33	11.86
	Ngoulémakong	↑	-44.02	45.27	0.37	0.00	12.34
	Niété	↓	-72.73	17.17	-26.06	-25.20	16.64
	Olamzé	↑	-13.70	80.00	31.24	33.92	19.39
	Oveng	↓	-64.50	28.92	-13.62	-13.78	12.25
	Sangmélima	↓	-55.40	44.33	-7.21	-7.32	13.70
	Zoétélé	↓	-50.47	44.33	-2.05	-1.74	13.55

Table 4: Statistics on the risks of change in 2050, Southern Region

A look at the risk of change for each district in these regions shows that for some districts, forest cover is in serious decline. In the Eastern region, the districts of Kentzou, Batouri, and Dimako, among others, would present means and standard deviations at 1 sigma of -28.76% to ±9.67% for Kentzou, -25.70% to ±12.61% for Batouri, and -25.68% to ±14.32% for Dimako (**Table 3**). The southern region is not on a leash. The districts of Loukoundjé, Niété, and Kribi I have means and standard deviations at one sigma of -27.85% to ±19.39% for Loukoundjé, -26.06% to ±16.64% for Niété, and -21.62% to ±19.32% for Kribi I (**Table 4**). However, some districts are likely to stand out from the others with positive averages. These include the districts of Bétaré-Oya and Garoua-Boulaï with statistics of 1.01% to ±13.58% for Bétaré-Oya, and 1.07% to ±9.11% for Garoua-Boulaï in the East region, and the districts of Olamzé and Ma'an, among others, with statistics of 31.24% to ±19.38% for Olamzé, and 17.97% to ±20.01% for Ma'an in the South region.

These risks of change send a strong message: the forests of the East and South are likely to see their area greatly diminished if there is no widespread awareness. Strong and contextualized barrier measures, as well as local and regional action, all aimed at tackling this global problem of forest cover loss, are to consider. Consequently, the compromised future of the next generations is because a reduction of forest areas implies a reduction of the goods and services that result from them, whether they are economic, social, or especially environmental. Because in environmental matters, it does not take much to impact the well-being of humans and ecosystems.

3.4. The potential for forest restoration

The study of the potential for forest restoration is hopeful in both the southern and eastern regions.

The Eastern region, which has observed a loss of 2.96% over the period 2001-2020 in relation to its forest cover in the year 2000, could be restored to 1.18% in relation to this same reference cover. At the scale of its districts, the forest cover in certain localities could be restored with difficulty. Following the example of the districts of Mboma, Angossas, Nguelemendouka, which have lost respectively 13.05%, 11.88%, 10.90% of their forest cover over the period 2001-2020, and present potential restoration rates respectively of 0.10%, 0.77%, and 0.50%. Conversely, the districts of Kentzou, Kétté, and Ngoura have high restoration potential (PR) despite the losses, they have suffered. The scores (losses over the 2001-2020 period and restoration potential) in these districts are as follows: 4.29% in losses versus 8.16% in PR for Kentzou, 2.75% in losses versus 8.99% in PR, 3% in losses versus 7.42% in PR for Ngoura (**Figure 17, Table 5**).

The Southern region, which has observed a loss of 6.29% over the period 2001-2020 compared to its forest cover in 2000, could restore up to 0.92% compared to this same reference cover. At the scale of its districts, the forest cover in certain localities could be restored with difficulty. Following the example of the districts of Kribi I, Kribi II, Kyé-Ossi, which have lost respectively 27.43%, 30.62%, 21.36% of their forest cover over the period 2001-2020, and present potential restoration rates respectively of 4.24%, 4.25%, and 0.11%. Conversely, only the arrondissement of Campo could reverse its balance, with scores (losses over the period 2001-2020 and restoration potentials) of 1.06% in losses against 1.81% in PR. Although the districts of Mintom, Oveng, and Akom II could, more or less, also reverse their balances (**Figure 18, Table 6**).

