Contribution of Remote Sensing and Geographic Information System in the Feasibility Study of an Oil Exploration Project in Democratic Republic of Congo: Case of the Mavuma Block in the Coastal Basin

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Abstract:- This study focuses on the application of digital processing of satellite images in the feasibility study of an oil exploration project in the southern part of the Mavuma oil block in the Democratic Republic of Congo. This area remains virtually unexplored despite confirmed oil seeps and huge tar sand potential. On this, we used SRTM images with a spatial resolution of 30 m and other shapefile type data from multiple sources that were integrated into a Geographic Information System to better understand the geomorphological and hydrographic characteristics exploration area. The processing of all this collected data allowed us to generate Digital Elevation Models, hydrographic modeling as well as measurement points for a geophysical and/or a geochemical survey arranged taking into account the geomorphological characteristics of the study area. The maps of the classification of measurement points produced at the end of this work indicated that 55.7% of the stations are located in the noisy zone, which is a region with several asperities on the geomorphological level covering almostthe entire eastern and northern part of our study area, and 20% of the stations are located along watercourses. However, this state of affairs will not be an obstacle for field measurements because the DEM has shown us that there would be low altimetric variability within our study area. This would therefore be favorable to the implementation of a ground survey in this region. Thirty days during the dry season and three teams of fiveagents will be needed to carry out data acquisition work in the field.

Keywords:- *Satellite images, Digital Elevation Model, Oil exploration, Mavuma block, DR Congo.*

I. INTRODUCTION

Located in the province of Kongo Central in the Democratic Republic of Congo, the Mavuma block is an integral part of the coastal basin of the Atlantic Ocean whose geophysical and geochemical database remains poor. This situation is detrimental to the oil promotion of the said block with a view to the granting of oil exploration permits because oil contractors are attracted to a block by the volume and quality of the data acquired during exploration work. It should also be noted that, except for a few reconnaissance campaigns on the ground, which led to the confirmation of the oil seeps located within it (05°29'50.7" S; 12°44'26.0" E, etc.) and enormous potential in tar sand, the oil database of the Mavuma block remains poor. In this context, a method based on the computer processing of SRTM-type satellite images in a Geographic Information System (GIS) was applied with the aim of developing a project for the acquisition of gravity and magnetic or geochemical data in the southern part of the Mavuma oil block. This method has been widely used by the geo scientific community for the past twenty years in the planning of geological, geochemical and geophysical campaigns in oil and mining exploration.

II. METHOD AND MATERIALS

The SRTM images used in this work have a resolution of 30 m and were downloaded using the Global Mapper software on April 13, 2022 from the earthexplorer.usgs.gov site. Starting from the fact that the power of a GIS lies in its ability to store, analyze and process several types of spatial databases that represent geographic information (Antoine Denis, 2016), in addition to satellite images, several types of shape file data from multiple sources have been integrated to better understand the geographic features of the study area. The analysis of this database in a GIS enabled us to achieve:

- Digital Elevation Models in 2D and 3D;
- Hydrographic modeling;

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- Generate geophysical/geochemical measurement points arranged taking into account the geomorphological characteristics of the study area;
- Define the different routes of the different teams on the ground.

To carry out this work, we used the following software:

- ArcGis: for geoprocessing operations, the production of various maps (slopes, HillShade, 2D, 3D DEM, etc.);
- Surfer: for the interpolation of spatial data;
- Global Mapper: for downloading SRTM satellite images with a spatial resolution of 30 m.

III. DESCRIPTION OF THE STUDY AREA

A. HUMAN DESCRIPTION

Our prospecting area is located in the territories of Lukula and Muanda. It is therefore entirely located in the Mayombe region located in the Kongo-Central province in DR Congo. Here are some descriptions of its human characteristics (CAID, 2016):

- **Demography:** the population of the territory of Lukula is estimated at 263,538 inhabitants;
- **Main ethnic groups:** the area is mainly occupied by the Yombé tribe;
- **Diet:** the dish most consumed in this region of Mayombe is fresh cassava or in the form of Chikwangue, accompanied by pondu, beans or mfumbwa with smoked fish;
- **Health situation:** the territory of Lukula includes a General Reference Hospital as well as several health centers. It should be noted that the most recurrent diseases in this area are: malaria, respiratory tract infections, typhoid fever, arterial hypertension and HIV;
- **Security situation:** the study area is currently calm.
- **Source of energy:** embers and kerosene for lamps: used in the villages; Electricity in large cities.
- **Road infrastructure:** mostly dirt roads.

B. BIOPHYSICAL DESCRIPTION

Entirely located in Kongo-Central precisely in the territories of Lukula and Muanda, the Mavuma Block is an integral part of the coastal basin. The study covers the southern part of the Mavuma Block which is rich in oil seeps and tar sands. Our exploration area covers an area of 492 km^2, and is between 12°38' and 12°48' East longitude, and between 5°40' and 5°23' South latitude (fig.1).

