ACTIVITY 1.4.1: INTERACTIVE MAPPING OF HUMAN-WILDLIFE INTERFACES REPORT

(DISTRICT DES MONTAGNES, CÔTE D'IVOIRE)

Report from STOP Spillover, Côte d'Ivoire

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STOP SPILLOVER

Strategies to Prevent Spillover (or "STOP Spillover") enhances global understanding of the complex causes of the spread of a selected group of zoonotic viruses from animals to humans. The project builds government and stakeholder capacity in priority Asian and African countries to identify, assess, and monitor risks associated with these viruses and develop and introduce proven and novel risk reduction measures. "Spillover" refers to an event in which an emerging zoonotic virus is transferred from a non-human animal host species (livestock or wildlife) to another, or to humans.

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ACRONYMS AND ABBREVIATIONS

BNETD	Bureau National d'Etudes Techniques et du Développement
CIGN	Centre de l'Information Géographique et du Numérique
CNTIG	Comité National de Télédétection et de l'Information Géographique
COU-SPV	Centre des Opérations d'Urgences de Santé Publique Vétérinaire
CURAT	Centre Universitaire de Recherche et d'Application en Télédétection
FAO	Food and Agriculture Organization of the United Nations
GTT	Groupe de Travail Technique
GOO	Google
INHP	Institut National d'Hygiène Publique
INS	Institut Nationale de la Statistique
MINEF	Ministère des Eaux et Forêts
OIPR	Office Ivoirienne des Parcs et Réserves
RGPH	Recensement général des populations et de l'habitat
SODEFOR	Société de Développement des Forêts

CONTEXT AND JUSTIFICATION

In Côte d'Ivoire, STOP Spillover focuses on human-wildlife interfaces where potential pathogen spillovers occur. These interfaces are often not covered by existing surveillance systems. The Côte d'Ivoire government has begun to update and modernize its veterinary public health legislation. Law no. 2020-995 of December 30, 2020, on the Veterinary Public Health Code was promulgated. Related implementing decrees were approved by the Council of Ministers on April 5, 2023, notably a decree creating the Veterinary Emergency Operation Center (Cellule des Opérations d'Urgences de Santé Publique Vétérinaire - COU-SPV) and another on the financing of animal health risk surveillance. In Côte d'Ivoire, the government's interest in veterinary public health has attracted the commitment of multiple stakeholders and donors who have invested in surveillance. As part of the "One Health" approach, STOP Spillover supports the Côte d'Ivoire government in strengthening its capacity to monitor and respond to epidemics at the human-wildlife interface. The One Health National Platform Surveillance Technical Working Group (TWG) (under creation) in collaboration with FAO/ECTAD will provide technical expertise to enhance the capacity of government agencies, line ministries and other relevant stakeholders to carry out disease surveillance, risk assessment and outbreak response at the human-wildlife interface. To achieve these objectives, a work plan including interventions approved by USAID was validated by national stakeholders in June 2023. This work plan comprises 4 major activities, including an activity titled "Disease surveillance and monitoring of pathogen spillover risks at the human-wildlife interface". It is in this context that the present project "Interactive mapping of human-wildlife interfaces in the District des Montagnes" was implemented.

OBJECTIVES

The main objective of this activity is to assist the government and stakeholders in setting up mechanisms for coordinating surveillance and monitoring the risk of pathogen spillover at the Human-Wildlife interfaces, by providing a GIS tool for mapping Human-Wildlife interaction interfaces in Côte d'Ivoire.

Specifically, the aim is to target the District des Montagnes in order to:

1. Collect data on wildlife ecosystems, the physical environment and human populations from central and local government departments;
2. Set up a spatial database on the physical environment and human populations occupying areas of high wildlife concentration;
3. Characterize and map evidence of interactions between human populations and wildlife;
4. Draw up a map of human-wildlife interfaces based on the combination of human-wildlife interaction indices in a multi-criteria spatial analysis;
5. Develop an online platform for various maps of human-wildlife interface zones.

METHODOLOGY

The methodology is subdivided into two sub-sections: materials and methods. The material section focuses on the following points: cartographic data sources used, types of data collected and software. The method focused on determining the indices for assessing interactions between humans and wildlife, prioritizing and spatializing the indices, merging the interaction indices to produce a map of human-wildlife interfaces, and developing an interactive mapping platform to disseminate the results.

EQUIPMENT

Mapped data sources

Various cartographic data (vectors) and surveys were collected from the following government institutions and their branches at departmental level:

1. Forest Development Corporation (SODEFOR);
2. Ivorian Parks and Reserves Agency (OIPR);
3. Ministry of Water and Forests (MINEF);
4. National Institute of Statistics (INS);
5. Bureau National d'Etudes Techniques et du Développement/Centre de l'Information Géographique et du Numérique (BNETD/CIGN);
6. National Committee for Remote Sensing and Geographic Information;
7. University Center for Research and Application in Remote Sensing (CURAT),
8. National Institute of Public Hygiene (INHP);
9. Ministry of Tourism and Leisure (MT).

Types of data collected

The following data were collected:

Presentation of the physical environment

- Hydrography;
- Topography;
- Land use;
- Farming;
- Forest areas.

Data on the spatial distribution of wildlife

- Classified forests, national parks and reserves;
- Wildlife markets and restaurants.

Level of infiltration of national parks and classified forests

- Level of human presence.

Data on the administrative division of the District des Montagnes

- District;
- Regions;
- Departments;
- Sub-prefecture;
- District capital;
- Regional capital;
- Departmental capital;
- Villages;
- Camps.

Infrastructure data

- Road network.

Population data

- General census of population and housing in Côte d'Ivoire 2021.

Software

ArcGIS software was used for mapping and geospatial analysis as well as for the development of the interactive platform:

- Operating system: Windows 10 Pro;
- Development software: Visual Studio Code;
- Framework: Angular CLI were used.

METHODS

The methodology consisted of a chain of operations that began with data collection, processing, and analysis of the results. The first step was to determine the indices that would be used to assess the intensity of human-wildlife interfaces. Each of these indices was then prioritized. Its intensity was determined from the information collected on the survey forms. This intensity was then spatially localized. Finally, the spatialized indices were merged in a multi-criteria spatial analysis to produce a synthesis map of human-wildlife interface zones.

Determining indices for assessing human-wildlife interactions

Three groups of indices were taken into account when assessing the human-wildlife interface.

The first index group is related to wildlife populations:

- The quantity (richness) and diversity of fauna present;
- The location of sites with high concentrations of wildlife. It should be noted that in the case of the District des Montagnes, sites with high concentrations of wildlife are essentially represented by the network of classified forests, national parks and reserves;

- Forest areas outside classified forests, parks and reserves. This type of forest is virtually non-existent. Where they do exist, they are generally sacred sites covering very small areas (2 to 3ha). They cannot be considered as prime refuge areas for wildlife. However, for certain wildlife species of interest, such as bats, a forest site of less than one hectare is sufficient to support large populations.

The second index group is related to indicators of direct contact between humans and wildlife:

- Consumption of wildlife in households, restaurants and hotels;
- Hunting and trapping of wildlife for self-consumption or for commercial purposes;
- The sale of wildlife, which includes not only supply sites, but also market outlets;
- The frequentation of tourist sites where wildlife is the focus of interest, with potential contact between tourists and wildlife.

The third index group takes stock of clues that bring humans and wildlife into indirect contact, as they share the same territory:

- The significant presence of inhabited sites around the sites with high concentrations of wildlife;
- The high densities per km^2 of the predominantly rural population in administrative districts containing classified forests, national parks, and reserves. It is important to remember that wildlife is the primary source of animal protein for rural populations;
- The number of people who have infiltrated sites with a high concentration of animals and settled there (habitat, farming, hunting, trapping, animal carcasses);
- The presence of traces of anthropic activities such as roads, which are used to infiltrate sites with high concentrations of wildlife.

In line with the data collected from stakeholders, five (5) indices for the characterization of Human-Wildlife interactions have been determined. The term "index" here refers to a rating system used to assess the quality or intensity of human-wildlife interactions, based on the results of stakeholder surveys. The human-wildlife interaction index determined are as follows:

1. Index #1: sale and consumption of bushmeat;
2. Index #2: length of roads within a 5Km radius of classified forests, parks, reserves;
3. Index #3: number of localities within a 5Km radius of classified forests, parks, Reserves
4. Index #4: level of infiltration of classified forests - parks - reserves;
5. Index #5: sub-prefectural population density within a 5km radius classified forests - parks - reserves.

Prioritization/Spatialization of Human-Wildlife Interaction Indexes

Index #1: sale and consumption of bushmeat

This index was generated by summing all the sites where wildlife meat is sold or consumed (hotels, restaurants and drinking room) in the various departments of the District des Montagnes. The summation of these data from the Ministry of Tourism and Leisure (MT), the

National Institute of Public Hygiene (INHP) and the Google (GOO) platform gave values ranged from 11 to 82 outlets selling or consuming bushmeat. A hierarchy of these values gave the three classes coded as follows:

Index	Range	Code
Strong index	(x ≥ 40)	Code : 3
Medium index	(40 ≥ x ≤15)	Code : 2
Low index	(x ≤15)	Code : 1

The number of outlets is represented by x. The codes assigned were used to spatialize this index and thus to draw up the bushmeat sales and consumption index map.

Index #2: length of roads within a 5Km radius of classified forests, parks, reserves

This index was generated by summing the lengths of all roads in meters within a 5km radius of classified forests, national parks and reserves. The determination of road lengths in the GIS consisted in creating buffer zones of 5 Km around classified forests, national parks and reserves. The lengths of all roads within these zones are then calculated. This operation yielded road lengths ranging from 119434 to 325407 meters. A hierarchy of these values gave the three classes coded as follows:

Index	Range	Code
Strong index	(x ≥ 300 000 m)	Code : 30
Medium index	(300 000 ≥ x ≥ 150 000 m)	Code : 20
Low index	(x ≤150 000 m)	Code : 10

The length of roads is represented by x. The codes assigned have been used to spatialize this index and thus to map the road length index within a 5Km radius of the classified forests - parks – reserves. The rural zone is considered to be a low-interaction zone compared to the classified forests, parks and reserves.

Index #3: number of localities within a 5Km radius of classified forests, parks and reserves

This index was generated by determining and then summing the localities within a 5Km radius of classified Forests - Parks - Reserves. Determining the number of localities in a GIS involved creating 5 Km buffer zones around classified forests, national parks and reserves. All localities within these areas are then counted. This operation resulted in a number of localities ranging from 45 to 504 around sites of interest. A hierarchization of these values generated the three classes coded as follows:

Index	Range	Code
Strong index	(x ≥ 250)	Code : 300
Medium index	(250 ≥ x ≤100)	Code : 200
Low index	(x ≤100)	Code : 100

The number of localities is represented by x. The codes assigned have made it possible to spatialize this index and thus to draw up the index map of the number of localities within a 5km radius of classified forests, parks and reserves. The rural zone is considered to be a low-interaction zone compared with the classified forests, parks and reserves.

