Geographical information system and support for monitoring road projects: the case of Projects jointly funded by the Ministry of Public Works.

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Abstract: Context: Since the 1960s, abbreviated geographic information systems, more commonly GIS, which are techniques combining cartography with databases, have emerged thanks to a grouping of information structured and organized in a certain logic in the computer tool called server. Our study focuses on jointly funded road projects. The latter comes up against the inaccessibility of remote work data since they are poorly archived; it is necessary to ask how to continue the control, and the correct archiving of the data of these projects so that we can have remote access and in real time if necessary?

Objective: Development of a geographic information and road project monitoring tool based on a multifunctional database.

Material and method: data collection with excel software and a smartphone, close to the project engineers, presentation of the processing and analysis processes of the acquired data (georeferencing which made it possible to set all the layers in the same repository, the digitalization of the linear concerned) as well as the development of the database followed by the design of the tools and production of the maps of the various projects.

Results: Implementation of a webmapping tool for the archives and remote data access consisting of a database supported by a dynamic information exchange tool and a cartographic interface configured for publication, visualization, project mapping.

Conclusion: This tool must allow the archiving of data from work already carried out, remote access to this data, monitoring of the progress of work, as well as the visualization of the cartography of the various works built.

Keywords: Database, GIS, Shapefile, Webmapping, spatial reference, webGeo, joint funding, georeferencing.

Abreviations list

AfDB: African Development Bank.
BDEAC: Development Bank of Central African States.
CPR-FC: Jointly Funded Road Projects Unit.
DB: Database
DSCE: Strategy Document for Growth and Employment.
ECCAS: Economic Community of Central African States.

ECOWAS: Economic Community of West African States.
EU: European Union
GIS: Geographic Information System.
IDB: Islamic Development Bank
MDGs: Millennium Development Goals.
PDCT-AC: Consensual Master Plan for Transport in Central Africa.
SHP: Shapefile.
WB: World Bank.

Introduction

The Cameroonian Government has relied on the strategy defined in the Strategy Document for Growth and Employment (DSCE) in which it reaffirms its desire to pursue the achievement of the Millennium Development Goals (MDGs), to develop its development projects. Its road projects also respond to the guidelines of Cameroon's transport sector policy, which emphasizes on the importance of road infrastructure development with a view to their contribution to economic growth, poverty reduction, improvement of access to basic social services, the opening up of rural areas, as well as regional integration. Some targeted roads are part of the priorities of the Consensual Master Plan for Transport in Central Africa (PDCT-AC) of ECCAS which aims to increase trade between the capitals of ECCAS. Others will contribute by increasing trade and strengthening cooperation between ECCAS countries and those of the Economic Community of West African States (ECOWAS) in general, and particularly between Cameroon and Nigeria. It should be noted that several of these infrastructures, in some specific road projects, are financed by technical and financial partners (BM, ADB, JICA, BDEAC, EU, AFD, BID, etc.). These projects are piloted in Cameroon by the Jointly Funded Road Projects Unit (CPR-FC) created by the Order No. 018 / PM of March 09, 2020 of the Prime Minister, Head of Government and is placed under the authority of the Minister of Works Public. Since its creation, several projects have been carried out but we realize that the data is not archived; it is noticed that some projects are not well documented. And also, there is a serious communication problem between the various stakeholders in these projects; we also noticed the accumulation of papers in the offices which cannot resist for a long time sometimes because of the climate as well as the loss of certain project data when the person in charge of the documents leaves the structure and also the impossibility to get access to the data from a distance.

The overall objective of this work is therefore to set up a dynamic tool to help monitor joint-funded road projects to allow not only the storage of data but also remote access to this data if necessary, by the different actors.

1. Methodology

The methodology adopted consisted mainly of a survey of the jointly funded road projects unit of the Ministry of Public Works, data collection, analysis of the data collected and development of the webGeo tool.

1.1 Historical background and location

As part of the implementation and monitoring of the execution of road projects including the financial support by the World Bank (WB) and the African Development Bank (AfDB), the Government of Cameroon by de decret N°_ 025/CAB/PM of February 13, 2008 setup a unit called BAD/BM-MINTP, unit modified and supplemented by order N°_ 018/PM of March 9, 2020 on the organization and operation of the project units joint-financed road (CPR-FC) of the Ministry of Public Works. It is placed under the authority of the Minister of Public Works.

Located in Yaoundé at the delegation of the Ministry of Public Works located opposite to the municipal lake.

1.2. Data Collect

The data collected is of two types, namely the data on the offer and the realization of the projects which we have called attribute data and the data on the location which we have called cartographic data.

1.2.1. Project attribute data

We have collected data on projects piloted by the CPR-FC from 2010 to the present day. This data included general information on the projects such as the name of the project or program, the different lots of the project, the loan agreement number by the funder, the different donors, the amount of credit mobilized by each donor, the total budget of the project, the date of approval, date of loan agreement, date of start of the project, the duration of the project, the project manager, the client and the company which carried out the project as well as the nationality of the company and that of the control mission. These data are recorded in a table 1.

1.2.2. Project mapping data

To obtain the cartographic data, we started from the downloaded Cameroon road map file and then we carried out several GIS operations, in particular the digitization of our road sections in order to be able to produce the cartography of each project.