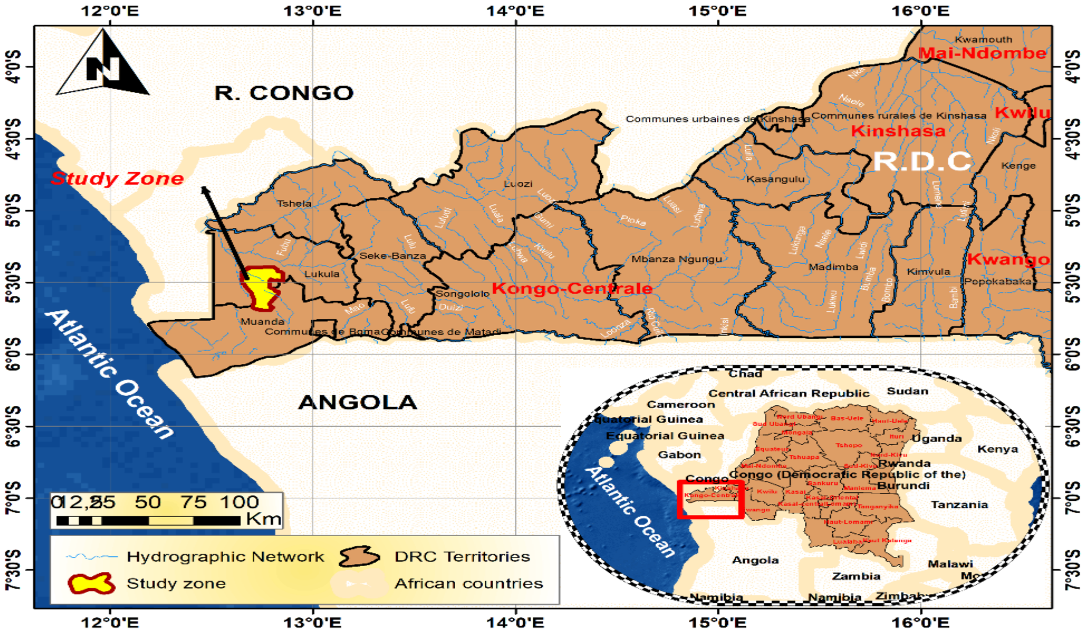

Fig. 1: Location of the prospecting area

The area is located south of the equator in an equatorial climatic zone with an oceanic influence and has two main seasons: the rainy season and the dry season. The great dry season, from June to September, is not felt as clearly as in the rest of Kongo-Central because of the altitude and as a result of the influence of the forest. Temperatures range from 17 to 22°C, but can drop to 15°C.

The dense forest with varied forest species, sometimes dotted with savannas dominate and characterize the appearance of this area. The area is watered by many fast and violent rivers that flow through these regions. The three most important rivers are: the Shiloango River and two of its main tributaries: The Lukula and the Lubuzi.

IV. PETROLEUM INTEREST IN THE STUDY AREA

The Mavuma oil block is located in the coastal basin which is to date the only sedimentary basin producing hydrocarbons in the DRC. It is close to the Nganzi, Lotshi, Yema, Ndunda and Matamba-Makanzi oil blocks and has several oil seeps (fig.2).

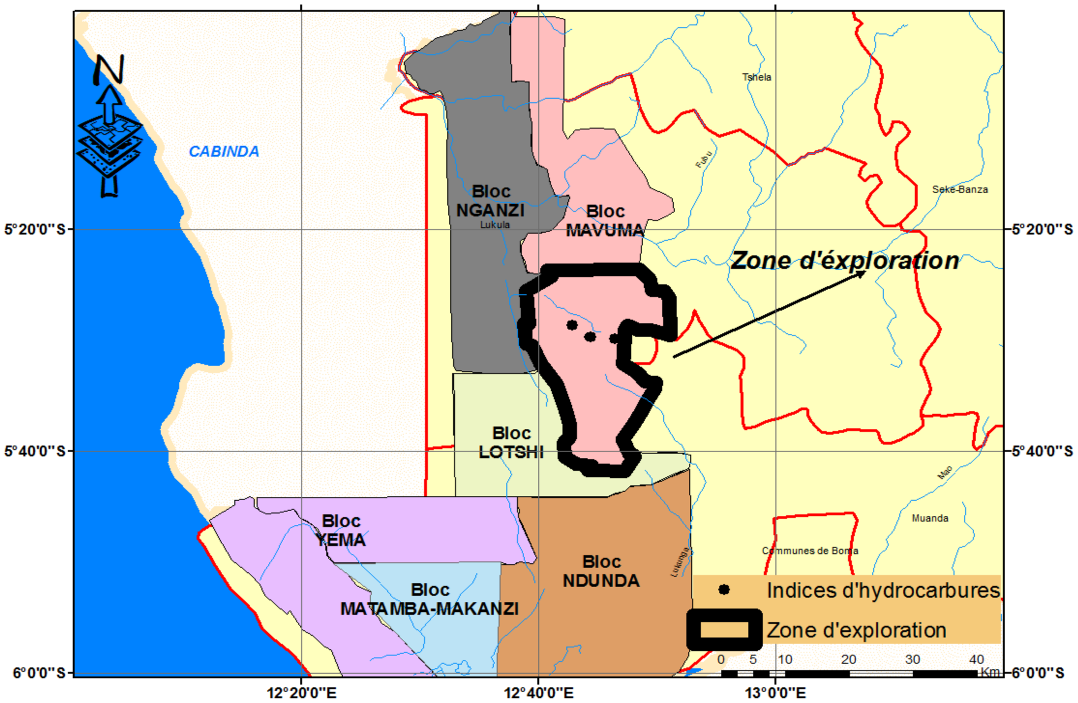

Fig. 2: Study location among the blocks of the coastal basin.

Several surface indices (tar sands, seeps of liquid hydrocarbons, rocks completely impregnated with hydrocarbons, etc.) (fig. 3) were observed during our descent on the ground in our study area, which clearly provide it with a capital gain.