Index #4: infiltration level of classified forests - parks - reserves

This index was generated by assessing the level of infiltration of classified forests in National Parks and Reserves, provided by the Société de Développement des Forêts (SODEFOR) and the Office Ivoirien des Parcs et Réserves (OIPR). This index indicates percentage values ranging from 0 to 100% infiltration. A hierarchical classification of these values gives three classes, coded as follows:

Index	Range	Code
Strong index	≥ 50% and ≤ 75%)	Code : 3000
Medium index	≥ 25% and ≤ 50%)	Code : 2000
Low index	≥ 0% and ≤ 25% or ≥ 75% and ≤ 100%)	Code : 1000

The codes assigned have made it possible to spatialize this index and thus to map the number of localities within a 5Km radius of classified forests, parks and reserves. The rural zone is considered a low-interaction zone compared with the classified forests, parks and reserves.

Index #5: sub-prefectural population density within a 5Km radius of classified forests, parks and reserves

This index was generated by assessing the population density of sub-prefectures within a 5km radius of classified forests, parks and reserves. Data from the RGPH (2021) indicate population densities ranging from 15 to 394 Hbt/Km^2. A hierarchization of these values gives three classes coded as follows:

Index	Range	Code
Strong index	(x ≥ 200 Hbt/Km^2)	Code : 30000
Medium index	≥ 200 and ≤100 Hbt/Km^2	Code : 20000
Low index	(x ≤ 100 Hbt/Km^2)	Code : 10000

The population density is represented by x. The codes assigned were used to spatialize this index and thus to draw up the sub-prefectural population density index map within a 5km radius of the classified forests, parks, and reserves. The rural zone is considered a low-interaction zone compared with the classified forests, parks and reserves.

Merging the five human-wildlife interaction indexes to produce the human-wildlife interface map

To produce the final map of human-wildlife interfaces, the five maps of human-wildlife interaction indices were merged by adding them together. This fusion was carried out in two main steps (Table 1).

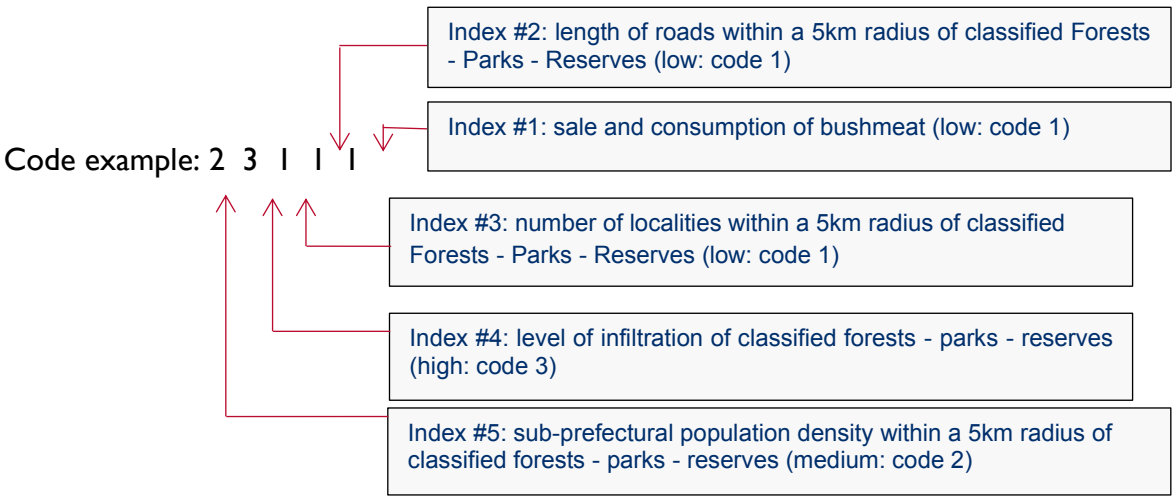
Step1: summation of index maps based on codes

This involved transforming the index maps from raster to vector format on the basis of hierarchical codes: strong, medium and weak. As shown in the graph in Table 1.

Index #1, Index #2, Index #3, Index #4, and Index #5 will have their weak, medium and strong prioritization codes represented by units (1, 2 ,3), tens (10, 20, 30), hundreds (100, 200, 300), thousands (1000, 2000, 3000) and tens of thousands (10000, 20000, 30000) respectively. Thus, the addition of the five human-wildlife interaction index maps with the "Map Algebra on ArcGIS" operation will result in a new map with 5-digit codes.

Step 2: Creation of the human-wildlife interface map

A reclassification of the map with the five-digit codes produces the human-wildlife interface map. The five-digit codes for reclassification are read from left to right starting with the digit representing the index #5 and ending with the index #1 to the right.



Thus, code 23111 will read:

Length of roads within a 5Km radius of classified forests, parks and reserves **(weak: code 1)**; sale and consumption of bushmeat **(weak: code 1**); number of localities within a 5km radius of classified forests, parks and reserves **(weak: code 1)**; level of infiltration of classified forests, parks and reserves (**high: code 3**) and sub-prefectural population density within a 5km radius classified forests, parks and reserves (**medium: code 2**).

The rule of interpretation is as follows:

- the Human-Wildlife interface will be considered strong if at least one digit in the series of five representing the indices has code 3.
- the Human-Wildlife interface will be considered medium if the highest number in the series of five representing the indices has the code 2.
- the Human-Wildlife interface will be considered weak if the series of five digits representing the clues is only code 1.

By applying this reading key, the Human-Wildlife interface map was drawn up.

Table 1. Merging the five Human-Wildlife interaction indices

Summary of human-wildlife interaction indexes				
1/ Sale and consumption of wildlife	2 / Road length within a 5km radius of classified Forests - Parks - Reserves	3/ number of localities within a 5km radius of classified Forests - Parks - Reserves	4 / Level of infiltration of Classified Forests - Parks - Reserves	5 / Sub-prefectural population density within a 5km radius of classified forests - parks - reserves)
Code 1 : Low 2 : Medium 3 : High	**Code** 10 : Low 20 : Medium 30 : High	**Code** 100 : Low 200 : Medium 300 : High	**Code** 1000 : Low 2000 : Medium 3000 : High	**Code** 10000 : Low 20000 : Medium 30000 : High

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STEP 1

Human-wildlife interface index table		
Low Code : 11111	**Medium** Code : 11112	**High** Code : 11113, 11131, 11132, 13113, 21123, 21211, 21213, 21213, 21232, 21322 21323, 21332, 21333, 22331, 22332, 23111, 23112, 23113, 23132, 23213, 31111, 31113, 31132, 31222, 31223, 31223, 31331, 31332, 32113, 33222
Reclassification code 1 : Low 2 : Medium 3 : High		

STEP 2

Development of interactive mapping platform for dissemination of results

The developed geospatial database includes layers of vector information on administrative subdivisions, environment, demography, as well as maps of interaction indices and the final map of human-wildlife interfaces. Database which was used to fill the interactive online platform.

Platform specification:

- Target platform: Web;
- Front-end framework: Angular;
- Programming language: TypeScript;
- Mapping library: Leaflet.js.

Implementation

- Modular design based on Angular development principles;
- Use of services to manage map data;
- Integration of iterative map display functionalities.

Testing

- Unit tests for each Angular component;
- Integration tests to check that the iterative display works properly;
- Performance tests to evaluate the application's responsiveness with large quantities of map data.

Deployment

- Configuration of IIS server on Windows Server 2016;
- Deploy the Angular application as a Web application on IIS;
- Configure security settings and access permissions on IIS;
- Implementation of a continuous deployment process for application updates.

RESULTS

INDEX #1: SALE AND CONSUMPTION OF BUSHMEAT

Taking into account sites where bushmeat is sold and consumed, the departments of Man and Danané show the highest interaction between humans and wildlife (Figure 1 and Table 1). Another point to note is that there is a high concentration of classified forests and national parks (08) in these two departments. If we consider that classified forests and parks are the sites where wildlife is hunted, we can conclude that they are under significant anthropogenic pressure. The center of the District des Montagnes including the departments of Bangolo, Zouan-Hounien, Blolequin and Toulepleu, has the lowest level of human-wildlife interaction. The northern and southern halves of the District des Montagnes have medium levels of interaction.

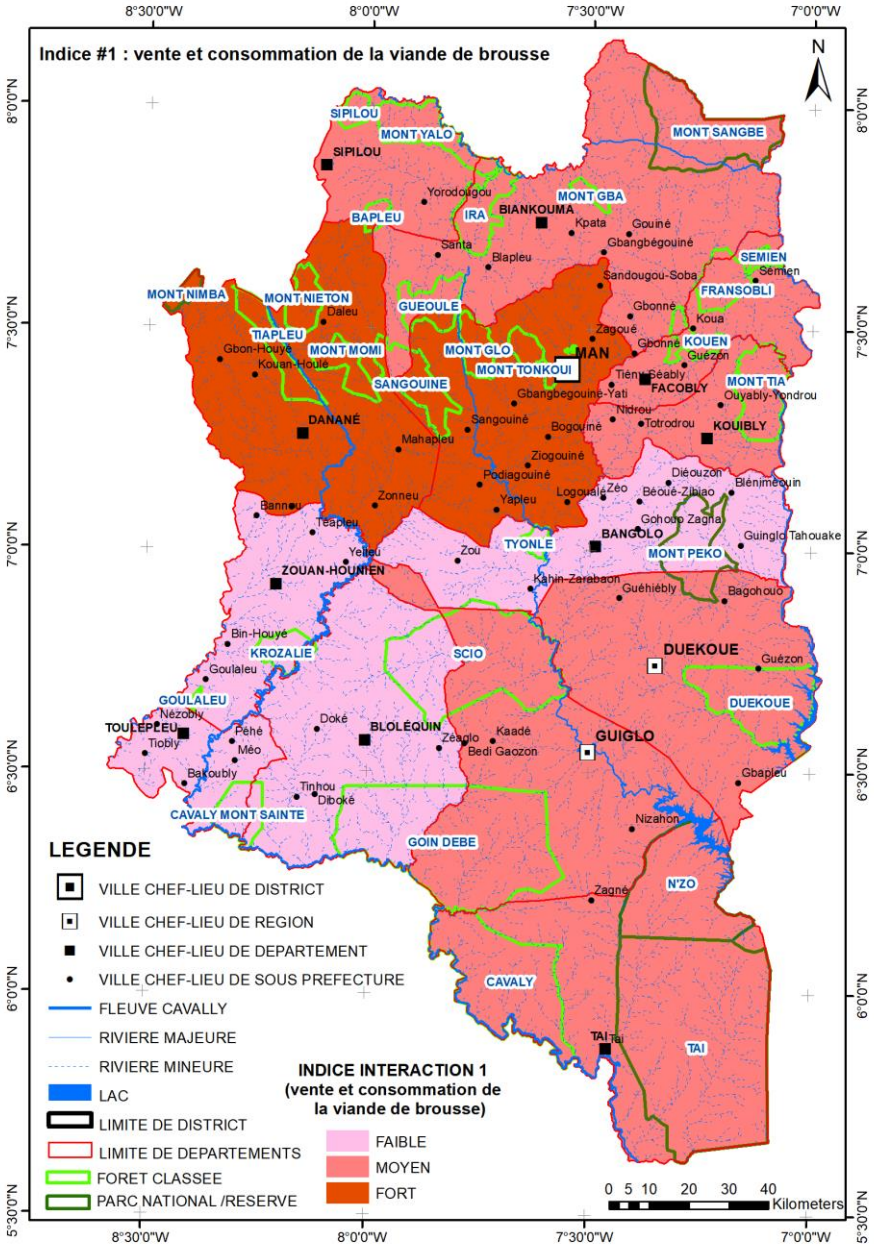

Figure 1: Bushmeat sales and consumption index map

Table 2. Hierarchization of bushmeat sales and consumption indexes

DEPART_N	HOTEL_MT	MAQUIS_INH	HOTEL_GOO	MAQUIS_GOO	TOTAL	CODE	LEGENDE
BANGOLO	0	6	3	2	11	1	FAIBLE
BLOLEQUIN	0	0	3	10	13	1	FAIBLE
TOULEPLEU	0	0	5	7	12	1	FAIBLE
ZOUAN-HOUNIEN	5	6	0	0	11	1	FAIBLE
BIANKOUMA	11	6	0	0	17	2	MOYEN
DUEKOUE	0	0	19	12	31	2	MOYEN
GUIGLO	0	0	17	13	30	2	MOYEN
KOUIBLY	6	11	0	0	17	2	MOYEN
DANANE	35	9	0	0	44	3	FORT
MAN	64	18	0	0	82	3	FORT