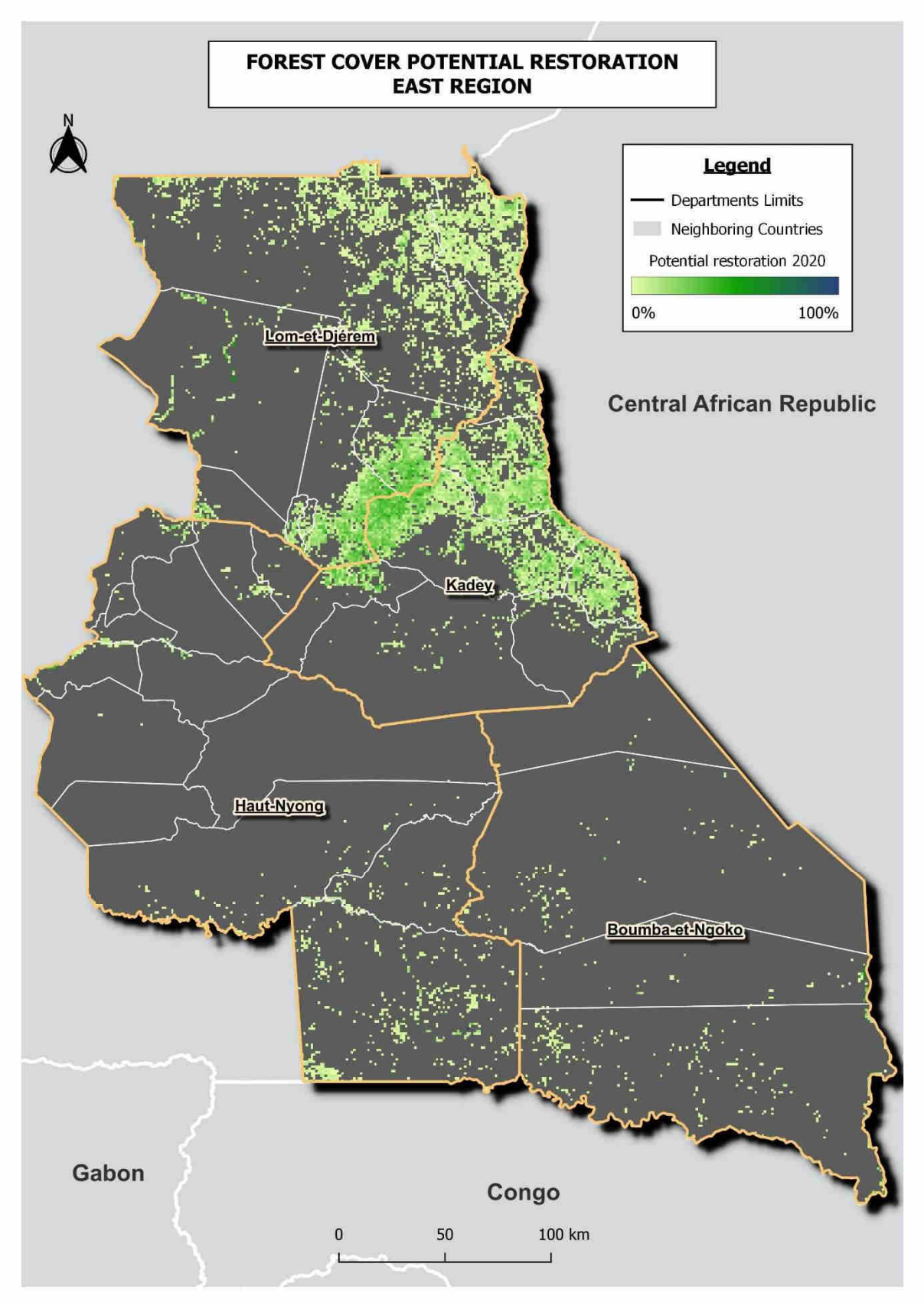

Figure 17: Forest cover restoration potential in 2020, Eastern Region

Region	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
East	129422	7020801	11047753.53	1.17%	10973988.23	2.96%	1.18%

Departments	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
Boumba-et-Ngoko	5699	2322386	3189488.89	0.18%	3167473.84	1.62%	0.18%
Haut-Nyong	7033	2403123	3621043.62	0.19%	3601406.01	2.88%	0.20%
Kadey	62334	949750	1619419.71	3.85%	1609190.89	3.26%	3.87%
Lom-et-Djérem	54350	1345429	2617801.31	2.08%	2595912.57	4.54%	2.09%

Districts	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
Abong-Mbang	207	96084	170349.40	0.12%	169428.64	5.91%	0.12%
Angossas	309	20534	40661.86	0.76%	40406.26	11.88%	0.77%
Atok	1091	44351	89310.70	1.22%	88882.30	9.44%	1.23%
Batouri	28990	211165	372662.08	7.78%	370201.47	4.87%	7.83%
Bélabo	2664	377077	667029.05	0.40%	658442.26	3.31%	0.40%
Bertoua I	890	9767	16829.34	5.29%	16326.17	9.23%	5.45%
Bertoua II	386	5058	9154.23	4.22%	8688.97	13.68%	4.45%
Bétaré-Oya	13184	569435	1180556.07	1.12%	1172776.25	5.45%	1.12%
Diang	958	46425	83009.63	1.15%	82552.57	6.16%	1.16%
Dimako	203	47201	72459.05	0.28%	72048.54	9.29%	0.28%
Doumaintang	61	104785	191941.75	0.03%	191032.90	9.12%	0.03%
Doumé	394	74150	120871.09	0.33%	120266.68	6.87%	0.33%
Gari-Gombo	220	226825	346845.13	0.06%	345238.35	2.37%	0.06%
Garoua-Boulaï	7872	107521	223085.74	3.53%	221121.96	2.87%	3.56%
Kentzou	8228	58124	101851.07	8.08%	100849.04	4.29%	8.16%
Kétté	17447	86804	195157.76	8.94%	194124.36	2.75%	8.99%
Lomié	771	517605	734430.24	0.10%	730843.81	1.07%	0.11%
Mandjou	15637	140990	265478.40	5.89%	264174.54	4.90%	5.92%
Mbang	556	348360	534809.14	0.10%	532127.32	1.95%	0.10%
Mboma	19	9588	19569.31	0.10%	19458.44	13.05%	0.10%
Messaména	3	178370	311681.95	0.00%	310255.42	3.60%	0.00%
Messock	385	191029	264735.15	0.15%	263420.49	1.79%	0.15%
Mindourou	0	339532	536236.33	0.00%	533814.76	0.98%	0.00%
Mouloundou	3830	784136	999536.35	0.38%	989210.44	0.98%	0.39%
Ndélélé	1478	129153	199233.01	0.74%	197212.25	3.54%	0.75%
Ngoura	12755	89085	172658.86	7.39%	171826.17	3.00%	7.42%
Ngoyla	3055	611837	785483.17	0.39%	779535.30	0.57%	0.39%
Nguélébok	4350	91668	149510.15	2.91%	148813.80	4.61%	2.92%
Nguelemendouka	533	57026	106253.30	0.50%	105742.42	10.90%	0.50%
Ouli	1283	24413	66196.50	1.94%	65859.96	0.76%	1.95%
Salapoumbé	1042	414203	552649.88	0.19%	549075.90	0.86%	0.19%
Somalomo	0	110870	177060.32	0.00%	176263.19	0.50%	0.00%
Yokadouma	606	897159	1290457.54	0.05%	1283946.73	2.22%	0.05%