1.3. Development of the database and webGeo tools

1.3.1. Development of the database

In our case, to develop our database system we will have as method of analysis that of Merise in which we will present MCD, MLD and MPD. Modeling according to the MERISE formalism. The modeling was based on the MERISE formalism with the PowerDesigner software. Subsequently, taking into account the spatial and geometric dimensions of the objects constituting the road project data that required another model specific to GIS. Regarding the formalism of MERISE, this method allows us to analyze and design project data information systems. It is mainly based on three steps: First the Conceptual Data Model (CDM, with the Entity-Association model), then the Physical Data Model (PDM) and finally the Logical Data Model (LDM, relational). The language used here is SQL. TThe DBMS is PostgreSQL that we will use its PostGIS extension which allows us to manage the cartography.

1.3.2. Development of the webGeo tool

In this part of the design, we will use the MVC model for the structuring of web pages and the programming languages are PHP and html.

General methodology

After creating the database with PostgreSQL and connecting it to the Qgis mapping software, we installed the GeoServer mapping server which will allow us to publish our GIS data and finally we will connect it to the DB.

2. Results and discussions

2.1. Results

Note that the collected data are of two types:

2.1.1. Presentation of attribute data

The data after processing is as follows:

Table 1. Summary of project tender data

N°	PROJET	N° ACCORD DE PRET	BAILLEURS	CREDIT MOBILISE	DATE D'APPROBATION	D'ACCORD DE PRET	CLOTURE INITIALE	CLOTURE ACTUALISEE
			GOV	10 169 000 000				
4	Programme d'appui au secteur des transports, phase I : Aménagement de la route Batcheng – Ntui – Yoko – Lena	BAD N°	BAD	101 057 391 377	26/11/201		31/12/2019	31/12/2024
		FAD N°2100150032293	FAD	9 238 031 000		28/03/2015	31/12/2019	
		154/CAM -15/01-INFRA	BDEAC	40 000 000 000				22/06/2020
		CCM 1342 01 H (N° 01)	AFD	45 916 990 000	09/07/2015	02/03/2016	31/12/2021	31/12/2021
		CMR0078	BID	109 544 819 000	26/04/2015	18/05/2016	22/04/2022	22/04/2022
		LA CM-P5	JICA	26 192 898 000	17/04/2015		23/07/2023	23/07/2023
			GOV	28 303 000 000				
5	Programme d'appui au secteur des transports, phase 2 : Réhabilitation de la route Yaoundé – Bafoussam – Babadjou, et aménagement des route Grand-Zambi – Kribi et Bogo – Pouss	BAD N° 2000200000702	BAD	177 208 000 000	23/11/2016	08/06/2017	31/12/2020	31/12/2024
		FAD N°2100150036598	FAD	10 596 000 000				
6	Programme d'appui au secteur de Transport: construction du ring road	N° 2000 20000 3405	BAD 1	11 780 987 720	27/11/2018	28/10/2019	31/12/2024	31/12/2024
		N° 2000 20000 4664	BAD 2	106 002 651 200	18/12/2019	18/06/2021	31/12/2024	31/12/2024
		N° 5050 20000 1056	AGTF	27 943 768 200	18/12/2019	30/12/2021	31/12/2024	31/12/2024
			GOV	21 540 353 000				
7	Programme intégrateur du réseau routier dans bassin du lac Tchad (Construction du pont sur Logone entre Yagoua (Cameroun) et Bongo (Tchad))	BAD N° 2000200002003	BAD	21856487240	11/12/2017	24/05/2018	31/12/2025	31/12/2025
		FAD N°2100150038644	FAD	7 789 000 000				31/12/2025
			UE	13 119 000 000				
			GOV	4 116 000 000				
8	PROJET DE DEVELOPPEMENT DU SECTEUR DE TRANSPORT	BIRD 8650CM	BM	82 674 559 196	27/10/201	20/04/2017	30/06/2022	30/06/2024
			GOV	6 013 160 600				
9	PROJET DE TRANSPORT MULTIMODAL	IDA5465CM	BM	32 184 325 112		20/08/2014	30/06/2021	31/12/2022
			GOV	9 550 000 000				
10	Projet Aménagement des Routes de désenclavement de la Zone Industrielle de Kribi (PARZIK)		BAD1	74 999 499 552		20/0	31/12/2028	31/12/2028
			BAD2					
			GOV	40 490 000 000				
	TOTAL GENERAL PORTEFEUILLE			1 361 335 757 048				