DEPART N: Department name; **HOTEL MT**: number of hotels (source Ministry of Tourism); **MAQUIS INH** : number of street food vendors and restaurants (source Institut National d'Hygiène Publique); **HOTEL GOO** : number of hotels (source Google Earth 2023); **MAQUIS GOO:** number of **TOTAL** : sum of the number of sites selling or where bushmeat is consumed; **CODE** : Index hierarchy code strong = 3 (number of sales/consumption sites greater or equal to 40); medium = 2 (number of sales/consumption sites between 40 and 15) and weak = 1 (number of sales/consumption sites less or equal to 15); **LEGEND**: summary level of bushmeat sale and consumption (Legend reported on the map).

INDEX #2: LENGTH OF ROADS WITHIN A 5KM RADIUS OF CLASSIFIED FORESTS, PARKS AND RESERVES

Considering the length of roads around classified forests, these areas are subject to greater anthropogenic pressures than national parks and reserves (Figure 2 and Table 3). We also note that the largest classified forests and national parks in terms of surface area, which are located in the south of the District, are those subject to the greatest pressure from roads.

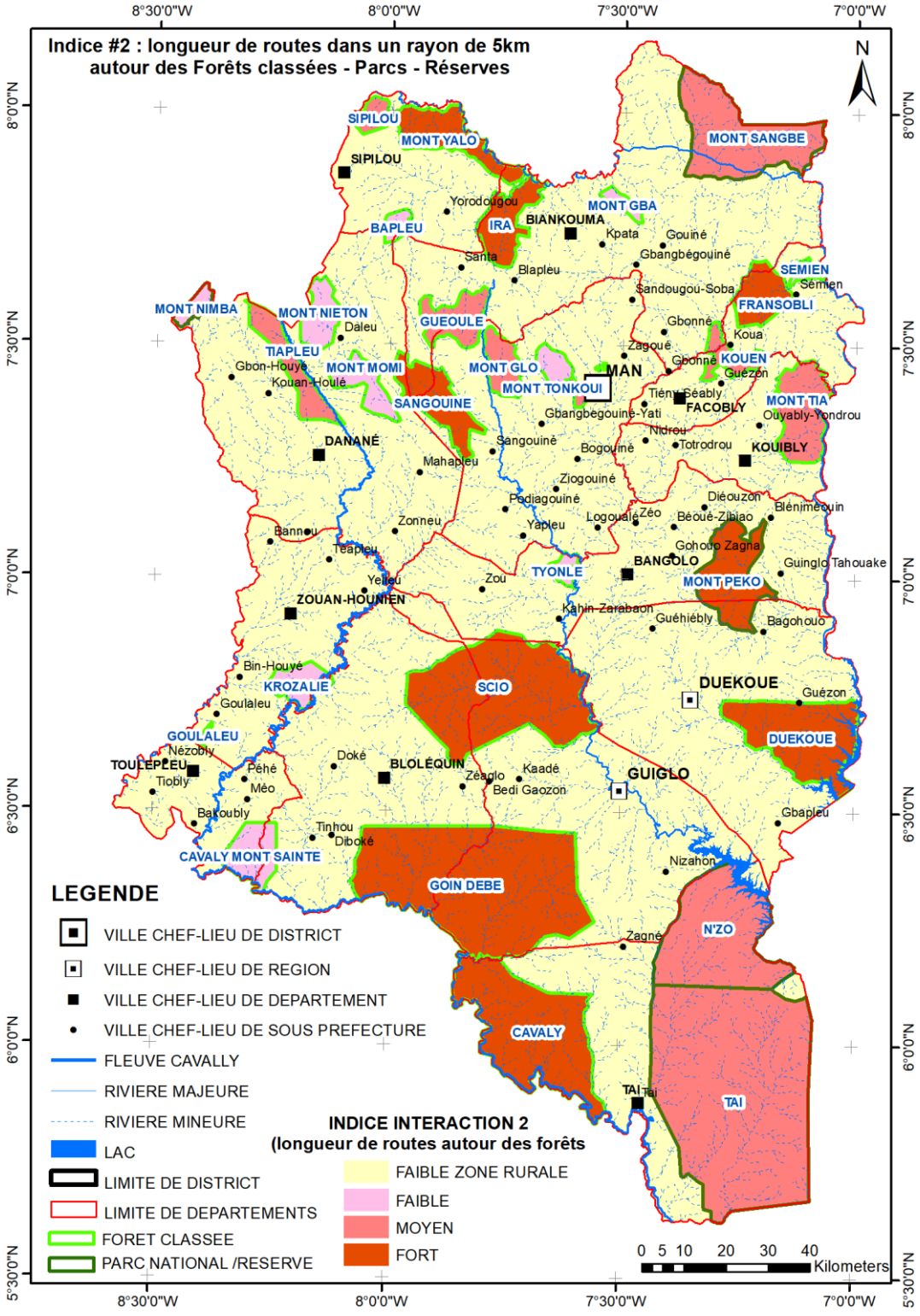

Figure 2: Map of road length index within a 5km radius of classified Forests - Parks – Reserves

Table 3. Hierarchization of the road length index within a 5km radius of classified forests, parks and reserves

STATUT	FORET_N	ROU_5KM_M	CODE	LEGENDE
ZONE RURALE		13606262	10	ZONE RURALE FAIBLE
FORET CLASSEE	FC_MONT GBA	119434,65	10	FAIBLE
FORET CLASSEE	FC_BAPLEU	110091,07	10	FAIBLE
FORET CLASSEE	FC_SEMIEN	131901,91	10	FAIBLE
FORET CLASSEE	FC_MONT TONKOUI	142651,97	10	FAIBLE
FORET CLASSEE	FC_MONT MOMI	135714,85	10	FAIBLE
FORET CLASSEE	FC_TYONLE	133896,15	10	FAIBLE
FORET CLASSEE	FC_KROZALIE	130562,9	10	FAIBLE
FORET CLASSEE	FC_GOULALEU	94000,95	10	FAIBLE
FORET CLASSEE	FC_CAVALY MONT SAINTE	133025,28	10	FAIBLE
FORET CLASSEE	FC_MONT NIETON	96729,24	10	FAIBLE
PARC NATIONAL	PN_MONT NIMBA	7186,8	10	FAIBLE
FORET CLASSEE	FC_DENT DE MAN	107484,2	10	FAIBLE
PARC NATIONAL	PN_MONT SANGBE	171719,9	20	MOYEN
FORET CLASSEE	FC_SIPILOU	168073,09	20	MOYEN
FORET CLASSEE	FC_GUEOULE	231699,6	20	MOYEN
FORET CLASSEE	FC_KOUEN	270723,28	20	MOYEN
FORET CLASSEE	FC_MONT GLO	177777,41	20	MOYEN
FORET CLASSEE	FC_MONT TIA	284795,96	20	MOYEN
FORET CLASSEE	FC_MONT GLA	189384,21	20	MOYEN
RESERVE	R_N'ZO	167062,7	20	MOYEN
PARC NATIONAL	PN_TAI	180682,09	20	MOYEN
FORET CLASSEE	FC_TIAPLEU	167545,34	20	MOYEN
FORET CLASSEE	FC_MONT YALO	454494,92	30	FORT
FORET CLASSEE	FC_IRA	428440,06	30	FORT
FORET CLASSEE	FC_FRANSOBLI	300158,08	30	FORT
FORET CLASSEE	FC_SANGOUINE	302868,65	30	FORT
PARC NATIONAL	PN_MONT PEKO	378132,79	30	FORT
FORET CLASSEE	FC_SCIO	691808,17	30	FORT
FORET CLASSEE	FC_DUEKOUE	525480,66	30	FORT
FORET CLASSEE	FC_GOIN DEBE	543918,29	30	FORT
FORET CLASSEE	FC_CAVALY	325407,64	30	FORT

STATUT: Land tenure status of Classified Forest, National Park, Reserve or Rural Area; **FORET N**: Denomination of Classified Forest, National Park or Reserve; **ROU 5KM M**: Length in meter of roads within a 5Km radius of Classified Forests, National Parks or Reserves; **CODE**: Index hierarchy code, strong = 30 (road length greater or equal to 300,000m; medium = 20 (road length between 300,000m and 150,000m) and low = 10 (road length less or equal to 150,000m); **LEGEND**: Summary level of road length (Legend reported on the map).

INDEX #3: NUMBER OF LOCALITIES WITHIN A 5KM RADIUS OF CLASSIFIED FORESTS - PARKS - RESERVES

If we consider the number of localities within a 5km radius of areas with a strong wildlife presence, classified forests, and particularly those located in the central area of the District des Montagnes have the greatest human-wildlife interactions (Figure 3 and Table 4).