Table 5: Forest restoration potential by eastern administrative subdivision

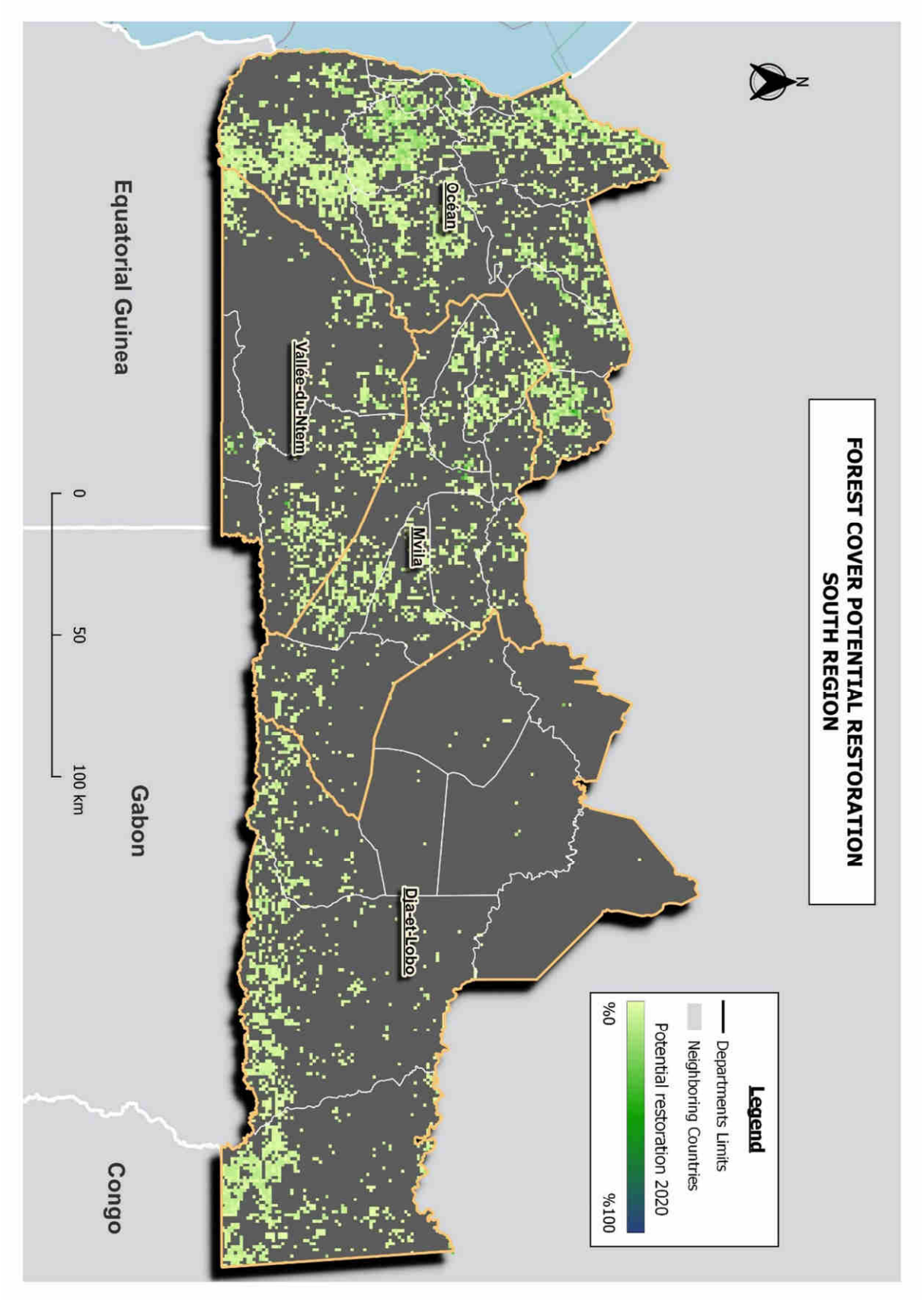

Figure 18: Potential for forest cover restoration in 2020, Southern Region

Region	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
South	43374	3564249	4738392.12	0.92%	4709167.35	6.29%	0.92%

Departments	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
Dja-et-Lobo	8357	1444720	2001152.19	0.42%	1990265.92	5.13%	0.42%
Mvila	6516	691227	871645.41	0.75%	867102.18	7.93%	0.75%
Océan	24548	912127	1143889.48	2.15%	1135297.25	7.67%	2.16%
Vallée-du-Ntem	3952	516084	721705.04	0.55%	716498.47	5.35%	0.55%

Districts	Restoration potential (ha)	Total potential (ha)	Area (ha)	Restoration potential in the locality	Forest cover 2000 (ha)	Losses from 2001 to 2020 compared to the year 2000	P.R. compared to forest cover in 2000
Akom II	2794	159051	193994.28	1.44%	193118.02	2.19%	1.45%
Ambam	1966	198991	246335.65	0.80%	244720.42	6.10%	0.80%
Bengbis	6	136086	226425.42	0.00%	225250.61	3.77%	0.00%
Bipindi	1954	106755	132550.45	1.47%	131893.17	3.45%	1.48%
Biwong-Bané	239	36001	46045.21	0.52%	45808.54	16.46%	0.52%
Biwong-Bulu	766	81338	98201.04	0.78%	97732.30	7.17%	0.78%
Campo	4948	225518	276804.72	1.79%	274087.96	1.06%	1.81%
Djoum	3011	426969	546607.26	0.55%	543862.94	1.79%	0.55%
Ebolowa I	875	58366	73799.03	1.19%	73400.30	9.72%	1.19%
Ebolowa II	1905	163254	200376.42	0.95%	199122.09	6.83%	0.96%
Efoulan	1435	69824	86023.06	1.67%	85618.54	7.83%	1.68%
Kribi I	853	15387	20422.53	4.18%	20145.89	27.43%	4.24%
Kribi II	436	7843	10536.69	4.14%	10261.30	30.62%	4.25%
Kyé-Ossi	29	20180	26958.70	0.11%	26728.38	21.36%	0.11%
Lokoundjé	5978	176476	229970.26	2.60%	227556.19	13.14%	2.63%
Lolodorf	1343	74000	96828.73	1.39%	96361.64	4.41%	1.39%
Ma'an	1689	266318	400487.43	0.42%	397614.30	3.40%	0.42%
Mengong	458	72513	89033.07	0.51%	88595.76	12.58%	0.52%
Meyomessala	24	129936	212833.48	0.01%	211670.16	15.70%	0.01%
Meyomessi	5	83289	124613.54	0.00%	124029.90	4.23%	0.00%
Mintom	4015	334346	408208.51	0.98%	405619.78	1.20%	0.99%
Mvangan	488	156634	208825.00	0.23%	207818.63	3.54%	0.23%
Mvengue	1932	63409	82273.81	2.35%	81860.49	11.54%	2.36%
Ngoulémakong	350	53223	69342.58	0.51%	69003.09	11.97%	0.51%
Niété	4307	83602	100508.03	4.29%	100009.25	23.14%	4.31%
Olamzé	268	30566	47923.27	0.56%	47434.25	8.83%	0.56%
Oveng	1182	144895	178955.73	0.66%	178137.14	1.32%	0.66%
Sangmélima	87	126012	194424.34	0.04%	193201.84	10.81%	0.04%
Zoétélé	27	63105	109083.91	0.02%	108490.16	15.85%	0.02%

Table 6: Forest restoration potential by southern administrative subdivision

The basic message of this last focal point of our study is that, despite the loss of forest area in the East and South Cameroon regions, not all is lost. One-way out could be to take small- and medium-scale action to create new forests, or to embrace reforestation as well as afforestation.

3.5. Assessing the reliability of change

From the evaluation of the 200 sample plots by augmented visual interpretation through Collect Earth Online, (**Table 7, Figure 19**), it appears that 65% of the sites were classified in accordance with the field reality in space and time. 35% were misclassified. It can be explained by the fact that of the 35%, 14% were sites with false forest gains due to high tree crop areas, 2% were visible classification errors, and 19% were sites where the change was not noticeable (**Figures 20 to 25**).