Fig. 3: Hydrocarbon indices in the study area (Mavuma block): (1) Bitumen seepage; (2) A non-impregnated original rock (a), overlying the impregnated part (b); (3) Sample of sandstone impregnated with hydrocarbons; (4) Limestone horizon in a sandstone formation impregnated with hydrocarbons

V. DATA PROCESSING AND RESULTS

SRTM data are images from topographic satellites obtained by the ‘Shuttle Radar Topography Mission’ radar system. An SRTM image database is available at earthexplorer.usgs.gov. The SRTM image used in this work have a resolution of 30 m and was downloaded using the Global Mapper software on April 13, 2022. They are used for the generation of the Digital Elevation Models and the automatic extraction of the hydrographic network in this region. The following figure 4 shows us the SRTM images downloaded using the Global Mapper software.

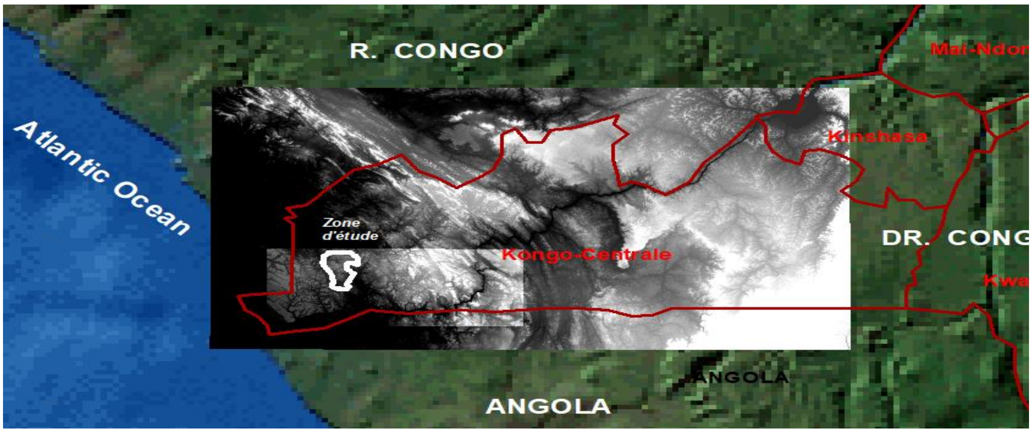

Fig. 4: Raw SRTM images of the study area downloaded via Global Mapper on 04/13/2022 (Source: earthexplorer.usgs.gov)

From the SRTM satellite images, we produced Digital Elevation Models (DEM) to have a fairly precise image of the geomorphology of the study area. Indeed, a DEM corresponds to a representation in digital form of the relief of a geographical area. This model can be composed of point vector entities (side points), linear (level curves), surface (facets) or represented in raster mode (cells) (J-P. Cherel, 2010). At this stage, we used the Spatial Analyst, 3D Analyst Tool and ArcScene extensions of the ArcGis software to produce DEMs. The steps are as follows:

- Extraction of the scene from the satellite image of our study area from the downloaded 30 m SRTM image;
- Apply shaded relief (Hillshade) and slope calculationfilters to better visualize the different geomorphological contrasts encountered in this region;
- Create maps of contours and colors to better analyze the variation in altitude in our study area;
- Import the results on ArcScene which offers a very dynamic 3D view.

Figure 5 below shows us the slope and hillshade maps of our study area with the contours of what we call 'the noisy zone'.