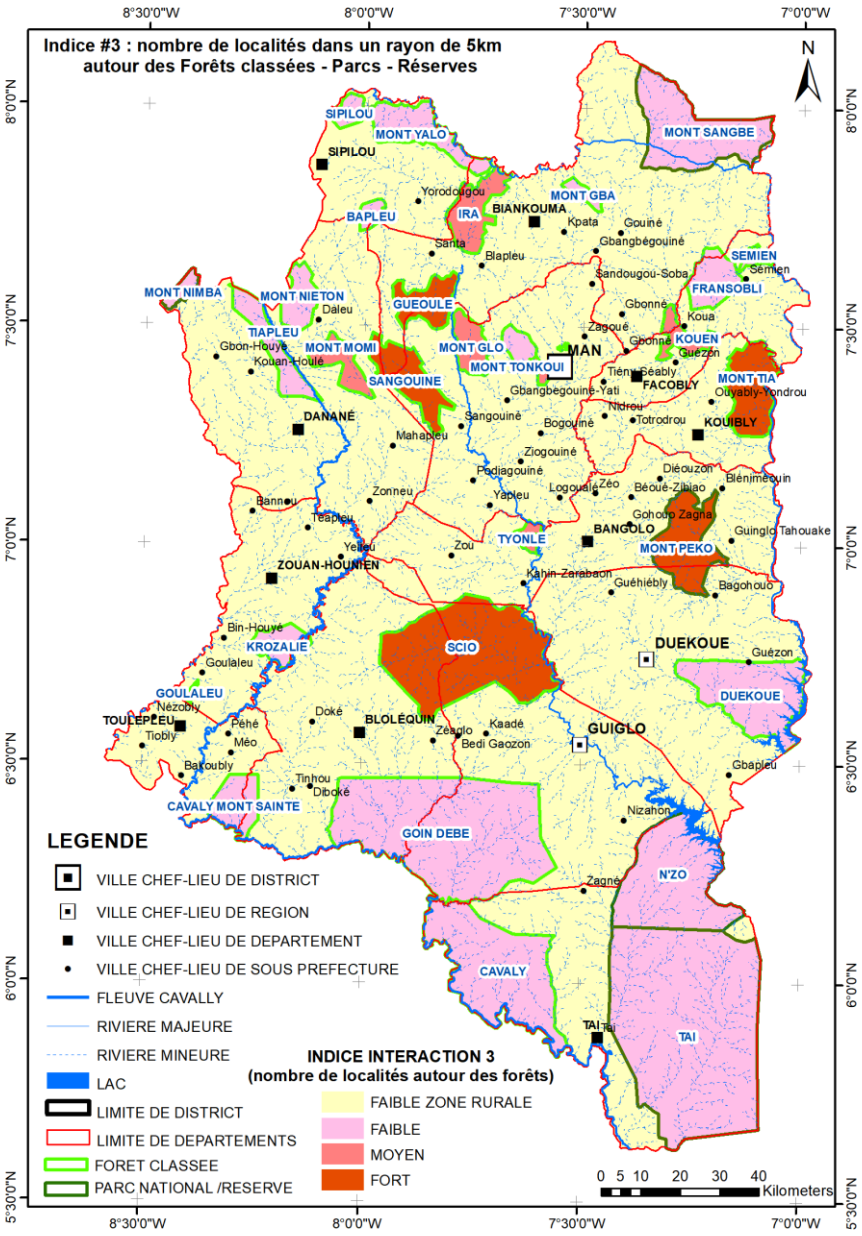

Figure 3: Map of the number of localities within a 5km radius of classified forests, parks and reserves

Table 4. Hierarchization of the number of localities within a 5km radius of classified forests, parks and reserves

STATUT	FORET N	LOC 5KM	CODE	LEGENDE
PARC NATIONAL	PN MONT SANGBE	45	100	FAIBLE
FORET CLASSEE	FC SIPILOU	29	100	FAIBLE
FORET CLASSEE	FC MONT YALO	51	100	FAIBLE
FORET CLASSEE	FC MONT GBA	28	100	FAIBLE
FORET CLASSEE	FC BAPLEU	33	100	FAIBLE
FORET CLASSEE	FC SEMIEN	47	100	FAIBLE
FORET CLASSEE	FC FRANSOBLI	82	100	FAIBLE
FORET CLASSEE	FC MONT TONKOUI	86	100	FAIBLE
FORET CLASSEE	FC KROSALIE	22	100	FAIBLE
FORET CLASSEE	FC DUEKOUE	67	100	FAIBLE
FORET CLASSEE	FC GOULALEU	21	100	FAIBLE
FORET CLASSEE	FC GOIN DEBE	58	100	FAIBLE
RESERVE	R N'ZO	28	100	FAIBLE
FORET CLASSEE	FC CAVALY	14	100	FAIBLE
PARC NATIONAL	PN TAI	30	100	FAIBLE
FORET CLASSEE	FC CAVALY MONT SANTE	15	100	FAIBLE
FORET CLASSEE	FC TIAPLEU	58	100	FAIBLE
FORET CLASSEE	FC MONT NIETON	27	100	FAIBLE
PARC NATIONAL	PN MONT NIMBA	7	100	FAIBLE
FORET CLASSEE	FC DENT DE MAN	23	100	FAIBLE
ZONE RURALE		7983	100	ZONE RURALE FAIBLE
FORET CLASSEE	FC IRA	151	200	MOYEN
FORET CLASSEE	FC KOUEN	151	200	MOYEN
FORET CLASSEE	FC MONT GLO	127	200	MOYEN
FORET CLASSEE	FC MONT MOMI	102	200	MOYEN
FORET CLASSEE	FC MONT GLA	128	200	MOYEN
FORET CLASSEE	FC TYONLE	134	200	MOYEN
FORET CLASSEE	FC GUEOULE	236	300	FORT
FORET CLASSEE	FC SANGOUINE	356	300	FORT
FORET CLASSEE	FC MONT TIA	571	300	FORT
PARC NATIONAL	PN MONT PEKO	346	300	FORT
FORET CLASSEE	FC SCIO	504	300	FORT

STATUT: Land status of Classified Forest, National Park, Reserve or Rural Area; **FORET N**: Name of Classified Forest, National Park or Reserve; **LOC 5KM**: Number of localities within a 5Km radius of Classified Forests, National Parks or Reserves; **CODE**: Index hierarchy code strong = 300 (number of localities greater or equal to 250); medium = 200 (number of localities between 250 and 100) and weak = 100 (number of localities less or equal 100); **LEGEND:** Summary level of number of localities (Legend reported on the map).

INDEX #4: LEVEL OF INFILTRATION OF CLASSIFIED FORESTS - PARKS – RESERVES

Considering infiltration levels, the classified forests on the western edge of the District des Montagnes have the highest human-wildlife interactions (Figure 4 and Table 5). Those in the heart of the District with infiltration rates of 75 to 100% have low human-wildlife interaction indices, as they have been almost entirely transformed into cocoa plots.

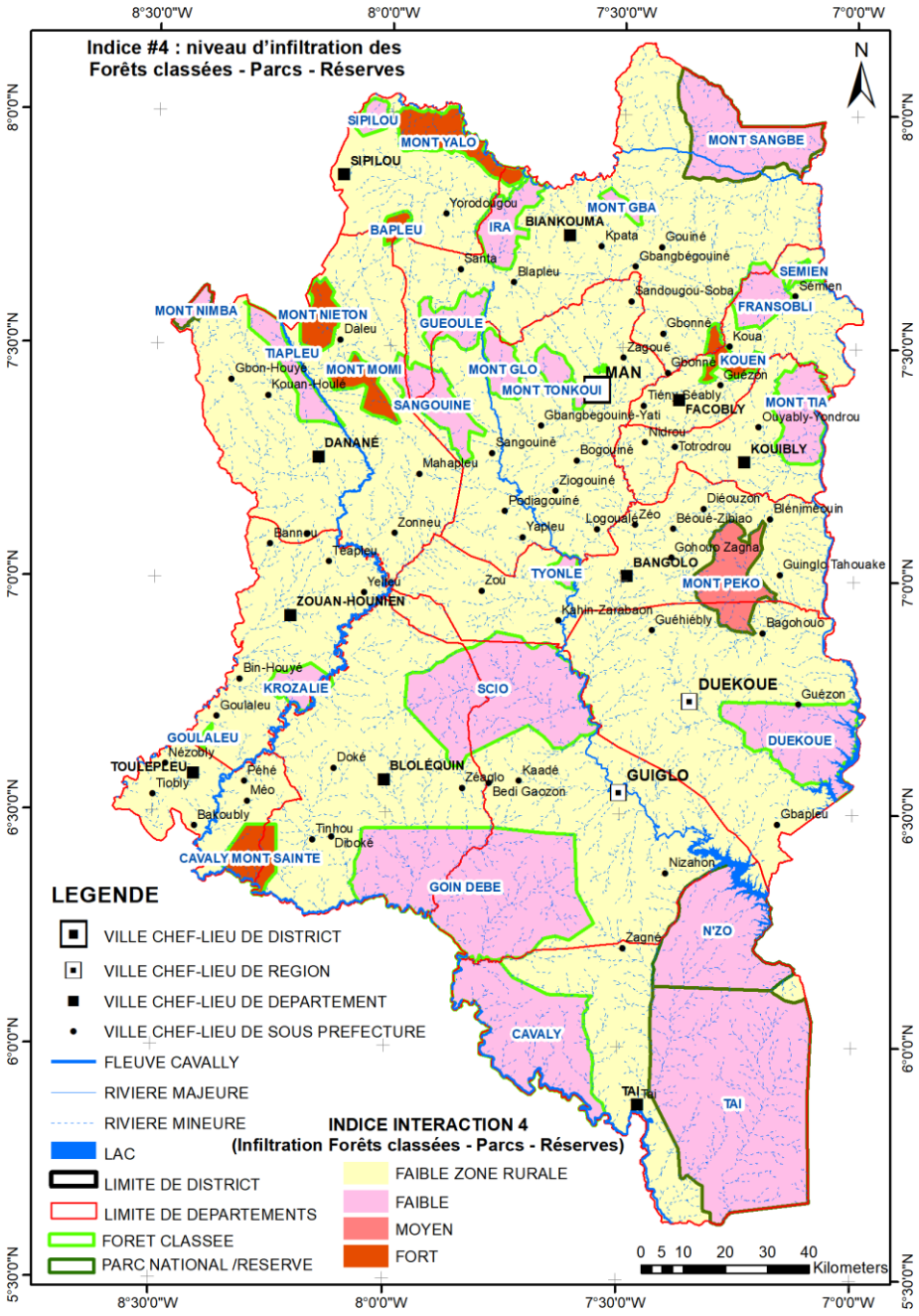

Figure 4: Infiltration level index map for Classified Forests - Parks – Reserves

Table 5. Hierarchization of the number of localities within a 5km radius of classified forests, parks and reserves