Digital Evaluation	Site Location	Classification fidelity	Reason for error	Number of plots
Losses	Strate 1	N	Observable gains	1
		N	No detectable changes	11
		Y	N/A	19
	Strate 2	N	No detectable changes	3
		Y	N/A	4
	Strate 3	N	No detectable changes	16
		Y	N/A	36
Gains	Strate 1	N	Crop area	15
		N	Observable losses	1
		N	No detectable changes	2
		Y	N/A	21
	Strate 2	N	Observable losses	2
		Y	N/A	10
	Strate 3	N	Crop area	14
		N	No detectable changes	5
		Y	N/A	10
No change	Strate 1	Y	N/A	13
	Strate 2	Y	N/A	10
	Strate 3	Y	N/A	7

Table 7: Plot assessment summary

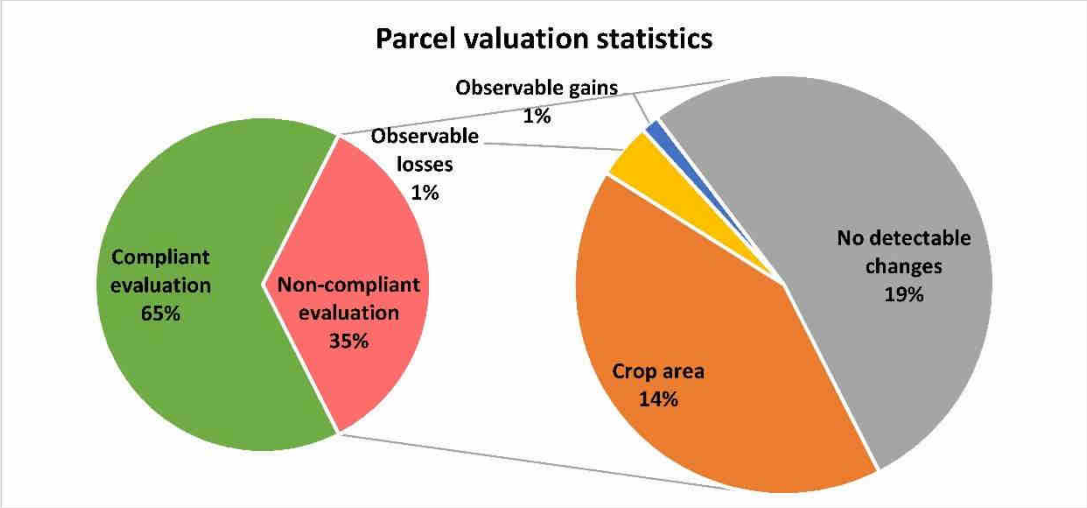

Figure 19: Parcel valuation statistics

Figure 20: VHR image of a forest cover gain site

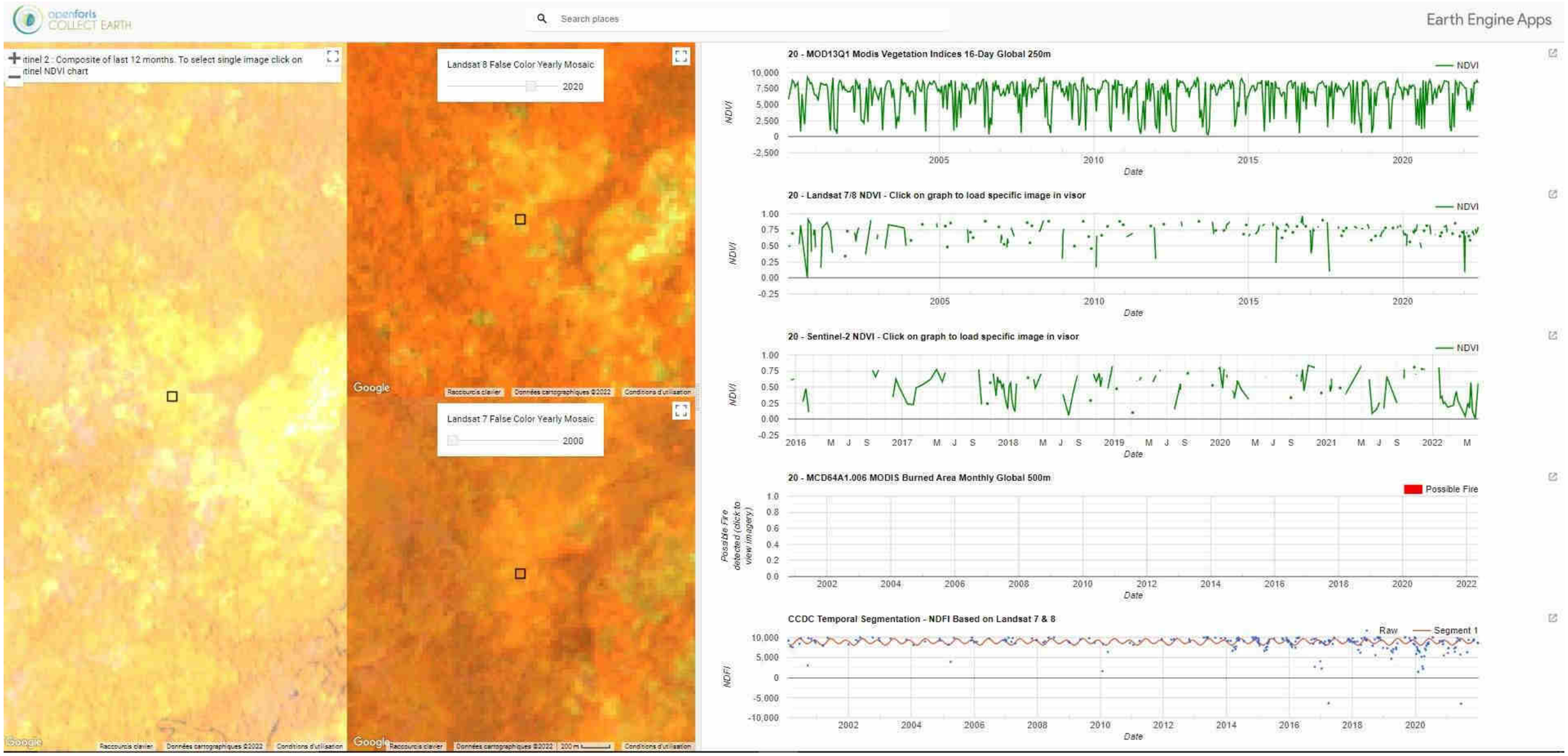

Figure 21: An augmented visual interpretation of a forest cover gain site

Figure 22: VHR image of a palm grove classified as a forest cover gain site

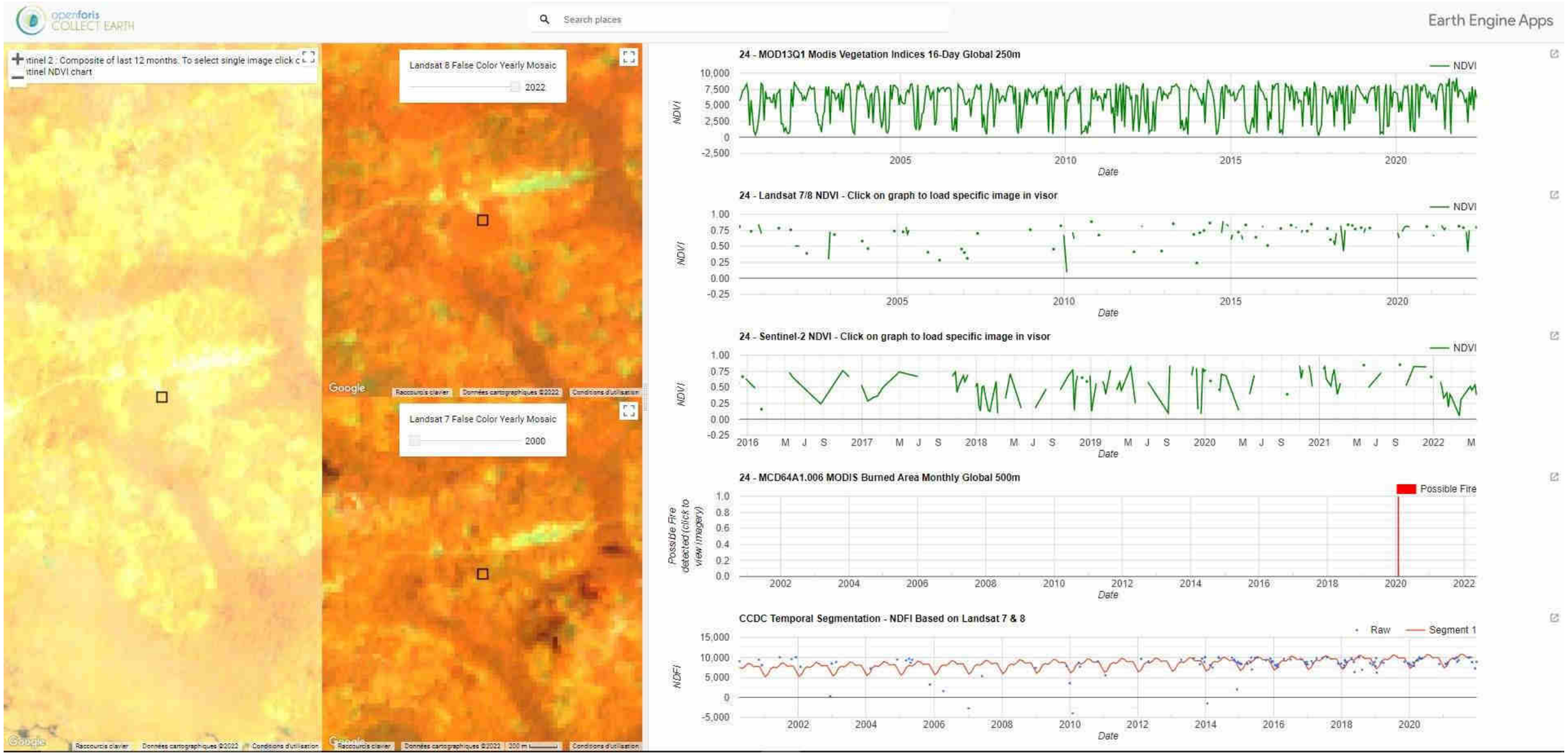

Figure 23: An augmented visual interpretation of a palm grove classified as a forest cover gain site

Figure 24: VHR image of a burned area, classified as a site at a loss of forest cover (Lom and Djerem, Belabo)