Table 2. Summary of project execution data

N°	PROGRAMME/PROJET	LOCALISATION DU PROJET			ALLOTISSEMET DES PROGRAMMES	ARRANGEMENT DU PROJET INSTITUTIONNEL				
		REGION	DEPARTEMENT	ARRONDISSEMENT		MAITRE D'OUVRAGE	Mission de controle	Nationalité	Entreprise	Nationalité
1.	PROGRAMME D'APPUI AU SECTEUR DE TRANSPORT PHASE I-BATCHENGA-NTUI-YOKO-LENA-TIBATI	CENTRE, ADAMAOU	MBAM-et-KIM, DJEREM MBAM-et-KIM, DJEREM		Batchenga-Ntui, 21,3 km	Ministere des Travaux Publics	GROUPEMENT STUDI INTERNATIONAL – ECTA BTP	Tunisienne/Camerounaise	Groupement RAZEL BEC/RAZEL CAMEROUN	Française
					Ntui-Mankim : 96.7 km	Ministere des Travaux Publics	GROUPEMENT CIRA S.A. BEC LA ROUTIÈRE	Française/camerounaise	ELEVOLUTION ENGENHARIA	
					Mankim-Yoko: 82,1 Km	Ministere des Travaux Publics	Grpt CIRA S.A/ BEC LA ROUTIERE,	Française/ Camerounaise	ELEVOLUTION ENGENHARIA	
					Yoko-Léna (44.9 km) Meiting-Yoko (20 km)	Ministere des Travaux Publics	Grpt CIRA S.A/ BEC LA ROUTIERE	Française/ Camerounaise	SINOHYDRO Ltd Corp	Chinoise
					Lena-Tibati-Ngatt : 167,5 km	Ministere des Travaux Publics	Grpt ALPHA CONSULT ACE	Gabonaise/	SOGEA SATOM	Française
2.	PROGRAMME D'APPUI AU SECTEUR DE TRANSPORT PHASE II-YDE-BAF-BAB/GZK/BP	CENTRE OUEST Sud et de l'Extrême-Nord	NDE, KHOUNG-KHI, MIFI, BAMBOUTOS MBAM ET INOUBOU ET DU NDE		Lot 1 : réhabilitation de la route Ebebda-Kalong y compris la construction d'un échangeur au lieu-dit carrefour Obala (63,75km) (pk 000+000-Pk63+750)	) /	Grpt SAFEGE A.C/SAFEGE/ SPEA ENGINEERING	Française/Algérienne	CGCOC GROUP Co. Ltd	chinoise
					Lot 2 : réhabilitation de la route Kalong-Tonga (PK 66+750) - (PK130+750) (67km)		Grpt SAFEGE A.C/SAFEGE/ SPEA ENGINEERING	Française/Algérienne	SINOHYDRO	chinoise
					Lot 3 : réhabilitation de la route Tonga-Bafoussam-Babadjou (110,242km) (PK130+750) -(PK240+992)		Grpt SAFEGE A.C/SAFEGE/ SPEA ENGINEERING	Française/Algérienne	CHINA RAILWAY N°5/GROUP Co. Ltd	chinoise
					Aménagement de la route Grand Zambi-Kribi (53km)		Grpt SAFEGE A.C/SAFEGE/ SPEA ENGINEERING	Française/Algérienne	CGCOC GROUP Co. Ltd	Chinoise
					Aménagement de la route Maroua – Bogo – Pouss (63,16km)	/	Grpt SAFEGE A.C/SAFEGE/ SPEA ENGINEERING	Française/Algérienne	STUDI International	Tunisienne
3.	PROGRAMME D'APPUI AU SECTEUR DE TRANSPORT PHASE III-RING ROAD	Nord-Ouest	MEZAM, NGOK ETUNJA, BUI, DONGA MANTUNG, MENTCHUM		Réhabilitation de la route Kumbo-Nkambe-Misaje, y compris la voie de contournement de Nkambe (96 km)					
					Réhabilitation de la route Misaje-Dumbo-frontière nigériane (50 km)					

NB: some projects here do not have data either because the project is still in progress or because the data has not been archived as mentioned above.

2.1.2. Project mapping data

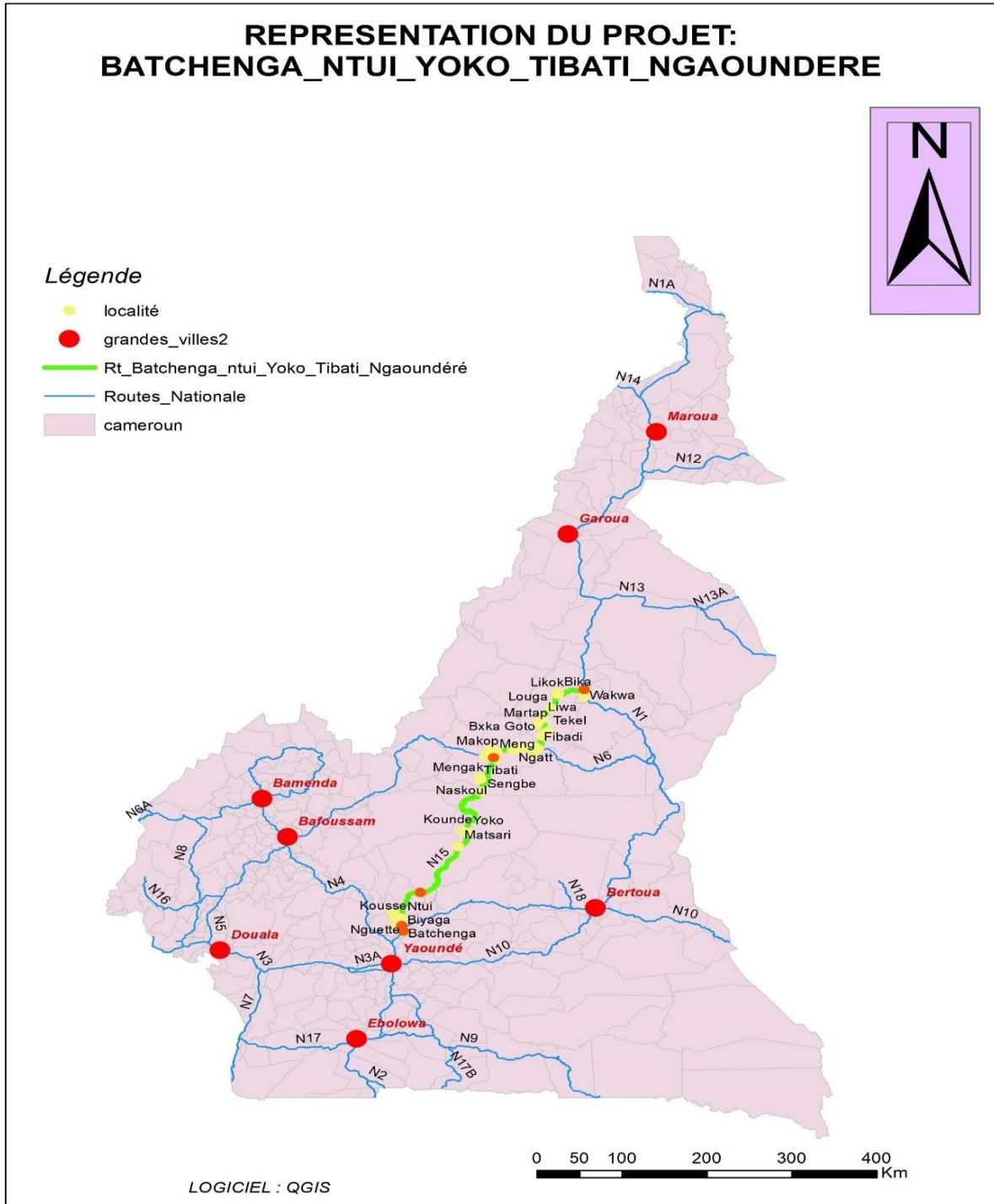Some geographical data which have been produced on the Qgis mapping software are as follows:

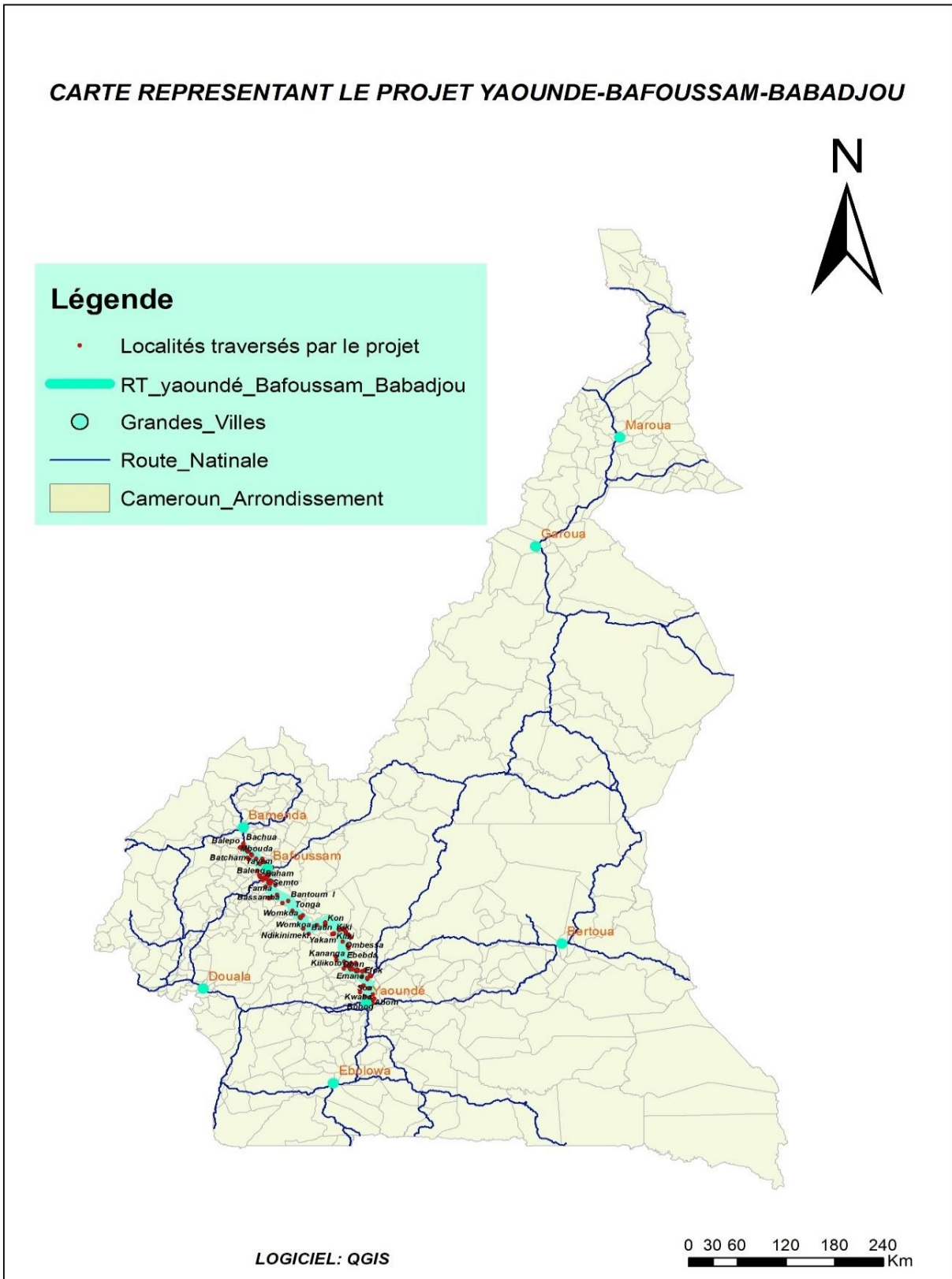**Figure 1. Map of the Batchenga-Ntui-Yoko-Lena-Tibati road rehabilitation project.**