STATUT	FORET N	INFILTRA	CODE	LEGENDE 2
PARC NATIONAL	MONT SANGBE	0-25%	1000	FAIBLE
FORET CLASSEE	SIPILOU	75-100%	1000	FAIBLE
FORET CLASSEE	IRA	75-100%	1000	FAIBLE
FORET CLASSEE	MONT GBA	75-100%	1000	FAIBLE
FORET CLASSEE	SEMIEN	75-100%	1000	FAIBLE
FORET CLASSEE	FRANSOBLy	75-100%	1000	FAIBLE
FORET CLASSEE	GUEOULE	75-100%	1000	FAIBLE
FORET CLASSEE	MONT GLO	75-100%	1000	FAIBLE
FORET CLASSEE	MONT TONKOUI	0-25%	1000	FAIBLE
FORET CLASSEE	SANGOUINE	75-100%	1000	FAIBLE
FORET CLASSEE	MONT TIA	75-100%	1000	FAIBLE
FORET CLASSEE	MONT GLA	75-100%	1000	FAIBLE
FORET CLASSEE	TYONLE	75-100%	1000	FAIBLE
FORET CLASSEE	SCIO	75-100%	1000	FAIBLE
FORET CLASSEE	KROZALIE	75-100%	1000	FAIBLE
FORET CLASSEE	DUEKOUE	75-100%	1000	FAIBLE
FORET CLASSEE	GOULALEU	75-100%	1000	FAIBLE
FORET CLASSEE	GOIN DEBE	75-100%	1000	FAIBLE
RESERVE	N'ZO	0-25%	1000	FAIBLE
FORET CLASSEE	CAVALY	0-25%	1000	FAIBLE
PARC NATIONAL	TAI	0-25%	1000	FAIBLE
FORET CLASSEE	TIAPLEU	75-100%	1000	FAIBLE
PARC NATIONAL	MONT NIMBA	0-25%	1000	FAIBLE
ZONE RURALE		100%	1000	FAIBLE
PARC NATIONAL	MONT PEKO	25-50%	2000	MOYEN
FORET CLASSEE	DENT DE MAN	25-50%	2000	MOYEN
FORET CLASSEE	YALO	50-75%	3000	FORT
FORET CLASSEE	MONT BAPLEU	50-75%	3000	FORT
FORET CLASSEE	KOUIN	50-75%	3000	FORT
FORET CLASSEE	MONT MOMI	50-75%	3000	FORT
FORET CLASSEE	CAVALY MONT SAINTE	50-75%	3000	FORT
FORET CLASSEE	MONT NIETON	50-75%	3000	FORT

STATUT: Land status of Classified Forest, National Park, Reserve or Rural Area; **FORET N:** Denomination of Classified Forest, National Park or Reserve; **INFILTRA**: Infiltration rate of Classified Forests, National Parks or Reserves expressed in %; **CODE**: Index hierarchy code strong = (infiltration levels greater or equal to 50%); medium = 2000 (infiltration levels between 25% and 50%) and weak = 1000 (infiltration levels ≥ 0% and ≤ 25% or ≥ 75% and ≤ 100%):**LEGEND:** Summary level of localities (Legend reported on the map).

SUB-PREFECTURAL POPULATION DENSITY WITHIN A 5KM RADIUS OF CLASSIFIED FORESTS - PARKS - RESERVES

In line with the concentration of localities within a 5 km radius of areas with a high wildlife presence, taking into account sub-prefectural population density, indicates that classified forests, and particularly those located in the central zone of the District, are those with the highest human-wildlife interactions **(Figure 5 and Table 5).**

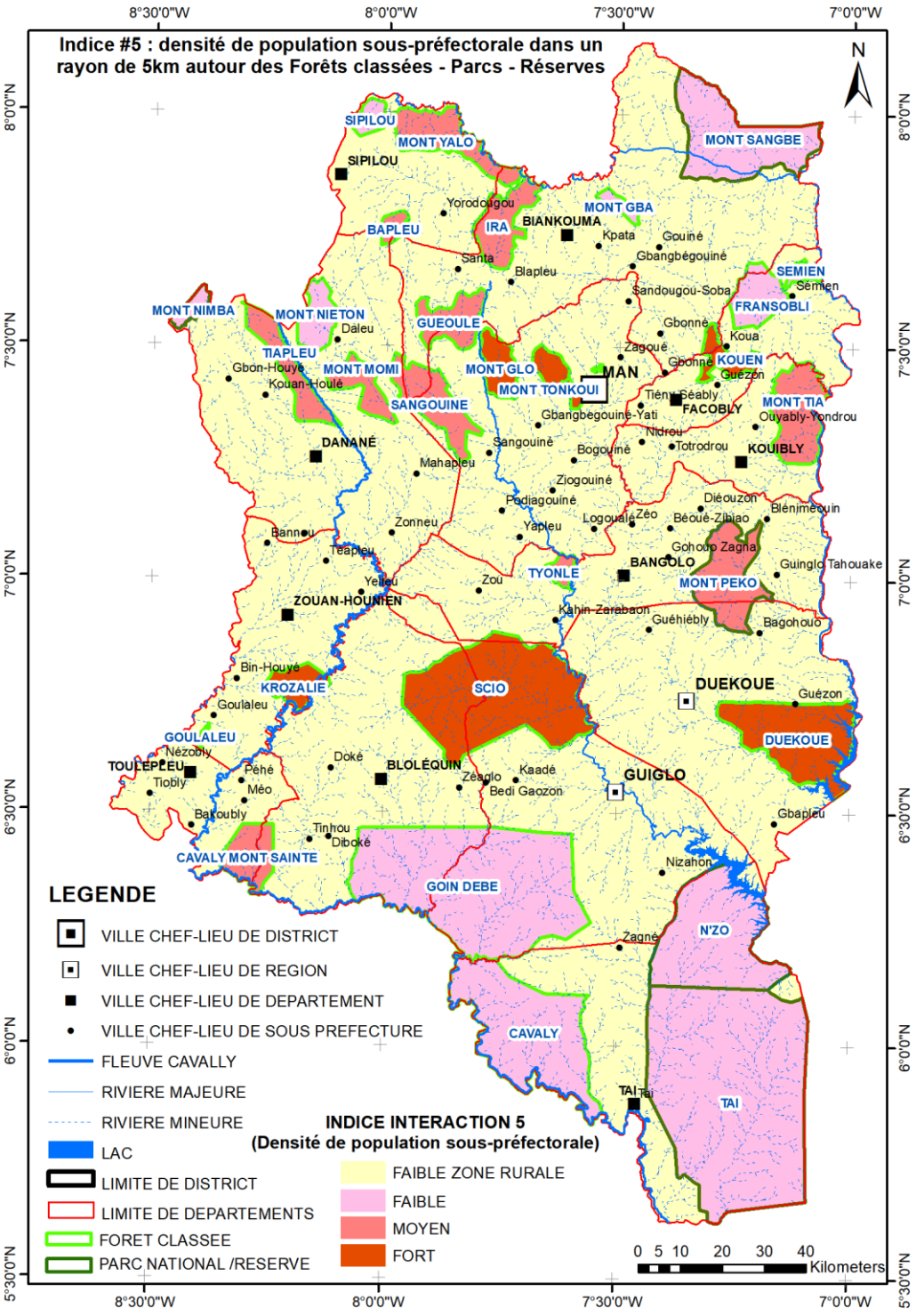

Figure 5: Map of sub-prefectural population density index within a 5km radius of classified forests - parks – reserves

Table 6. Hierarchization of the sub-prefectural population density index within a 5km radius of classified forests, parks and reserves

STATUT	FORET_N	DENSITE_HA	CODE	LEGENDE
PARC NATIONAL	PN_MONT SANGBE	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_SIPILOU	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_MONT GBA	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_SEMIEN	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_FRANSOBLI	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_GOIN DEBE	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
RESERVE	R_N'ZO	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_CAVALY	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
PARC NATIONAL	PN_TAI	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
FORET CLASSEE	FC_MONT NIETON	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
PARC NATIONAL	PN_MONT NIMBA	MOINS DE 100HAB/KM2 RAYON DE 5KM	10000	FAIBLE
ZONE RURALE		ZONE RURALE FAIBLE	10000	ZONE RURALE FAIBLE
FORET CLASSEE	FC_MONT YALO	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_IRA	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_BAPLEU	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_GUEOULE	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_SANGOUINE	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_MONT MOMI	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_MONT TIA	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
PARC NATIONAL	PN_MONT PEKO	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_TYONLE	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_CAVALY MONT SAINTE	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_TIAPLEU	100 A 200HAB/KM2 RAYON DE 5KM	20000	MOYEN
FORET CLASSEE	FC_KOUEN	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_MONT GLO	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_MONT TONKOUI	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_MONT GLA	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_SCIO	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_KROZALIE	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_DUEKOUE	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_GOULALEU	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT
FORET CLASSEE	FC_DENT DE MAN	200HAB/KM2 ET PLUS RAYON DE 5KM	30000	FORT

STATUT: Land tenure status of Classified Forest, National Park, Reserve or Rural Area; **FORET N:** Name of Classified Forest, National Park or Reserve; **DENSITE HA**: Population density per Km^2 of Sub-Prefectures in the vicinity of Classified Forests, National Parks or Reserves; **CODE** : Index hierarchy code strong = 3000 (Population density per Km^2 of Sub-prefectures greater or equal to 200 Hbt/Km^2); medium = 20000 (Population density per Km^2 of Sub-prefectures between 200 and 100 Hbt/Km^2) and weak = 10000 (Population density per Km^2 of Sub-prefectures less or equal to 100 Hbt/Km^2); **LEGEND**: Summary of population density (Legend reported on the map).

MAPPING HUMAN-WILDLIFE INTERFACES IN THE DISTRICT DES MONTAGNES BASED ON THE FIVE-INTERACTION INDEX

The map in Figure 6 shows that the level of human-wildlife interfaces in the District des Montagnes is particularly high in the departments of Man and Danané**.** In addition, there are various classified forests, national parks and reserves, which also have a high level of human-wildlife interface. Figure 7 shows the same map, but considers forest formations outside classified forests, national parks, and reserves. These forests have a medium level of human-wildlife interface (Code 2). This type of forest is virtually non-existent. Where they do exist, they are generally very small sacred sites (2 to 3ha). They cannot be considered as prime refuge areas for wildlife. However, for certain wildlife species of interest, such as bats, a forest site of less than one hectare is sufficient to support large populations. The contribution of these forests to the determination of human-wildlife interfaces is most noticeable in the central

zone (Toulepleu, Zouan-Hounien, Bloléquin, Bangolo) of the district, which had the weakest interfaces.

