Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 08, Issue, 12, pp.7073-7082, December, 2017

RESEARCH ARTICLE

ROLE OF REMOTE SENSING AND GEOPHYSICS TO DETERMINE POTENTIAL SITES FOR BOREHOLES IN THE CRYSTALLINE BASEMENT OF THE WADI FIRA REGION: CASE STUDY OF IRIBA

[1]MASSING Oursingbé, [1]ADOUM Issak, [1,2,*]ABDERAMANE Hamit and [3]DINGAMNODJI Ndingané

[1]Department of Geology, Faculty of Exact and Applied Sciences, University of N'djamena, P. O. Box 1027
[2]National Higher Institute of Livestock, Moussoro
[3]Ministry of Water and Sanitation, Documentation and Geographic Information Centre

ARTICLE INFO

Article History:
Received 28th September, 2017
Received in revised form
26th October, 2017
Accepted 04th November, 2017
Published online 30th December, 2017

Key words:
Basement,
Underground Water,
Remote Sensing, Electrical Sounding,
Lineaments, Iriba.

ABSTRACT

The extraction of groundwater from the basement is one of the best methods of water supply to populations. Actually, the aquifers of the cracked basement are excellent water reservoirs in the area of Iriba. The objective of this study is to determine the potential sites of boreholes, which are likely to provide appropriate discharges in the area of Iriba. The combination of remote sensing and geophysical methods constitutes the methodology used in this study. In this vein, we designed a map portraying the morphological and structural alignments, which highlighted some lineaments of which major directions include NS, NE-SW, EW and NW-SE. In a bid to better characterise these locations, we undertook a geophysical study totalling 22 vertical electrical soundings (SEV) broken down into 18 electrical profiles from different directions. This study enabled to enhance the knowledge of the underground geological structure for water supply in 11 villages of the study area. It further proved that the geological structures present different depths due to the tectonics.

INTRODUCTION

The availability of potable water is essential for the smooth development of any country. The Chadian government and its development partners consider potable water as a top priority and a challenge to address in the upcoming years. Just like other regions of Chad, the Wadi Fira Region faces some difficulties in terms of accessibility to underground water resources. Specifically, the area of Iriba has a complex geology, which comprises discontinuous aquifers of the crystalline basement, unfavourable climate conditions and low rainfall level. In addition, against a backdrop of climate change noticed by unstable rainfall, the scarcity of water resources in this region will hamper growth and economic development. To overcome the above-mentioned challenges, the Ministry of Water and Sanitation was granted funds by the Economic and Social Development Agency (ADES) to determine the potential sites of boreholes in Iriba. This study required the use of remote sensing and geophysical methods to identify the areas which are adapted to the construction of boreholes.

Corresponding author: **ABDERAMANE Hamit,**
[1]Department of Geology, Faculty of Exact and Applied Sciences, University of N'djamena, P. O. Box 1027.
[2]National Higher Institute of Livestock, Moussoro.

Indeed, the knowledge of the fractures network, which constitutes the major underground runoffs, is key to research works on underground waters (Lasm, 2000; Youan *et al.*, 2008; Ngo *et al.*, 2010; Yao *et al.*, 2012). The geophysical prospecting through the use of electrical methods complements studies conducted by satellite imaging. It enables to determine the exact location of the tectonic discontinuity and the hydrogeological areas of interest (Youan *et al.*, 2008). The general objective of this study is to contribute to the increase of water supply in the area by optimising the potential sites of boreholes in the crystalline basement through the mapping of fractures networks coupled with geophysics.

Geographical and geological features of Iriba

The study area is located in the tropical Sahel strip and presents a dry continental climate. It depends on the administrative Division of Kobé and the Region of Wadi-Fira of which headquarter is Biltine (Fig.1). The annual rainfall level is close to 450 mm in the southern part and 150mm in the northern part of the Region. The rainy season usually runs from July to September with brief and intense precipitations. The vegetation of the area comprises the shrub and herbaceous steppe (*acacias sp* and *Aristida)*, which covers the major part of the region.