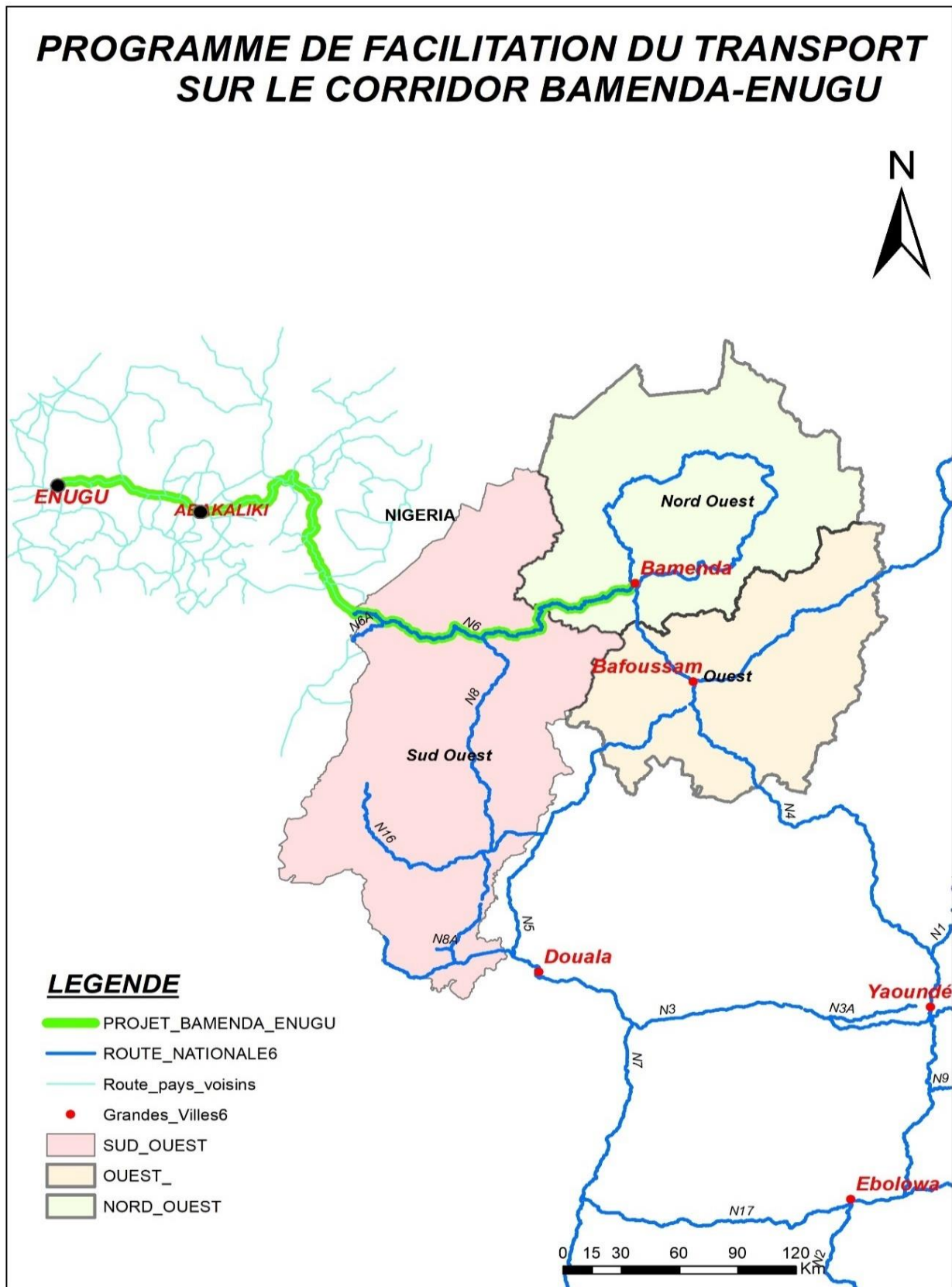**Figure 2. Map of the Yaoundé-Bafoussam-Babadjou road rehabilitation project.**