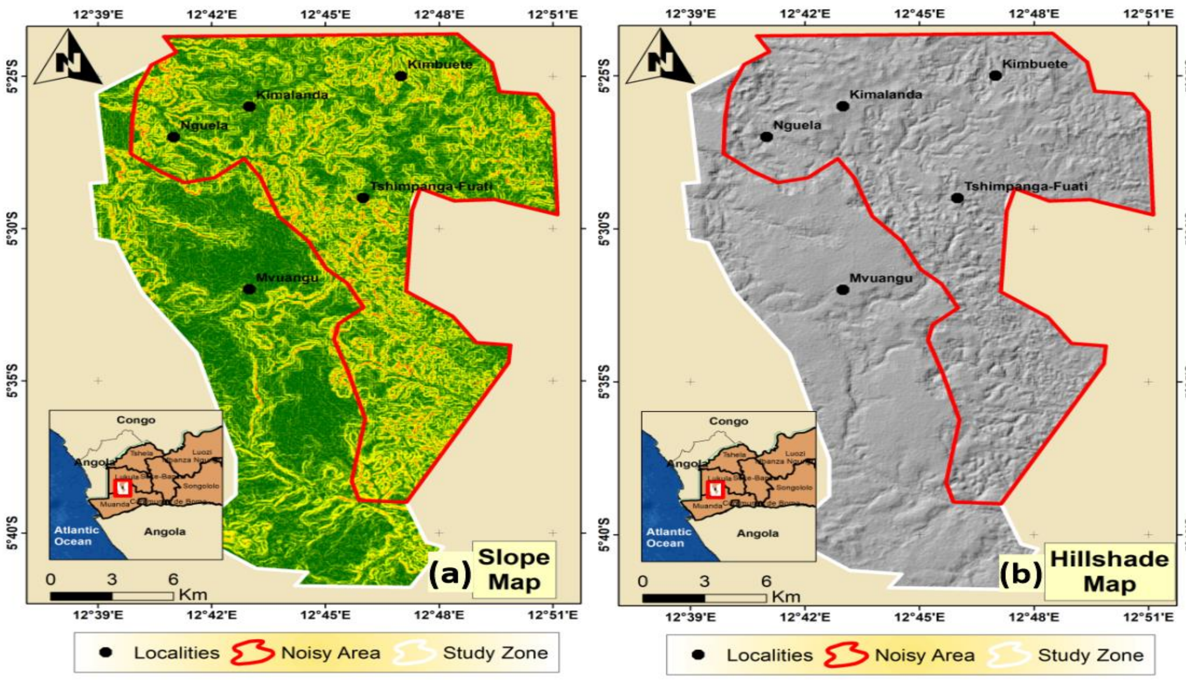

Fig. 5: (a)Slopemap; (b) Hillshade map

The noisy zone perfectly visible on the two maps above is a region with several geomorphological asperities covering almost the entire eastern and northern part of our study area. There are rapid variations of peaks and troughs on the slope map (fig. 5a) as well as an undulating relief compared to the western part of this zone (fig. 5b). Ground exploration can be difficult because of the somewhat rugged terrain in this area. From the SRTM satellite image, we carried out an unsupervised classification of the image based on the variation in altitude as a function of longitude and latitude. This allowed us to generate a DEM to have a fairly precise image of the geomorphology of the study area (fig. 6).

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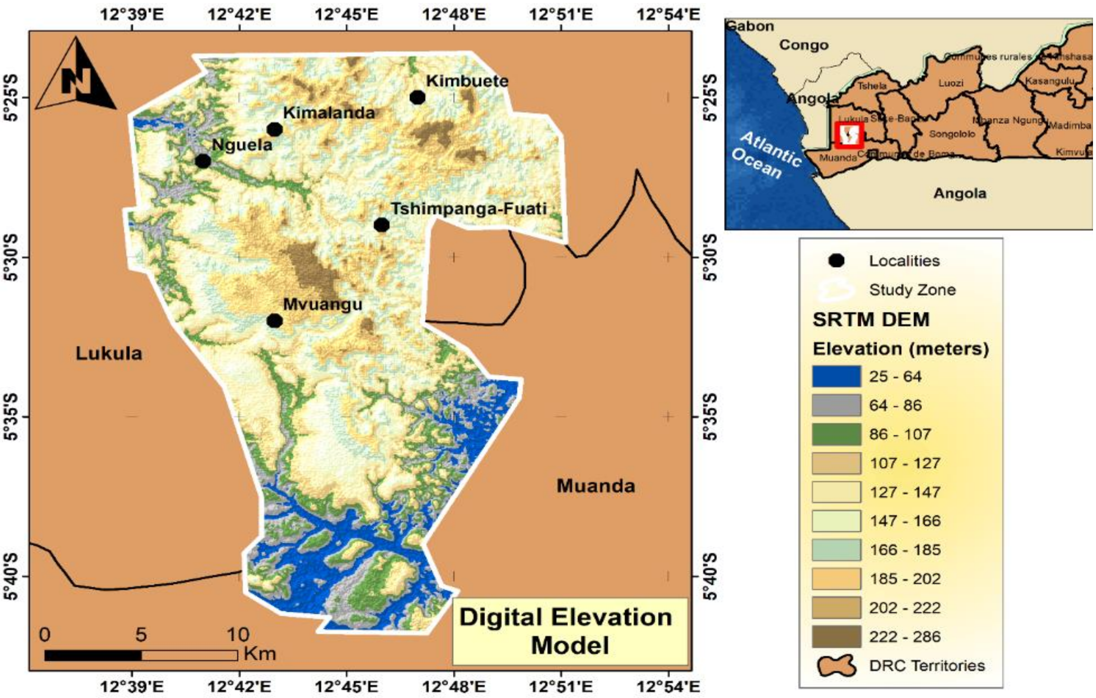

Fig. 6: Digital Elevation Model of the study area

This DEM shows us that the geomorphological variability observed is representative of the relief observed in this region. The altitudes vary decreasingly from north to south, an area approaching the low plains of the mouth of the Congo River. The lowest altitudes (from 25 to 86 m) are logically observed to the south of this zone in the territory of Muanda. Altitude peaks (202 to 286 m) are observed near the villages of Mvuangu in the center as well as Kimalanda and Kinvuete in the territory of Lukula to the north of this area. This DEM shows us a low altimetric variability within our study area. This state of affairs would favor the implementation of a ground survey in this region, including in the noisy zone.

Using the 'hydrology' algorithm of the ArcGIS software, we were able to extract the hydrographic network of our study area from the SRTM image (fig. 7).