In conclusion, the departments with the highest human-wildlife interfaces are Danané and Man **(Table 7 and Figure 8).**

Table 7. Priority 1 locations for additional data collection on human-wildlife interfaces

N	REGION	DEPARTMENT	SUB-PREFECTURE
1	TONKPI	DANANE	DANANE
2	TONKPI	DANANE	KOUAN-HOULE
3	TONKPI	DANANE	DALEU
4	TONKPI	DANANE	MAHAPLEU
5	TONKPI	DANANE	ZONNEU
6	TONKPI	DANANE	GBON-HOUYE
7	TONKPI	DANANE	SEILEU
8	TONKPI	MAN	MAN
9	TONKPI	MAN	LOGOUALE
10	TONKPI	MAN	SANGOUINE
11	TONKPI	MAN	YAPLEU
12	TONKPI	MAN	PODIAGOUINE
13	TONKPI	MAN	BOGOUINE
14	TONKPI	MAN	SANDOUGOU-SOBA
15	TONKPI	MAN	GBANGBEGOUINE-YATI
16	TONKPI	MAN	FAGNAMPLEU
17	TONKPI	MAN	ZIOGOUINE
18	TONKPI	MAN	ZAGOUE

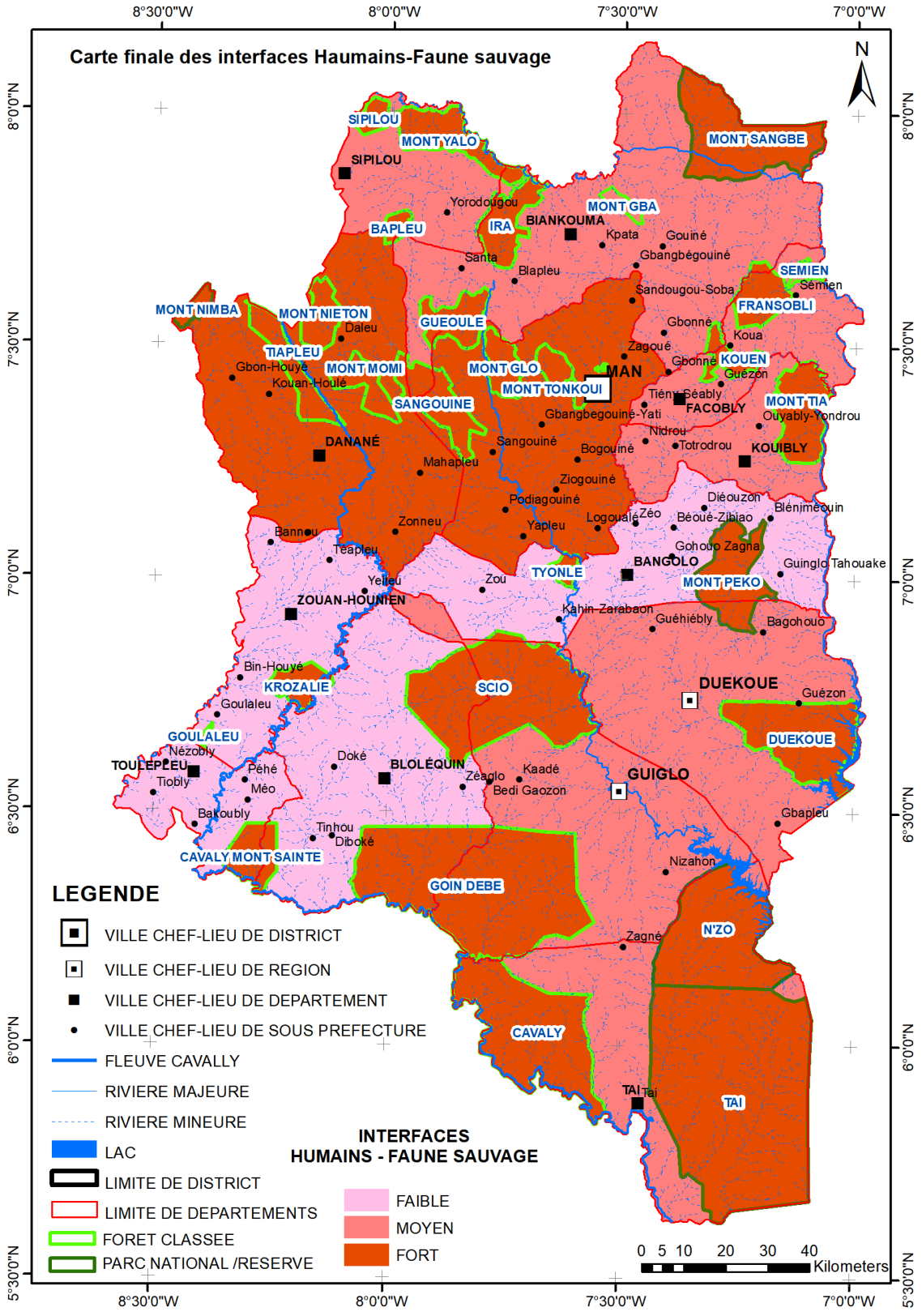

Figure 6: Final map of human-wildlife interfaces in the District des Montagnes

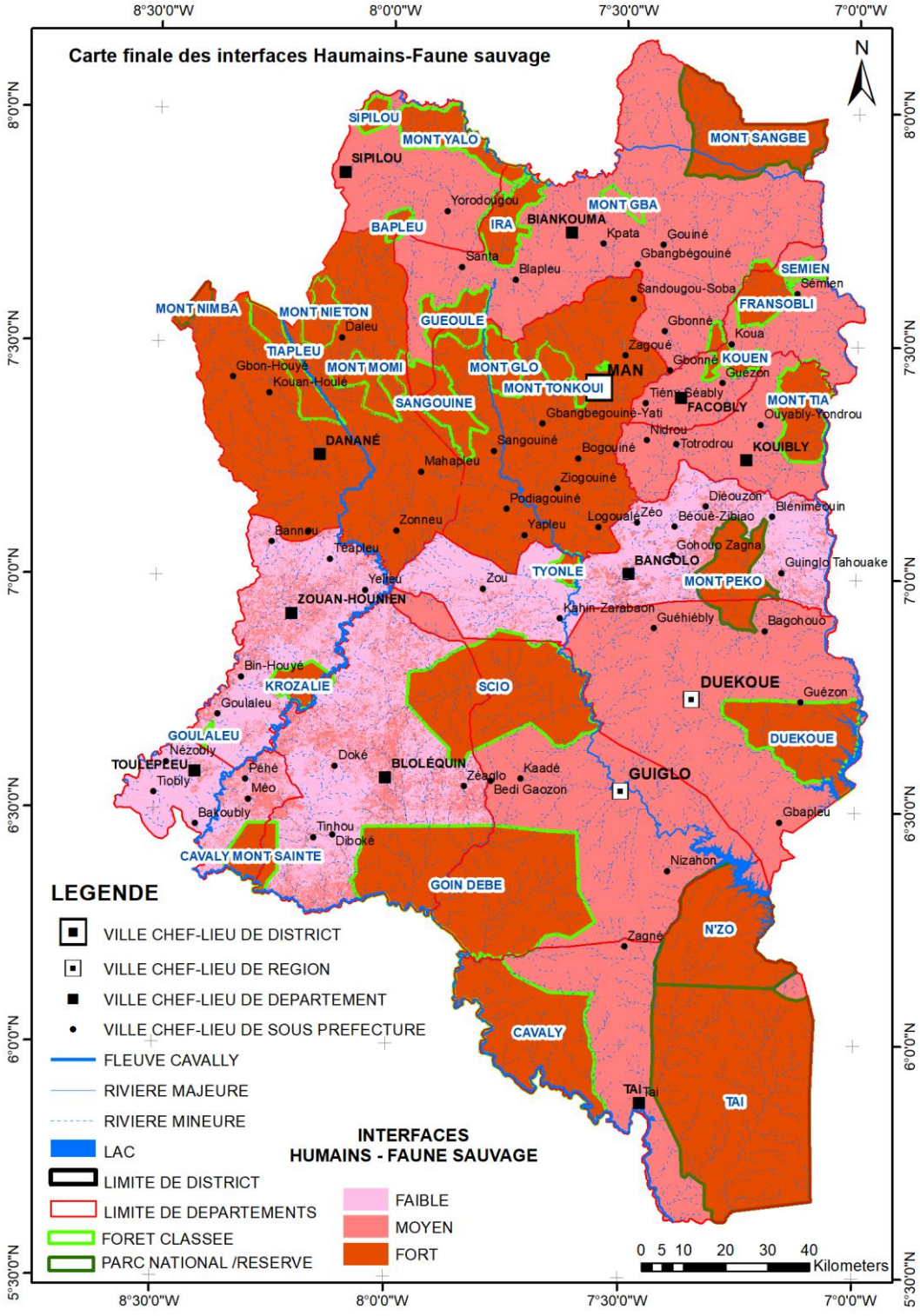

Figure 7: Final map of human-wildlife interfaces in the District des Montagnes (including forests other than classified forests, parks and reserves)

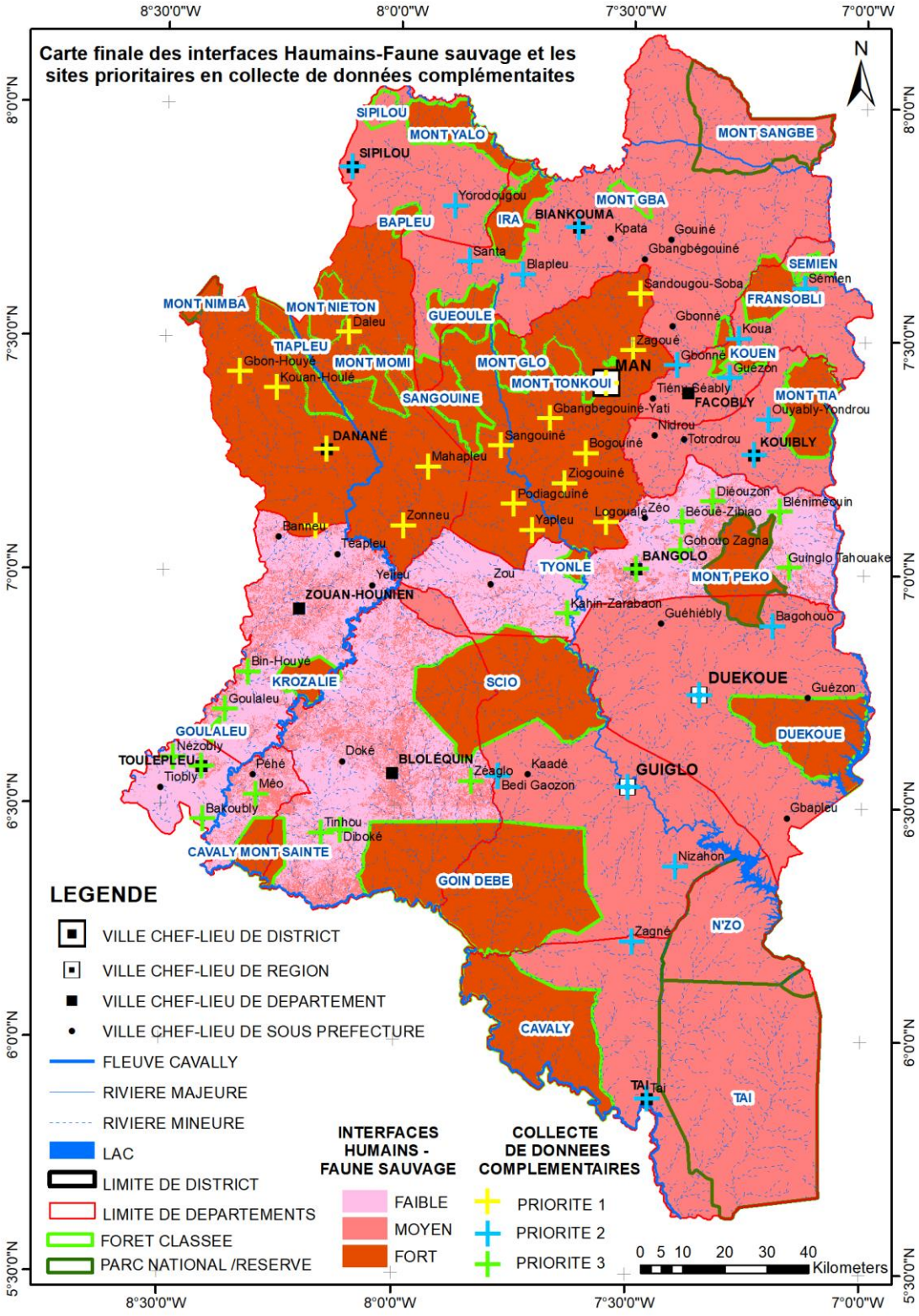

Figure 8: Final map of human-wildlife interfaces in the District des Montagnes and priority locations for additional data collection

In addition to the Danané and Man Departments, which are classified as priority 1, all the Sub-Prefectures bordering classified Forests, Parks and Reserves are also sites deserving special attention and will be classified as priority 2 and 3 depending on their location in a zone of medium or low human-wildlife interface (**Figure 8 and Tables 8 and 9**). It will not be necessary to visit all these localities during the data collection mission, but rather to carry out a reasoned sampling because of the same characteristic of the areas.