Figure 3. Map of the Bamenda-Enugu Corridor Rehabilitation Project.
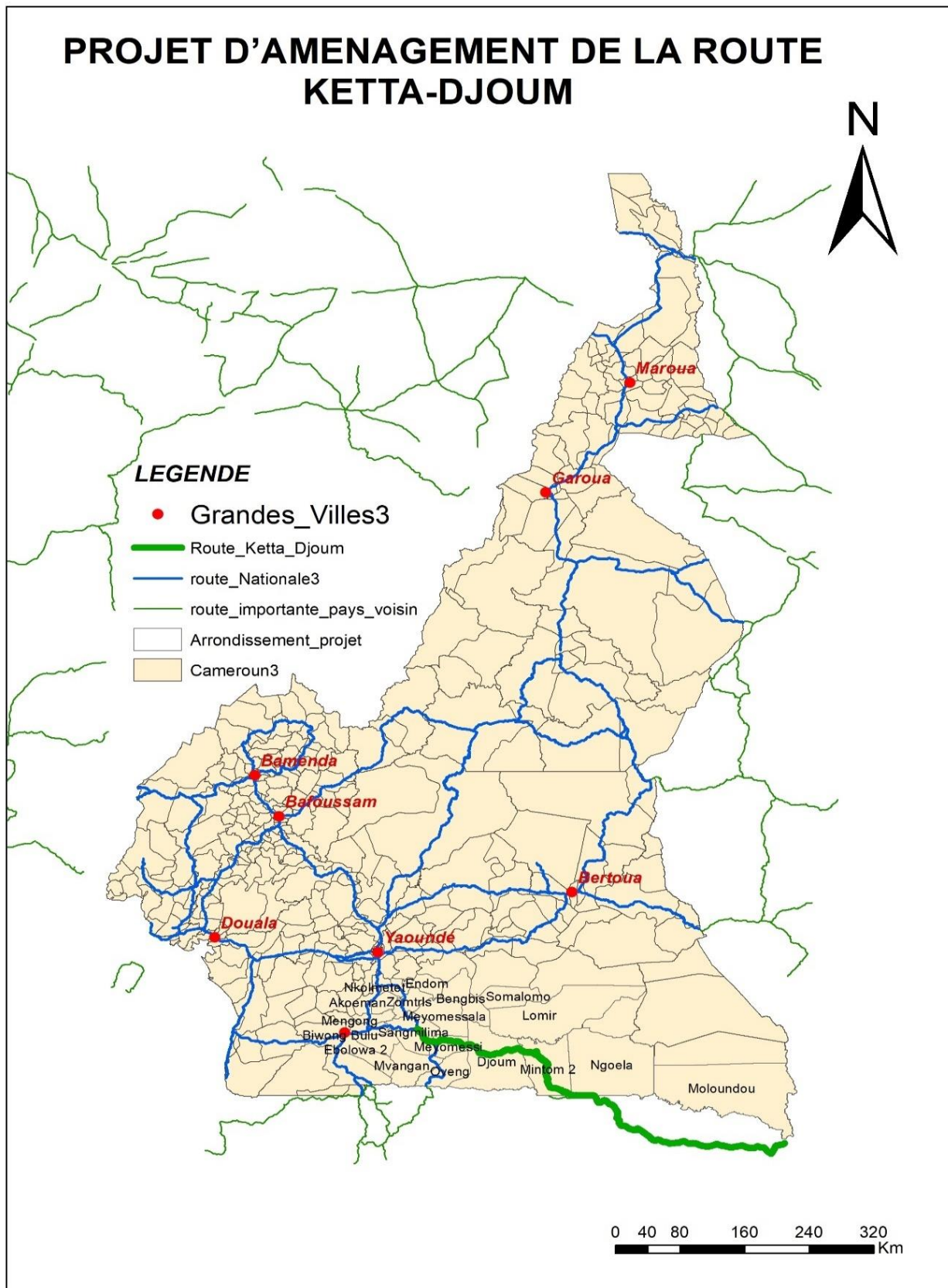
Figure 4. Mapping of the Ketta-Djoum road redevelopment project.

2.1.3. Presentation of the webGeo tool

The interface of our webGeo tool has four essential tabs and to access the tool it can be done from a browser and in our case, we used to google chrome by inserting the URL.
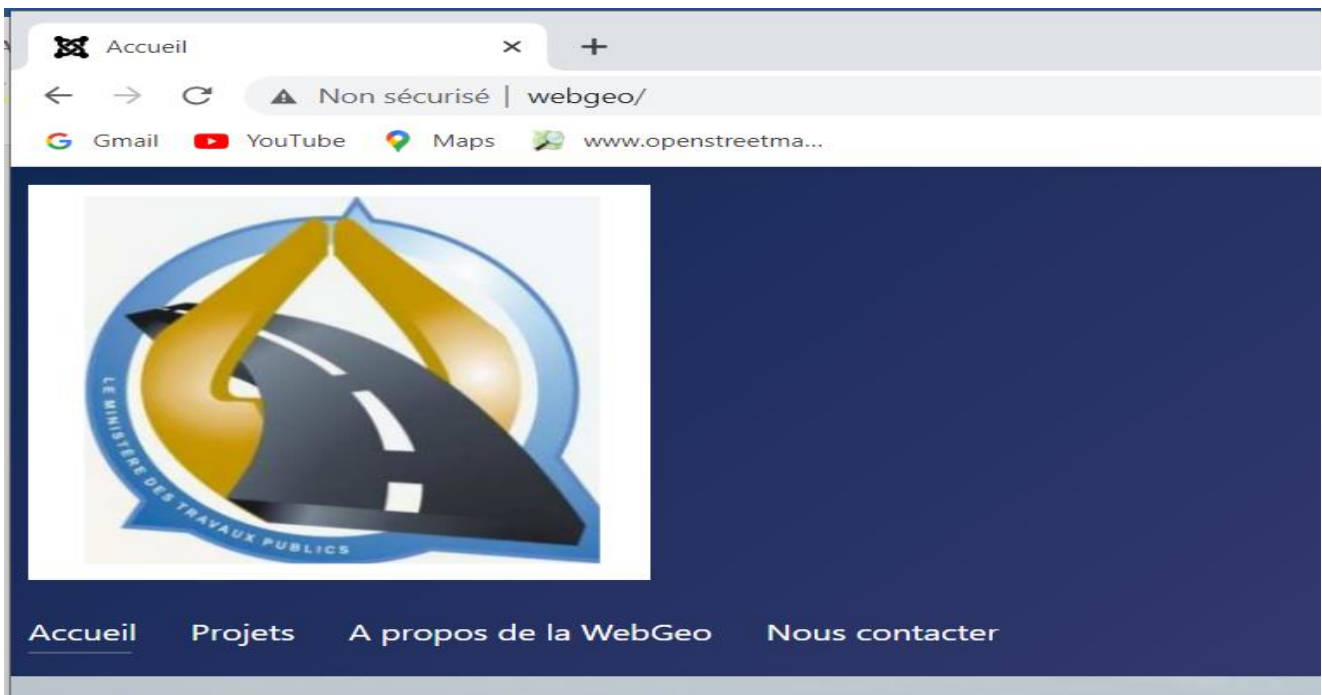

Figure 5. Tool Access Shortcut.

Figure 6. Different fields of the webGeo tool.