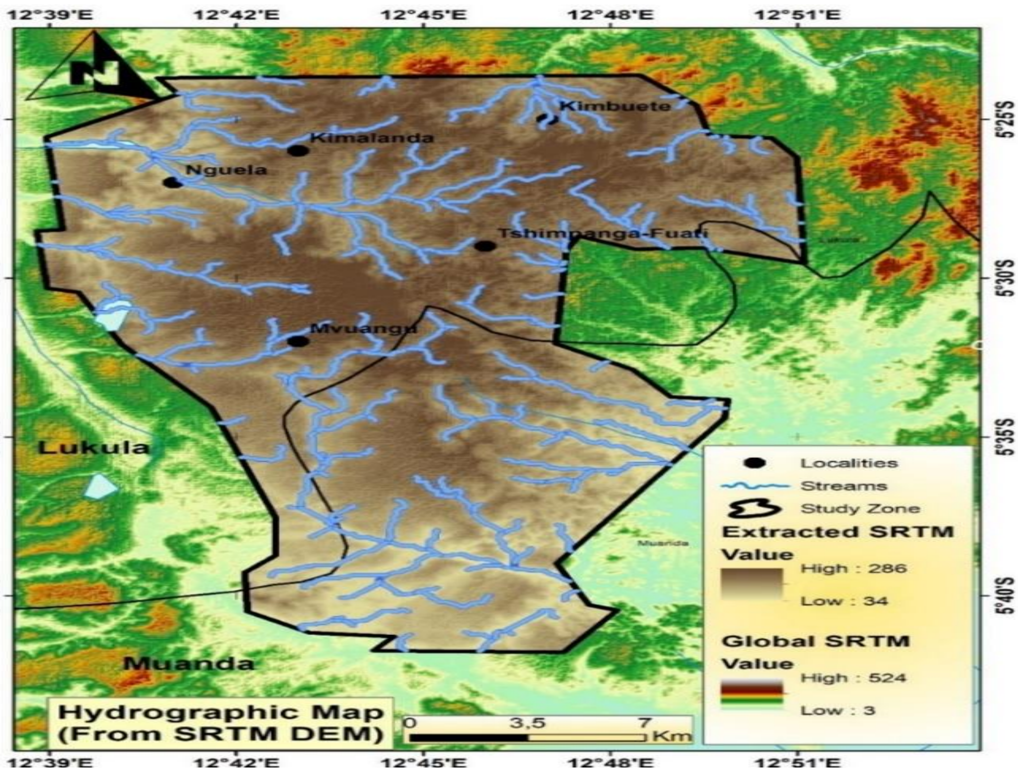

Fig. 7: Map of the hydrographic network extracted from the study area

The configuration of the hydrographic network is closely linked to the geomorphological nature of the environment. The map above shows us that the study area is crossed by several rivers which have their sources on the hills and flow towards the south-east for the most part. Knowledge of the hydrographic network is very important when implementing a terrestrial survey because the teams on the ground can decide to follow the watercourses or not for sampling or taking measurements. It should also be noted that the study of the spatial distribution of the hydrographic network reveals specific adaptations. These particular alignments form the hydrographic lineaments and reflect a disturbing geological reality of the network: passage of a fault, presence of a hard seam bank or oriented lithological particularities (Moore 1983).

We draped the generated stream network over the DEM. This draping makes it possible to see in three dimensions how these rivers flow thanks to the property of SRTM images to show hills and valleys (fig. 8).

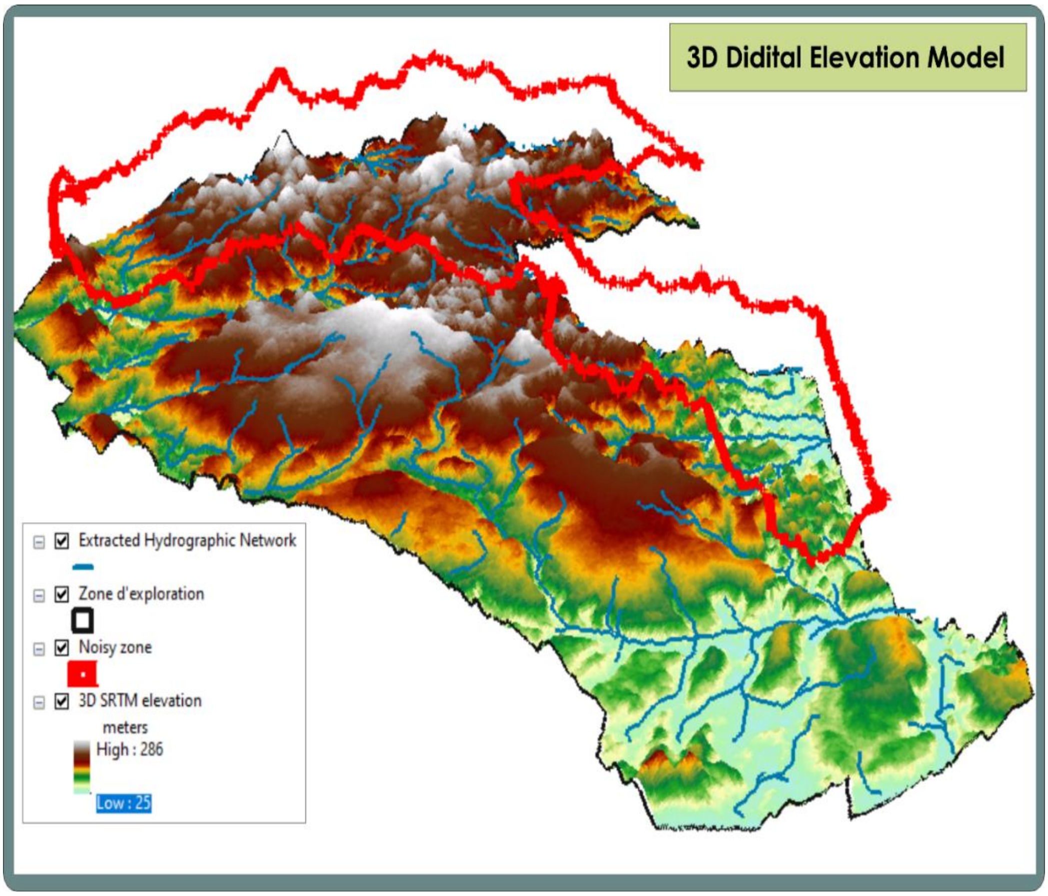

Fig. 8: Draping of the hydrographic network on the 3D DEM

VI. APPLICATION TO THE PLANNING OF A GEOPHYSICAL/GEOCHEMICAL SURVEY IN THE STUDY AREA

In this part of the work, we apply the results of the various analyzes carried out in the previous point for the planning of a geophysical (gravity or magnetic) and/or geochemical survey in the southern part of the Mavuma block. This involves planning the grid of the survey, the different routes to be traveled as well as the distribution of tasks to be assigned to the different survey teams. It should be noted that ground surveys are carried out according to a plan duly elaborated in the office.