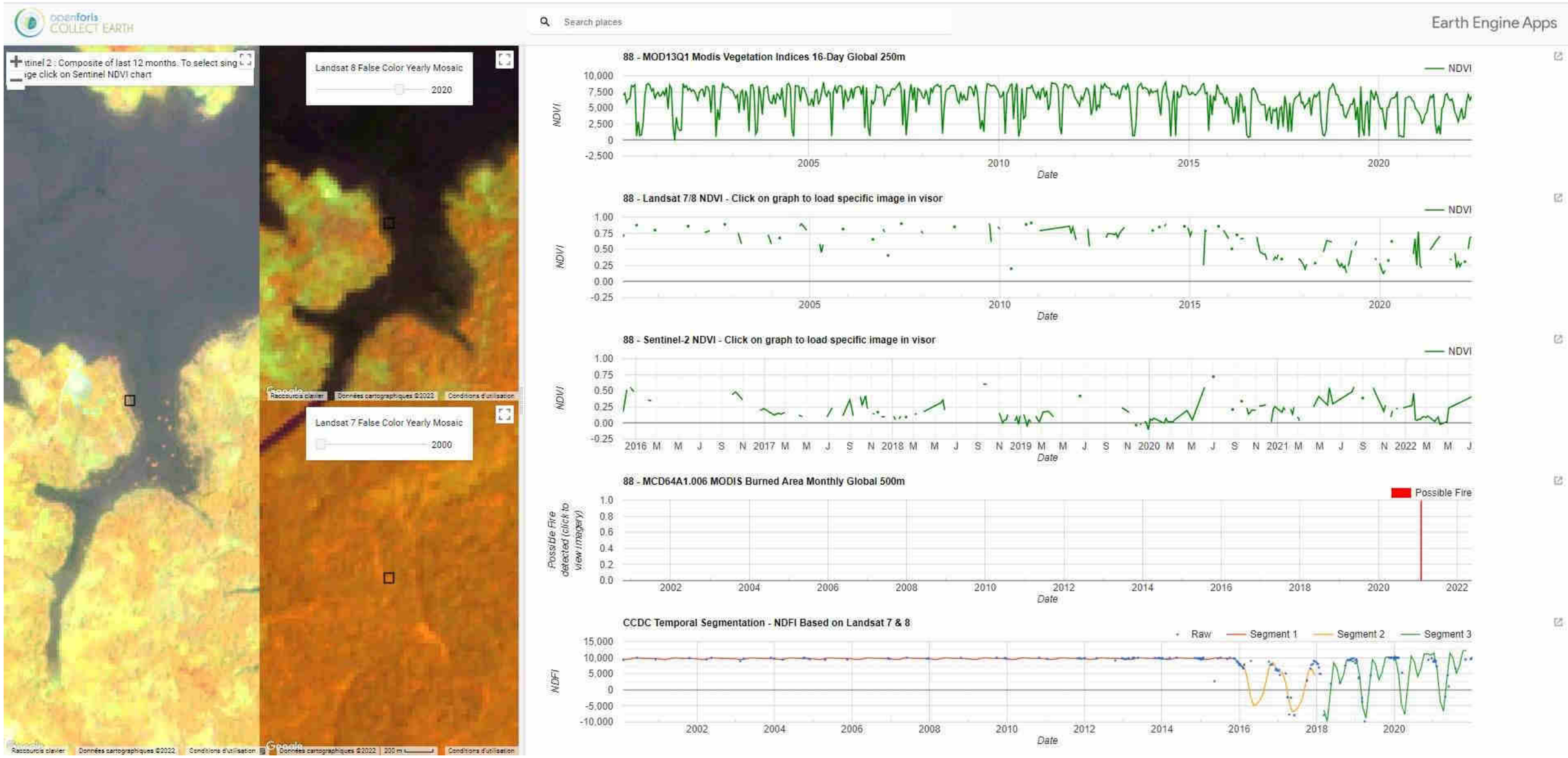

Figure 25: An augmented visual interpretation of a burned area, classified as a site at a loss of forest cover (Lom and Djerem, Belabo)

3.6. Synthesis of results: principal component analysis

A synthesis of our work is presented through the graphs of the biplots of the distances on the planes of the factorial axes F1 and F2, F1 and F3 (**Figures 26, Figure 27**). This synthesis reports the results obtained in the 62 districts of our study area, with respect to the key points or primary variables that we investigated, namely: changes in forest cover, the integrity of forest landscapes, the forecasts of changes in forest cover for the year 2050 and the quantification of the potential for forest restoration. To better interpret these graphs, it is important to understand the main steps of the principal component analysis used to derive them.