➤ **Home page**

In this tab we have the history of the jointly funded road projects unit, its main objective, its mission as well as the operating chart of the latter.

➤ **Projets**

The project tab gives us information on the different projects that are in the comic strip, just click on project and you access the different projects as well as the related information.
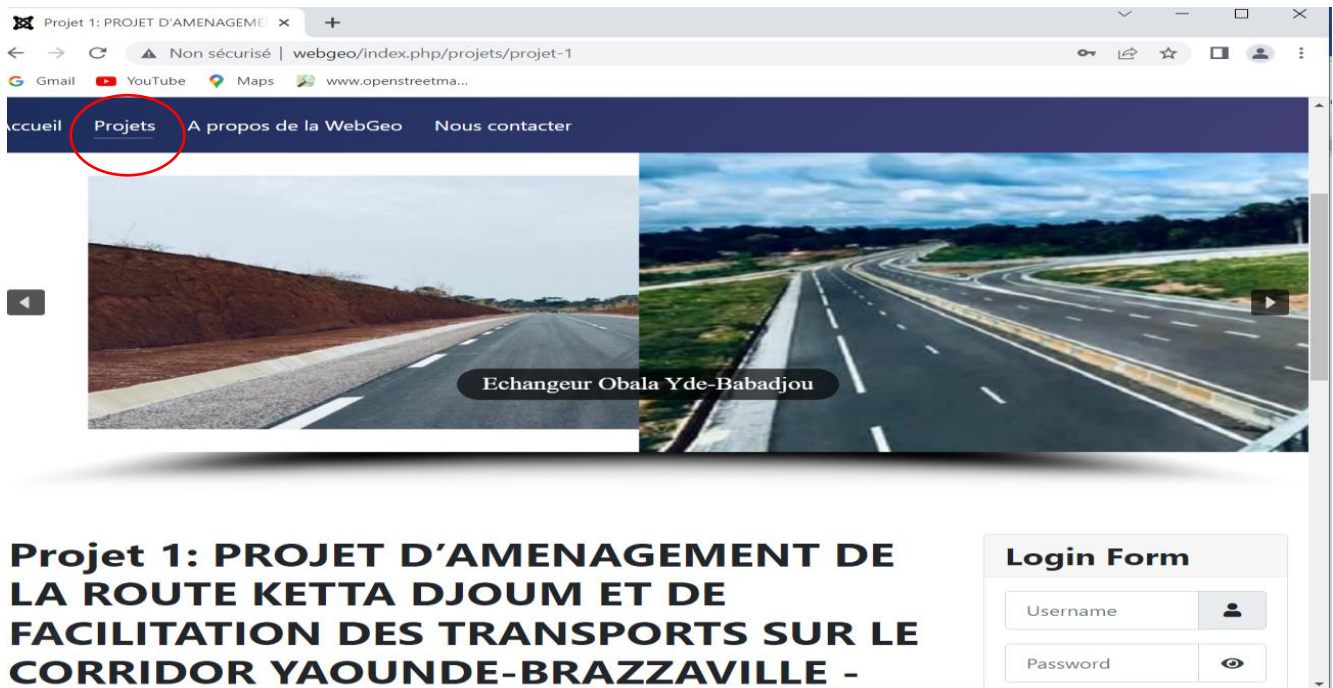

Figure 7. Access to the various projects and related information (webGeo).

To view the project map, simply click on the link below each project; this will take you to the GeoServer software, cartographic server where the maps are published after completion.
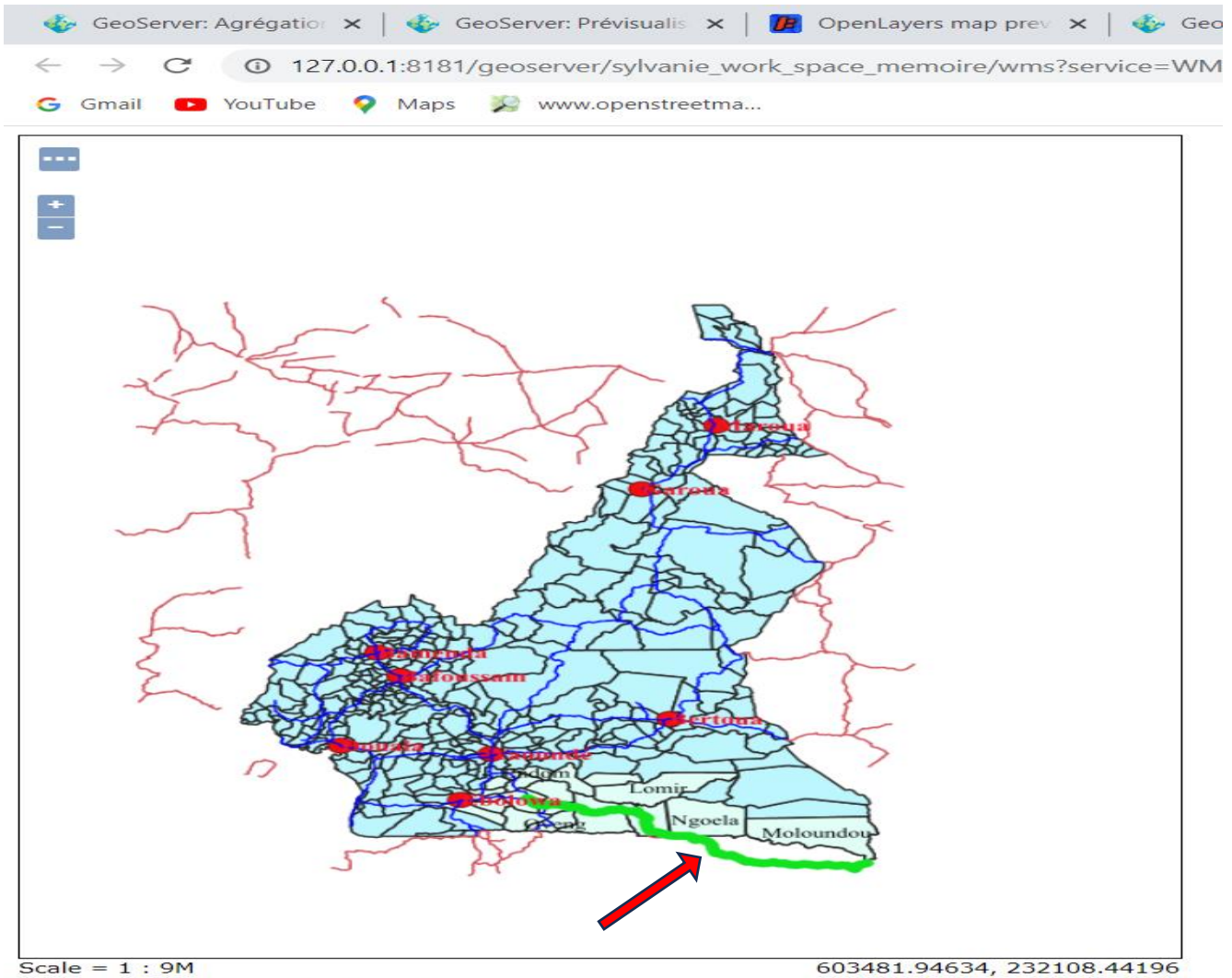