A. MEASUREMENT GRID

The measurement grid can be defined as the spatial arrangement of measurement stations or observation points/profiles of a quantity and/or a physical, chemical, geological or geographical parameter of a given area. The grid of measures that we adopt within the framework of this project is a function, like all kinds of data acquisition, of the realities on the ground: geomorphology, limits of the study region, accessibility of the region, the hydrographic network, etc. Thus, we generated measurement stations with regular spacing. Figure 9 below illustrates the base map that operators will need to follow to complete the survey.

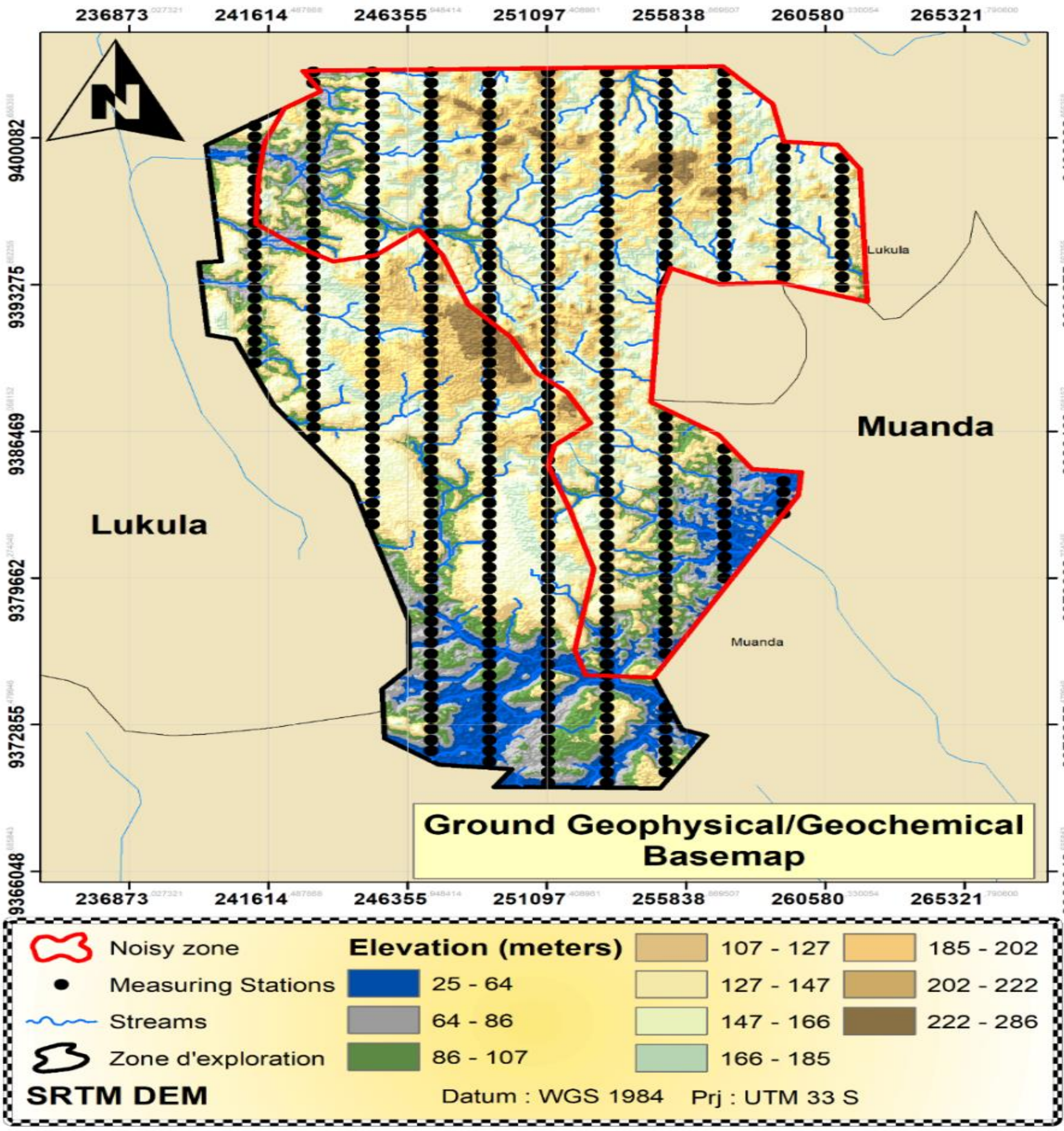

Fig. 9: Survey basemap

The figure above shows the following:

- The extent of the study area is 492 km^2;
- The number of generated stations is 475;
- The equidistance between 2 contiguous lines is 2 km, while thatbetween 2 contiguous stations on the same line is 500 m;
- There are 14 lines of varying length and whose direction is oriented north-south.