Table 8. Priority 2 locations for collecting additional data on human-wildlife interfaces.

N	REGION	DEPARTMENT	SUB-PREFECTURE
1	GUEMON	BANGOLO	DIEOUZON
2	GUEMON	BANGOLO	GOHOUO-ZAGNA
3	GUEMON	BANGOLO	KAHIN-ZARABAON
4	TONKPI	BIANKOUMA	BIANKOUMA
5	TONKPI	BIANKOUMA	GBONNE
6	TONKPI	BIANKOUMA	SIPILOU
7	TONKPI	BIANKOUMA	SANTA
8	TONKPI	BIANKOUMA	GBANGBEGOUINE
9	TONKPI	BIANKOUMA	YORODOUGOU
10	TONKPI	BIANKOUMA	BLAPLEU
11	TONKPI	BIANKOUMA	GOUINE
12	TONKPI	BIANKOUMA	KPATA
13	CAVALLY	BLOLEQUIN	BLOLEQUIN
14	CAVALLY	BLOLEQUIN	DOKE
15	CAVALLY	BLOLEQUIN	TINHOU
16	CAVALLY	BLOLEQUIN	ZEAGLO
17	CAVALLY	BLOLEQUIN	DIBOKE
18	GUEMON	DUEKOUE	DUEKOUE
19	GUEMON	DUEKOUE	GUEHIEBLY
20	GUEMON	DUEKOUE	BAGOHOUO
21	GUEMON	DUEKOUE	GUEZON
22	GUEMON	DUEKOUE	GBAPLEU
23	CAVALLY	GUIGLO	GUIGLO
24	CAVALLY	GUIGLO	TAI
25	CAVALLY	GUIGLO	ZAGNE
26	CAVALLY	GUIGLO	BEDY-GOAZON
27	CAVALLY	GUIGLO	NIZAHON
28	CAVALLY	GUIGLO	KAADE
29	GUEMON	KOUIBLY	FACOBLY
30	GUEMON	KOUIBLY	KOUIBLY
31	GUEMON	KOUIBLY	TOTRODROU
32	GUEMON	KOUIBLY	SEMIEN

33	GUEMON	KOUIBLY	NIDROU
34	GUEMON	KOUIBLY	OUYABLY-YONDROU
35	GUEMON	KOUIBLY	GUEZON1
36	GUEMON	KOUIBLY	KOUA
37	GUEMON	KOUIBLY	TIENY-SEABLY
38	CAVALLY	TOULEPLEU	TOULEPLEU
39	CAVALLY	TOULEPLEU	PEHE
40	CAVALLY	TOULEPLEU	TIOBLY
41	CAVALLY	TOULEPLEU	BAKOUBLI
42	CAVALLY	TOULEPLEU	MEO
43	CAVALLY	TOULEPLEU	NEZOBLY
44	TONKPI	ZOUAN-HOUNIEN	BIN-HOUYE
45	TONKPI	ZOUAN-HOUNIEN	GOULALEU

Table 9. Priority 3 locations for additional data collection on human-wildlife interfaces

N	REGION	DEPARTMENT	SUB-PREFECTURE
1	GUEMON	BANGOLO	BANGOLO
2	TONKPI	ZOUAN-HOUNIEN	ZOUAN-HOUNIEN
3	GUEMON	BANGOLO	GUINGLO-TAHOUAKE
4	GUEMON	BANGOLO	ZEO
5	GUEMON	BANGOLO	ZOU
6	TONKPI	ZOUAN-HOUNIEN	TEAPLEU
7	TONKPI	ZOUAN-HOUNIEN	BANNEU
8	GUEMON	BANGOLO	BLENIMEOUIN
9	GUEMON	BANGOLO	BEOUE-ZIBIAO
10	TONKPI	ZOUAN-HOUNIEN	YELLEU

PRESENTATION OF THE INTERACTIVE PLATFORM

The interface for accessing the interactive platform for interfaces at high risk of zoonotic transmission in the mountain district features on its first page a field for the username and password. Once these two elements have been entered, it gives access to the map display on Leaflet background and the layer selection tool. Thus, people can select a layer from the drop-down menu.