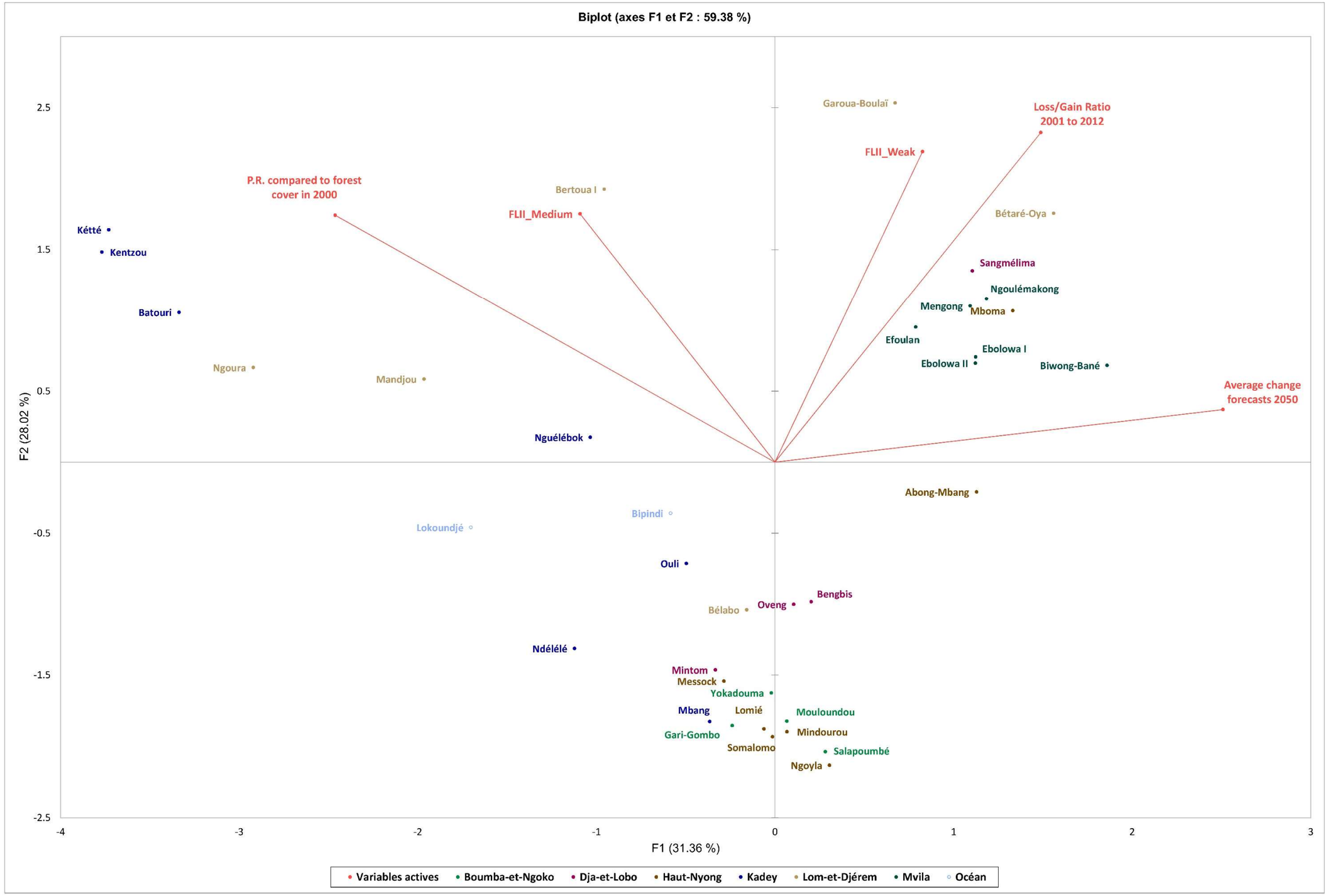

Figure 26: Biplot of distances on the plane of axes F1 and F2

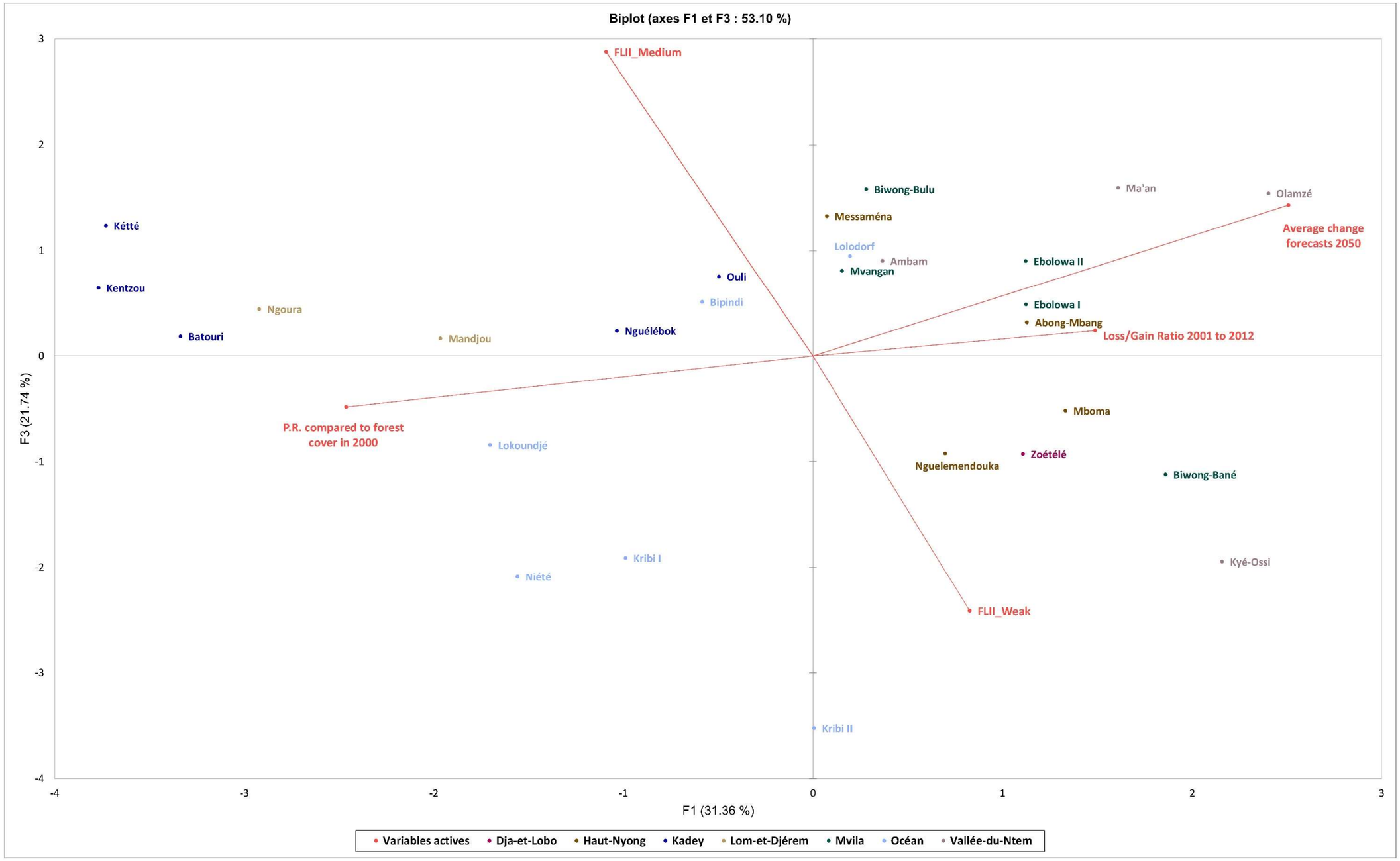

Figure 27: Biplot of distances on the plane of axes F1 and F3

The Pearson correlation matrix standardises or normalises the data before the calculations to avoid inflating the impact of variables with high variance on the result. (**Table 8**). Since principal component analysis is a projection method, the algebraic study of the matrix of variables/observations makes it possible, by the projection of a vector space into itself, to define a space of uncorrelated factors, which are linear combinations of the initial variables. This new space admits for reference the eigenvectors F1 to F5, whose coordinates in the starting space (space of the variables) are stated in the table of the eigenvectors (**Table 10**). The coordinates of the starting space in the target space are set in the table of the coordinates of the variables (**Table 11**). The eigenvalues are factors associated with each eigenvector that allow the transition from the eigenvector table to the variable coordinate table (**Table 9**). They reflect the quality of the projection when going from N dimensions (N being the number of variables, here 5) to a smaller or equal number of dimensions. In our case, we see that the first eigenvalue is 1.568 and represents 31.362% of the variability. This means that if we represent the data on a single axis, then we will always have 31.362% of the total variability preserved. Each eigenvalue has a corresponding factor. Each factor is in a linear combination of the starting variables. The factors have the particularity of being uncorrelated. The eigenvalues and factors are classified by decreasing order of represented variability. The table of variable contributions (**Table 12**) shows the share of each variable in the determination of the factor. For example, the variables forecasted mean change 2050, and R.P. relative to 2000-forest cover contributed more to the determination of the F1 factor than the loss of the variable/gain ratio 2001-2012, and FLII_Low. This can be confusing for the interpretation of these projections, so it is wise to refer to the cosine squares table (**Table 13**). Therefore, the F1 factor will be chosen in the interpretation to explain these first two variables. The last two variables above will be better explained by the F2 factor.