Thus, by using the data mentioned in the previous paragraph, in this case the equidistance of 500 meters between the stations and 2 kilometers between the lines as well as the geographical limits of our study region, we will be able to generate the projected coordinates of the automatic measurement stations by choosing the Datum: Word Geodetic System 1984 and the Projection: UTM 33 South. The points were superimposed on the DEM, which allowed us to have the elevation of each measurement station. A sample of generated measurement stations is shown in Table 1 below.

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Table 1: Sample of generated measurement stations

Measuring Stations

FID	Shape	Id	Elevation_m	X	Y
0	Point	0	76	243155	9403147
1	Point	0	94	245155	9403147
2	Point	0	193	247155	9403147
3	Point	0	174	249155	9403147
4	Point	0	278	251155	9403147
5	Point	0	142	253155	9403147
6	Point	0	155	255155	9403147
7	Point	0	186	257155	9403147
8	Point	0	96	243155	9402647
9	Point	0	142	245155	9402647
10	Point	0	168	247155	9402647
11	Point	0	162	249155	9402647
12	Point	0	208	251155	9402647
13	Point	0	113	253155	9402647
14	Point	0	123	255155	9402647
15	Point	0	181	257155	9402647
16	Point	0	126	245155	9402147
17	Point	0	192	247155	9402147
18	Point	0	172	249155	9402147
19	Point	0	230	251155	9402147
20	Point	0	149	253155	9402147
21	Point	0	150	255155	9402147
22	Point	0	162	257155	9402147
23	Point	0	96	243155	9401647
24	Point	0	141	245155	9401647
25	Point	0	191	247155	9401647
26	Point	0	201	249155	9401647
27	Point	0	176	251155	9401647

475 (0 out of 475 Selected)

Measuring Stations

Based on the data in the table above, we have classified the measurement stations according to the spatial distribution of the rivers in the region and the noisy zone (fig. 10).

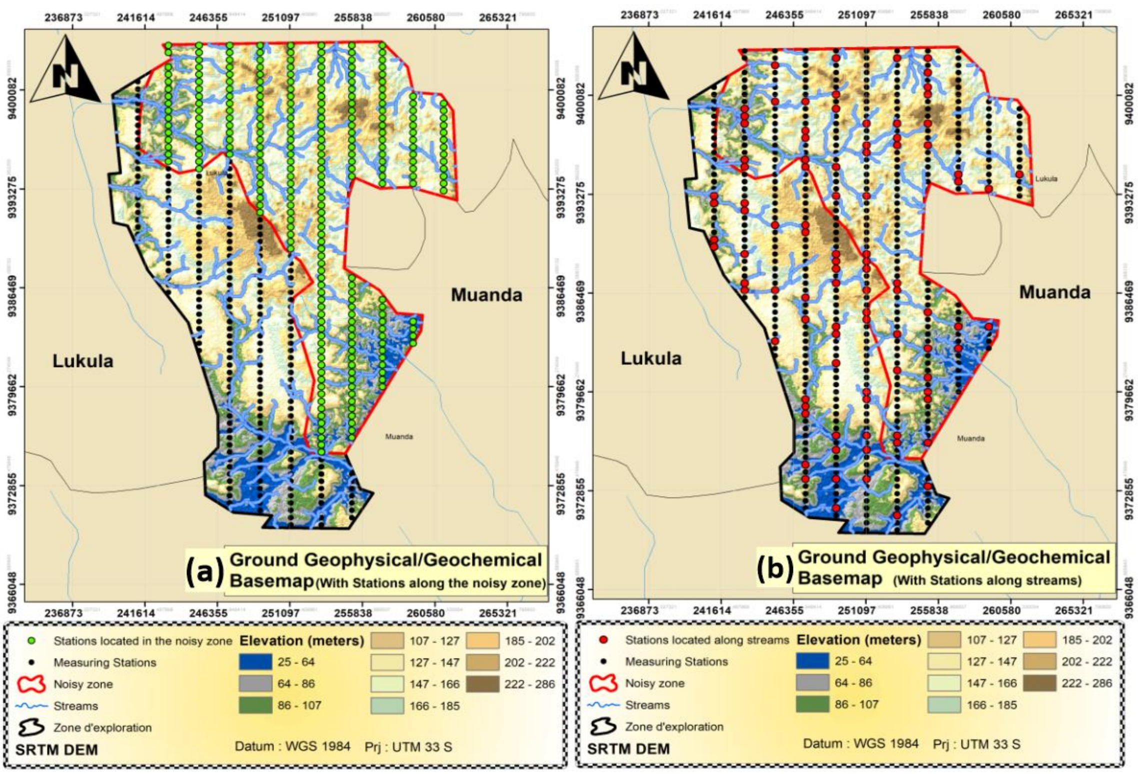

Fig. 10: Maps of the classification of measurement points: (a) According to the noisy zone; (b) Depending on the hydrographic network of the study area

The measurement point classification maps above tell us that:

- 265 stations out of 475, or 55.7% of stations are located in the noisy zone and;
- 95 stations out of 475, or 20% of stations are located along watercourses.

It should be noted that this state of affairs will not be an obstacle for field measurements because the DEM in Figure 6 showed us that there would be low altimetric variability within our study area. This state of affairs would therefore be favorable to the implementation of a terrestrial survey in this region, including in the noisy zone.