Figure 8. Map access link (webGeo).

Figure 9. Preview of project mapping in GeoServer.

2.1.4. WebGeo operating tools

- **Layers table**

It is a table that lists all the layers that we use to produce the cartography of each project. And on this table we can check and uncheck the layers we want to see or not; which avoids making the map bulky.

- **Zoom Tool**

As an online map, the zoom tool is essential; that's why in our webGeo we have two ways to zoom. The first is to use Scale (located on the right of the web page), when we click on this option, a list of several scales appears so we choose which one we want to use. The second way is the easiest and best known when we are on a map. Indeed, in this case, you just have to click on the symbols + (to zoom in) or – (to zoom out). On a smartphone, the zoom is done just by placing two fingers on our screen, spreading them apart or closing them.

- **Selection tool**

This tool helps when you want to view the map and you want to have information about a specific place, then just click on it, then a request will be made on the server which contains the database and it gives you all the information related to what you clicked on.

2.2. Discussions

2.2.1. Analysis

The tools developed will allow managers and the various project stakeholders to get advantages such as:

- ❖ Remote access to project data;
- ❖ Digital archiving of project data so as not to lose it
- ❖ Reducing the congestion rate of documents and searching through piles of physical documents when information is needed;
- ❖ The publication of the cartographic representation of each project.

2.2.2. Recommendations

- Develop in-house software tools for the automation of topographic and more particularly cartographic tasks such as the digitization and assembly of cartographic data for each project;
- Acquire a more efficient computer for viewing all raster elements (NVIDIA RTX graphics card);
- Focus on geographical data in the production of reports.

Conclusion

The main objective of this work was to set up an information system through a dynamic tool to help monitor joint-funded road projects. The webGeo application developed during this work is a tool for viewing, creating/editing and archiving project information. It will allow access to information on road projects and its control by making it available on the Internet. From an architectural point of view, the developed webGeo tool is composed of a DBMS (PostgreSQL/PostGIS) inside which stores the text data as well as the layers in shapefiles and SLD files (for style management maps), a web application that interacts with users and a cartographic server (GeoServer to publish the maps of the various projects). This project is a tool to help manage and communicate the various project data with the contribution of new GIS technologies; the work was divided into several parts.

First, it was a question of presenting our methodological approach; it was as follows: first, we did an analysis of our needs with the definition of our systems; then from this definition flowed the conceptual, physical and logical modeling of our data by following the formalism of MERISE (which consists in analyzing, designing and creating geographic information systems); after the modeling we have processed it and imported our spatial data under PostgreSQL; from this then flowed the cartography of the road projects, then the configuration of our Cartographic servers; and the design of the Webmapping tool finally we published our maps online with GeoServer.

In the results, we presented our webGeo tool (its functionalities, its interface, the different tabs and the tools). Finally, to complete this part, we made analyzes on our database as well as on the tool by showing the advantages which it could bring in the realization of the projects.

Declarations

Conflicts of interest

The authors declare no conflict of interest.

Funding Statement

Administrative authorization

Author contributions

WOUNBA Jean François, contributed to the design of the study
NOUMBOUH SEGNOU Ramatou contributed to the collection, analysis, data processing and writing of the manuscript
NOUMBOUH SEGNOU Ramatou and TCHIO POKAM Jude Desmond contributed to the development of webGeo
MVONDO FANGA Aubin Loïc and TCHIO POKAM Jude Desmond contributed to the critical reading and improvement
All authors have read and approved the final version of the manuscript.

Acknowledgment

What we know about this subject

In most structures, the work data is not archived in a web server, which makes it impossible to access this data remotely and to effectively monitor the progress of the work, and yet the latter can also be beneficial in carrying out the future projects.

What webGeo brings

- Digital archiving, monitoring and data security of road projects.
- Remote access to work data by the actors

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