Variables	Loss/Gain Ratio 2001 to 2012	Losses from 2001 to 2020 compared to the year 2000	FLII_Weak	FLII_Medium	Average change forecasts 2050	P.R. compared to forest cover in 2000
Loss/Gain Ratio 2001 to 2012	**1**	0.151	**0.321**	0.150	0.230	-0.068
Losses from 2001 to 2020 compared to the year 2000	0.151	**1**	**0.914**	-0.159	0.050	0.129
FLII_Weak	**0.321**	**0.914**	**1**	-0.128	0.118	0.181
FLII_Medium	0.150	-0.159	-0.128	**1**	0.052	**0.353**
Average change forecasts 2050	0.230	0.050	0.118	0.052	**1**	**-0.423**
P.R. compared to forest cover in 2000	-0.068	0.129	0.181	**0.353**	**-0.423**	**1**

Bold values are different from 0 to a significance level alpha=0.05

Table 8: Correlation matrix (Pearson (n))

	F1	F2	F3	F4	F5
Eigenvalue	1.568	1.401	1.087	0.639	0.305
Variability (%)	31.362	28.021	21.742	12.778	6.097
Cumulative %	31.362	59.383	81.124	93.903	100.000

Table 9: Eigenvalues

	F1	F2	F3	F4	F5
Loss/Gain Ratio 2001 to 2012	0.367	0.573	0.059	-0.696	0.220
FLII_Weak	0.204	0.540	-0.595	0.369	-0.419
FLII_Medium	-0.269	0.432	0.710	0.126	-0.471
Average change forecasts 2050	0.619	0.091	0.353	0.561	0.412
P.R. compared to forest cover in 2000	-0.607	0.430	-0.119	0.219	0.620

Table 10: Eigenvectors

	F1	F2	F3	F4	F5
Loss/Gain Ratio 2001 to 2012	0.460	0.679	0.062	-0.556	0.121
FLII_Weak	0.255	0.639	-0.621	0.295	-0.232
FLII_Medium	-0.337	0.511	0.740	0.100	-0.260
Average change forecasts 2050	0.775	0.108	0.368	0.449	0.227
P.R. compared to forest cover in 2000	-0.760	0.508	-0.124	0.175	0.342

Table 11: Variable coordinates

	F1	F2	F3	F4	F5
Loss/Gain Ratio 2001 to 2012	13.478	32.861	0.351	48.472	4.838
FLII_Weak	4.156	29.183	35.441	13.625	17.595
FLII_Medium	7.237	18.667	50.347	1.575	22.174
Average change forecasts 2050	38.265	0.834	12.444	31.518	16.940
P.R. compared to forest cover in 2000	36.865	18.454	1.417	4.810	38.454

Table 12: Contribution of variables

	F1	F2	F3	F4	F5
Loss/Gain Ratio 2001 to 2012	0.211	**0.460**	0.004	0.310	0.015
FLII_Weak	0.065	**0.409**	0.385	0.087	0.054
FLII_Medium	0.113	0.262	**0.547**	0.010	0.068
Average change forecasts 2050	**0.600**	0.012	0.135	0.201	0.052
P.R. compared to forest cover in 2000	**0.578**	0.259	0.015	0.031	0.117

Table 13: Square cosines of variables

4. Conclusion

This article has shown that forest cover losses in the East and South Cameroon regions are increasing exponentially from year to year. Efforts to restore these forests are largely insufficient, considering the losses and are disproportionate at the district level. 46% of our study area can be qualified as a zone of high integrity of forest landscapes with respect to anthropic pressures, 37% as a zone of medium integrity, and 17% as a zone of low integrity. These overall results hide alarming situations in certain districts and require closer monitoring of these forests or management with a smaller environmental footprint. Under the assumption of the circumstance, the Eastern and Southern regions would observe a systematic loss of tree cover in 2050 compared to 2020. This is evaluated on average at 13.32% in the Eastern region and 8.63% in the Southern region. Although some departments in this region are likely to see an increase in tree cover. A forest restoration action would restore nearly 40% of the cumulative losses over the period 2001-2020 in the Eastern region, and only 14% of the cumulative losses over the same period in the Southern region. Even if we can claim to have achieved all the objectives we set out to achieve and obtained results that satisfy the assumptions we made as a prelude, it is fair to mention that this study has two limitations:

- The implemented technique overestimates the gains in forest cover. The technique implemented overestimates the gains in forest cover, as it does not distinguish between an area of high crop and a forest area. This is notwithstanding the threshold of tree height imposed for the study is 5 m, and oil palm plantations, among others, manage to pass the filter;
- The quantification of the gains in forest cover was only done for the period 2001-2012 because according to our investigations, there was no forest restoration action in these regions during this period.

References

Bastin, Jean-Francois, Yelena Finegold, Claude Garcia, Danilo Mollicone, Marcelo Rezende, Devin Routh, Constantin M. Zohner, and Thomas W. Crowther. “The global tree restoration potential”. *Science* 365, no. 6448 (2019): 76-79.

Bellouin, N., W. J. Collins, I. D. Culverwell, P. R. Halloran, S. C. Hardiman, T. J. Hinton, C. D. Jones et al. “The HadGEM2 family of met office unified model climate configurations”. *Geoscientific Model Development* 4, no. 3 (2011): 723-757.

Breiman, Leo. “Random forests”. *Machine learning* 45, no. 1 (2001): 5-32.

Cochran, William G., and G. William. “Sampling techniques. new york: John wiley& sons”. (1977).

Food and Agriculture Organisation [FAO]. “Global Forest Resources Assessment 2020. Terms and Definitions”. (2018).

Grantham, H. S., A. Duncan, T. D. Evans, K. R. Jones, H. L. Beyer, R. Schuster, J. Walston et al. “Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity”. *Nature communications* 11, no. 1 (2020): 1-10.

Hansen, Matthew C., Peter V. Potapov, Rebecca Moore, Matt Hancher, Svetlana A. Turubanova, Alexandra Tyukavina, David Thau et al. “High-resolution global maps of 21st-century forest cover change”. *science* 342, no. 6160 (2013): 850-853.

Hurrell, James W., Marika M. Holland, Peter R. Gent, Steven Ghan, Jennifer E. Kay, Paul J. Kushner, J-F. Lamarque et al. “The community earth system model: a framework for collaborative research”. *Bulletin of the American Meteorological Society* 94, no. 9 (2013): 1339-1360.

INS. 2020a. Monographie de la région de l’Est : Enquête Complémentaire à la quatrième Enquête Camerounaise Auprès des Ménages (EC-ECAM 4). [online] Yaoundé. Available at: <https://ins-cameroun.cm/wp-content/uploads/2022/06/RAPPORT-MONOGRAPHIE-EST_VF.pdf> Accessed June15, 2022.

INS. 2020b. Monographie de la région du Sud : Enquête Complémentaire à la quatrième Enquête Camerounaise Auprès des Ménages (EC-ECAM 4). [online] Yaoundé. Available at: <https://ins-cameroun.cm/wp-

content/uploads/2022/06/RAPPORT-MONOGRAPHIE-SUD_VF.pdf> [Accessed June 15, 2022.

Schreuder, Hans T., Timothy G. Gregoire, and Geoffrey B. Wood. *Sampling methods for multiresource forest inventory*. John Wiley & Sons, 1993.