B. CALENDAR OF ACTIVITIES

The International Association of Geophysical Societies (IAGS) strongly recommends taking into account certain criteria before any geophysical campaign. In this case the time of year, the regulations in force, the nature of the operations, the socio-cultural heritage, the fauna and flora, as well as the emergency system. According to the climatology of our study area, the favorable time of year to carry out this campaign is the dry season. 30 days will be required to carry out the acquisition work on the ground.

C. DISTRIBUTION OF TASKS AND DEFINITION OF ROUTES

Let us subdivide the study region into 2 subsets X and Y (fig. 11) each subset of which has an average width of approximately 16.5 km. Let us again subdivide subset X into 3 subsets A, B and C, each of which has a width of approximately 5.5 km. Figure 12 defines, for illustrative purposes, the routes that the three teams (Teams 1, 2 and 3) will follow at the time of data acquisition. Note that teams 1 and 2 will be under the supervision of the head of mission while team 3 will be under the supervision of the deputy head of mission and note that all 3 teams will follow almost identical routes.

Fig. 11: Subdivision of the study area into two parts for the definition of routes

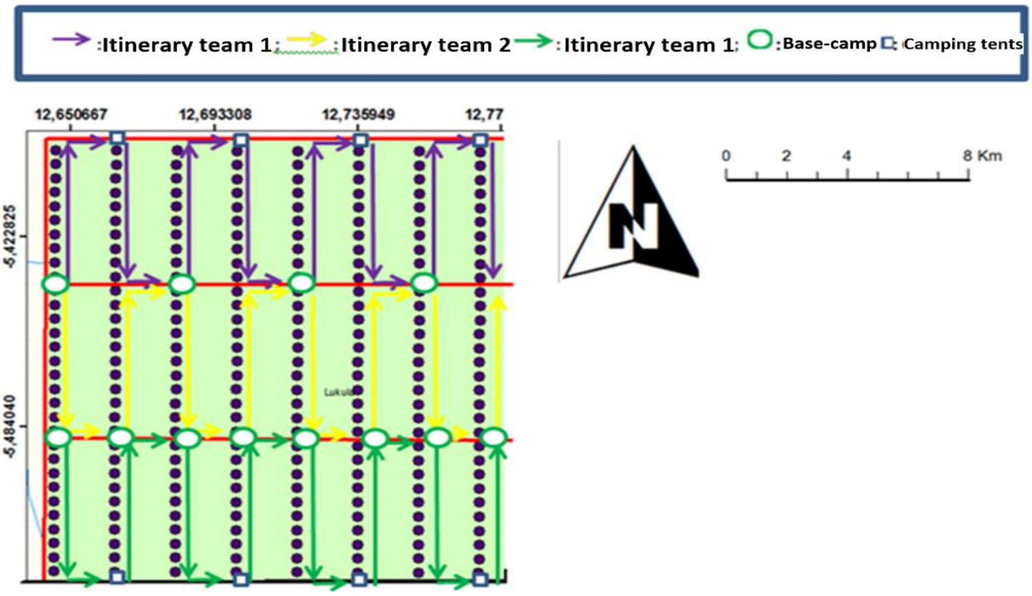

Fig. 12: Route definition

The routes illustrated in the figures above as well as the distribution of tasks are responsibilities assigned to the principal head of mission as well as to his deputy, knowing that the latter performs almost the same functions as his incumbent. From the above, the two head of mission will be responsible for leading the 3 teams (2 teams for the head of mission and 1 team for the deputy head of mission) of five people each. These teams will be made up of four survey operators for taking measurements and using the GPS and a peon. One of the survey operators will be responsible for leading this newly formed team. Equipped with survey tools (Gravimeter, GPS, Compass, etc.), station by station on foot, the various teams will cover the entire study area in accordance with the plan.

With the means of communication placed at their disposal (THURAYA satellite telephone, walkie-talkie), the heads of mission remaining at the base camp will transmit the injunctions to their subordinates, and will receive from them substantial information. Communication between explorers in the field is therefore a way for heads of missions and operators to know the progress of the campaign in real time. This involves transmitting technical and security information to each other in order to take appropriate measures.

VII. CONCLUSION

The objective of this work was to carry out a feasibility study of an oil exploration project in the Mavuma block in DR Congo based on remote sensing and Geographic Information System methods. We used the Global Mapper software to download the SRTM image as well as the Spatial Analyst, 3D Analyst Tool and ArcScene extensions of the ArcGis software to produce DEMs. Using the 'hydrology' algorithm, we were able to extract the hydrographic network of our study area from the SRTM image. The slope and hillshade maps of our study area allowed us to define the contours of what we call 'the noisy zone'. The latter is a region with several geomorphological asperities covering almost the entire eastern and northern part of our study area. There are rapid variations of peaks and troughs on the slope map as well as an undulating relief compared to the western part of this area. Terrestrial exploration can bedifficult because of the somewhat rugged terrain in this area, however, the low altitudes and low altimetric variability within our study area would favor the implementation of a terrestrial surveyin this region including in the noisy zone. At the end of this study, we generated 475 measurement stations automatically by choosing an equidistance of 2 km between 2 contiguous lines and 500 mbetween 2 contiguous stations of the same line. The measurement point classification maps indicate that 55.7% of the stations are located in the noisy zone and 20% of the stations are located along waterways. The best time of year to carry out this campaign is the dry season and 30 days will be needed to carry out the acquisition work on the ground. Three teams made up of four survey operators for taking measurements and using GPS and a peon will be needed to carry out this campaign. Equipped with survey tools, station by station on foot, the various teams will cover the entire study area in accordance with the plan.

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