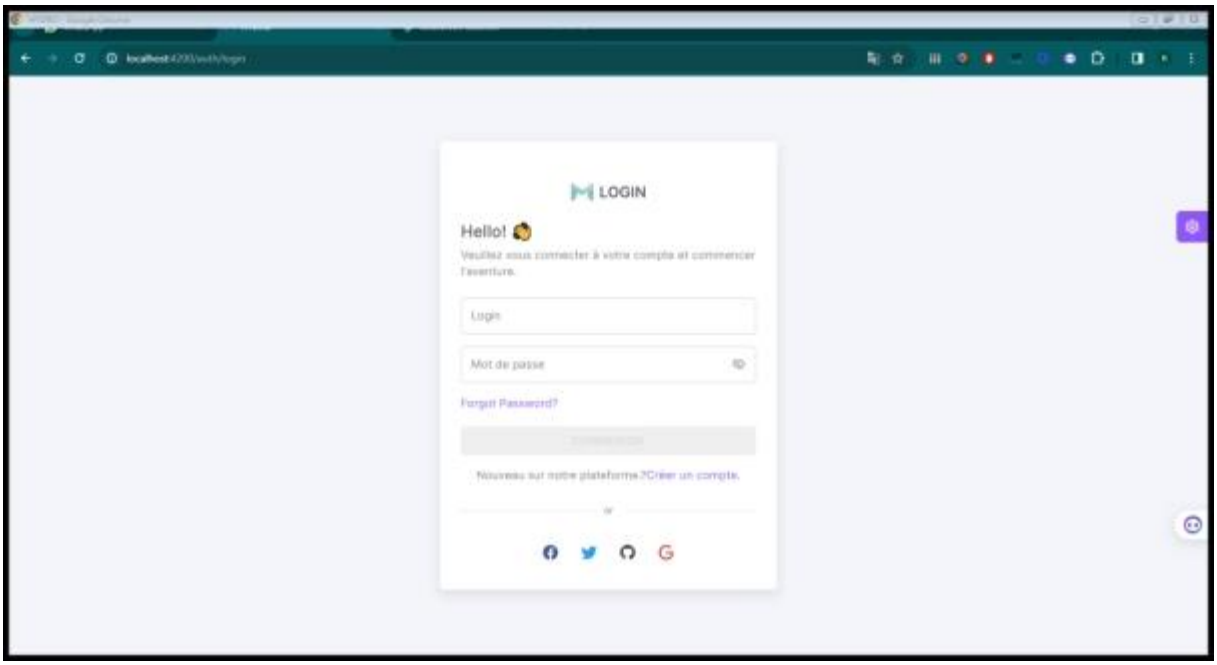

Figure 9: Login form

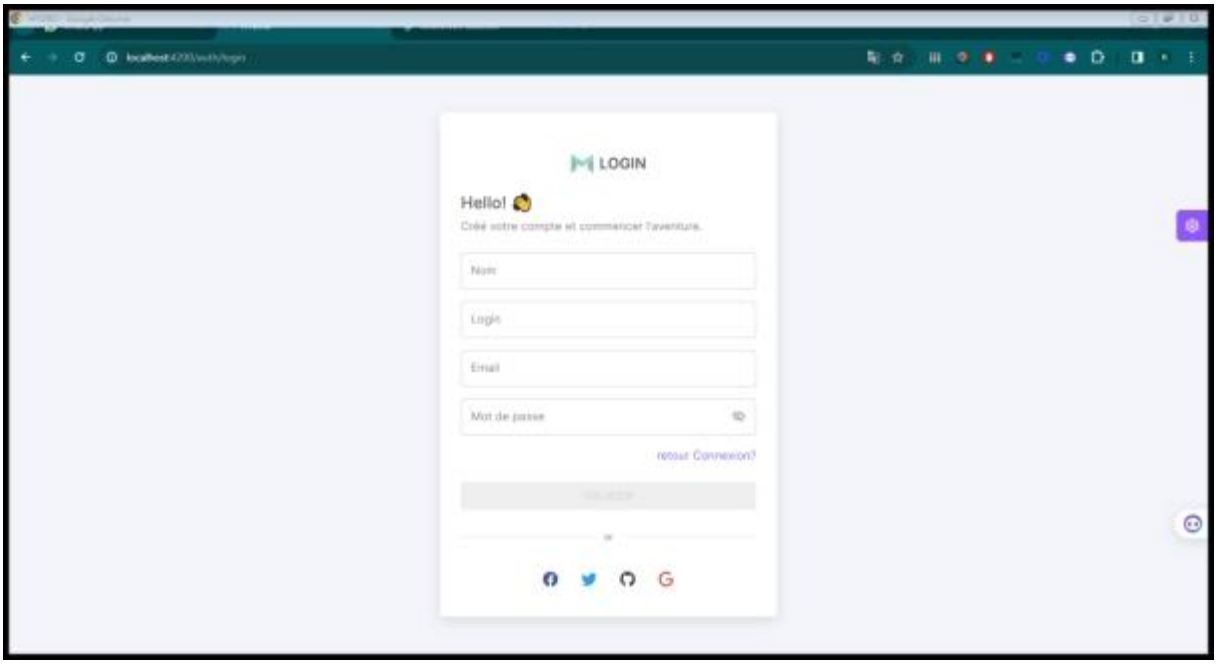

Figure 10: User account creation form

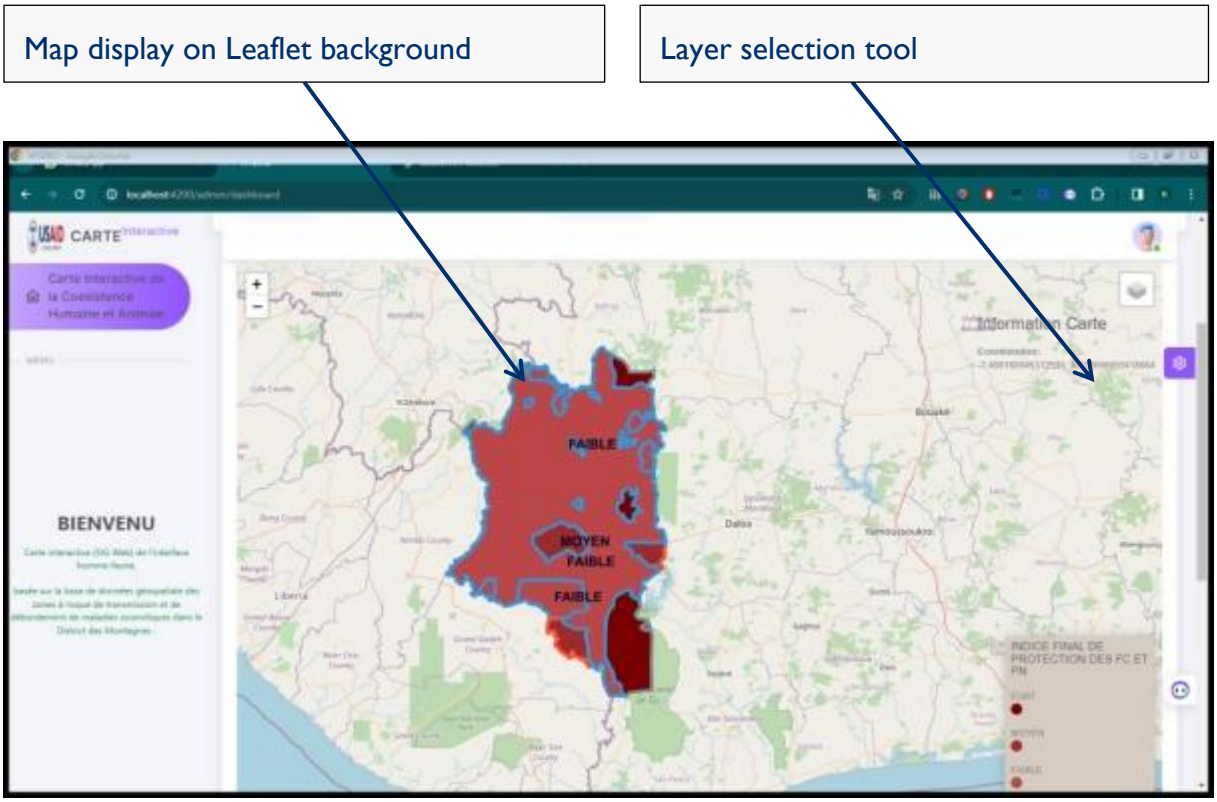

Figure 11: Tools for displaying and viewing information layers

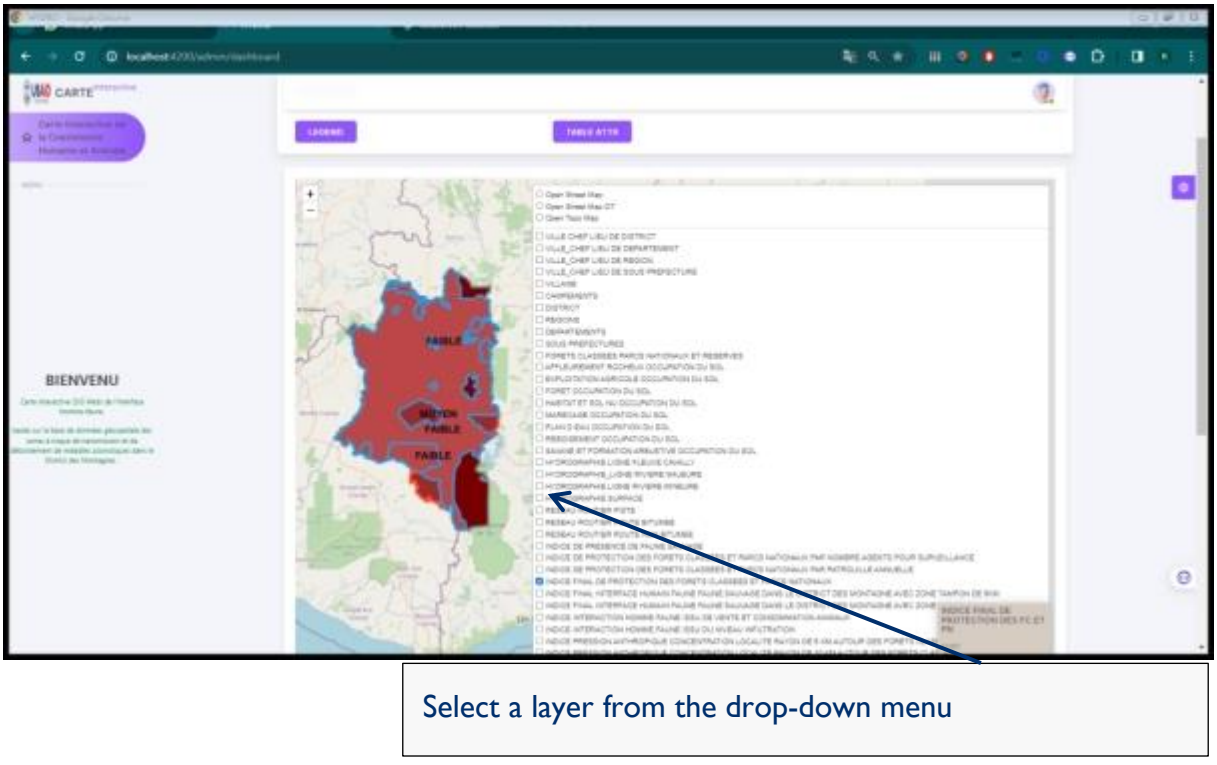

Figure 12: Selecting an information layer

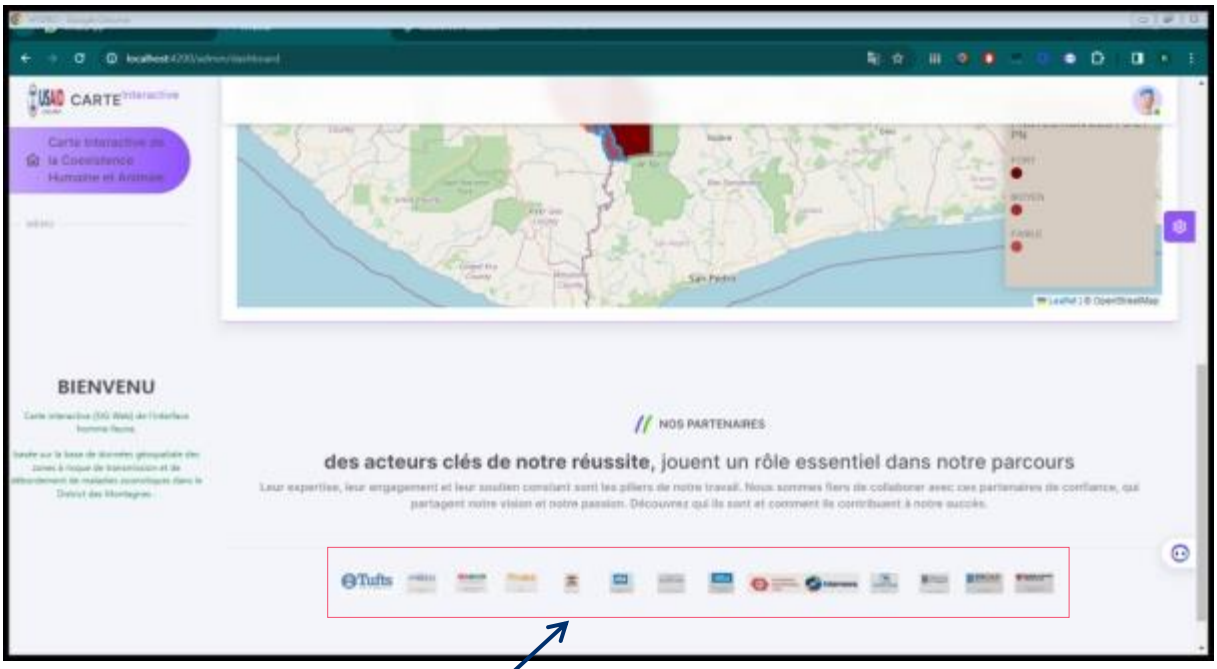

Figure 13: List of project partners

CONCLUSION AND OUTLOOK

The development of this interactive database, which can be consulted online, is the fruit of the collaboration of numerous stakeholders, who have contributed either by making available the data in their possession, or by offering suggestions and constructive criticism in the development and implementation of the methodological approach.

One of the most important results of this project is the spatial database that has been compiled. This database, which particularly highlights the level of interaction between humans and wildlife in the Mountain District, allows us to conclude that the departments of Man and Danané have the highest levels of interaction between humans and wildlife. Added to these departments are the various classified forests, national parks and reserves, which also have a high level of interaction between humans and wildlife. This map of human-wildlife interfaces is based on a combination of five indices:

- Index #1: sale and consumption of bushmeat;
- Index #2: length of roads within a 5km radius of classified Forests - Parks - Reserves;
- Index #3: number of localities within a 5km radius of Forêts classées - Parcs - Réserves;
- Index #4: level of infiltration of Classified Forests - Parks - Reserves;
- Index #5: sub-prefectural population density within a 5km radius of Forêts classées - Parcs - Réserves.

This interactive mapping project is intended as an important decision-support tool for government and stakeholders, enabling them to:

- Locate areas of high human-wildlife interaction, and therefore potentially high zoonotic disease risk;
- Target additional data collection areas to refine the accuracy of the first maps of human-wildlife interfaces;
- Organize targeted risk-based surveillance of potential high-risk areas for zoonotic diseases as part of anticipatory strategies.

The richness of the information contained in the database, together with the possibility of enriching it with additional data and updating it, make this interactive platform an important source for any further analysis of the physical, environmental and social environments of the District des Monatgnes and Côte d'Ivoire. However, like all human endeavors, this project has a number of limitations that need to be addressed in the second phase.

Thus, the prospects for this first phase are as follows:

- Collect more precise data on the presence of animals and particularly target wildlife (e.g., non-human primates and bats) to refine the Human-Wildlife interface maps already developed;
- Consider specific human-wildlife interaction maps for each wildlife species of interest;
- Update bushmeat sale and consumption sites in the interfaces identified by the results of this first phase;

- Collect data on major human occupations and related gender aspects;
- Collect data on the sale of wildlife species, specifying quantity and organoleptic quality;
- Collect data on major production activities and related markets;
- Identify wildlife and domestic transhumance zones;
- Collect socio-economic data on human-wildlife interfaces, as well as resources and other points of tourist interest;
- Collect data on arrests and volume of bushmeat seizures.

Suggestions for additional data collection include:

DATA	**POTENTIAL DATA SOURCES**
Population distribution by village (only sub-prefectural data available)	National Institute of Statistics
Sale sites, bushmeat market sites	Data collection from local authorities in the field
Types and density of wildlife marketed	Data collection from local authorities in the field
Wildlife density in protected areas	OIPR with ecology monitoring data Data for the national flora-fauna inventory of Côte d'Ivoire (2021)
Socio-economic activities at human-wildlife interfaces	Local government
Wildlife and domestic transhumance zones	OIPR with ecology and DSV monitoring data