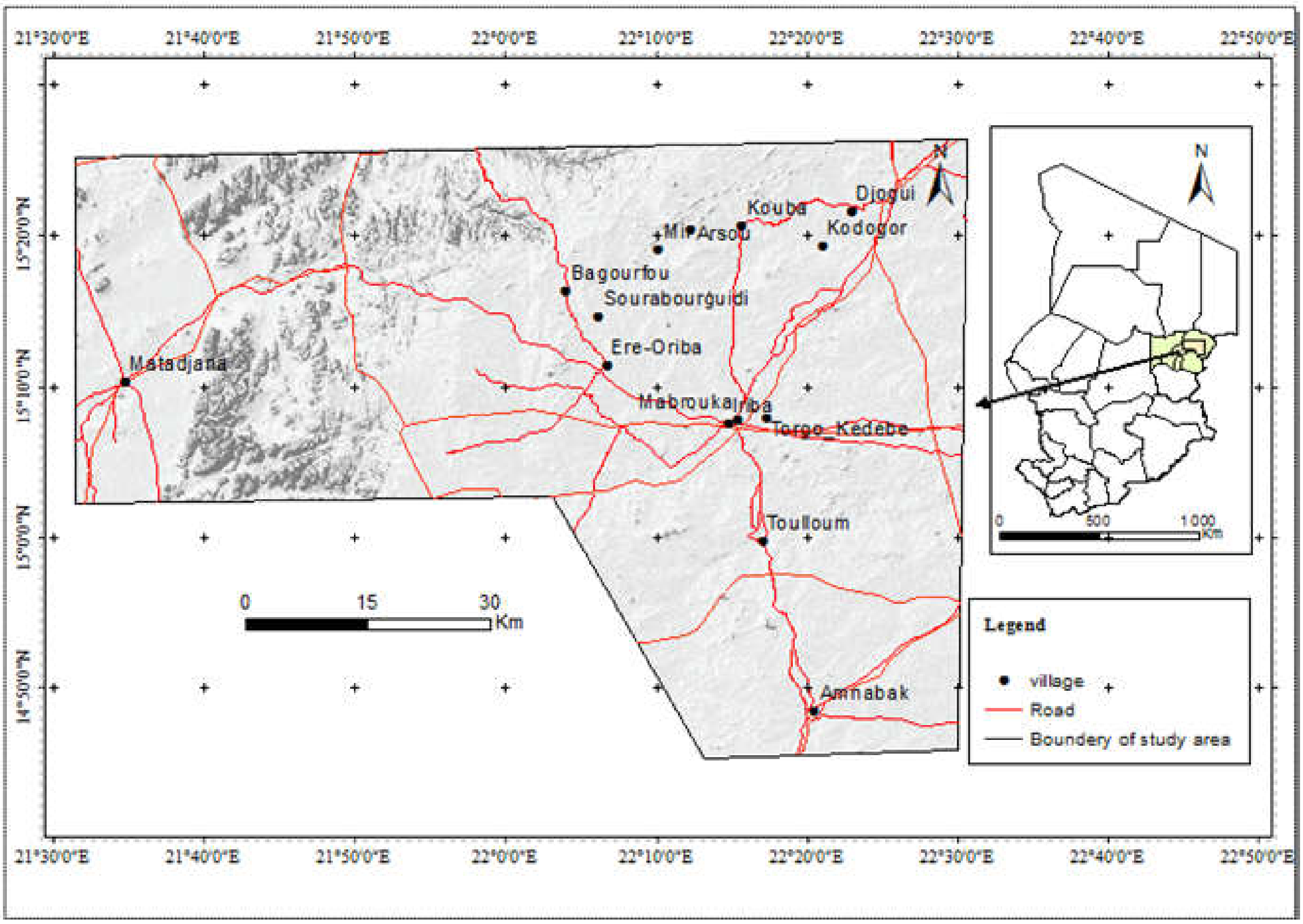

Figure 1: Index map sheet of the study area

This vegetation homogeneity is attributed to the nature of soil and topography, which present ouaddis in the entire region. The morphology of the relief ranges between 403 and 1,054m elevation. It includes plains, plateaus, small mountains and many sub-basins drained by seasonal watercourses. The hydrographic network of this part of Chad is fully complex (Fig.2) in the small mountains and piedmont plains. This network is formed by intermittent ouaddis which flow towards the southern part of the Region from July to October. This runoff reduces as one gets closer to more desert latitudes.

There are two geological eras in the Wadi Fira Region: (i) the Precambrian era composed of the granitic basement, which is mostly altered; (ii) the quaternary era composed of sandy and argillous alluvions, which rely on a granitic substratum. The geological formations are intruded rocks of the Precambrian period , which include, inter alia, the calc-alkaline granites, the amphiboles and quartz diorites, which are closely interconnected (Marc-André and Yves, 2005 ; Gachet and Foreste, 2005). At the hydrogeological level, the Wadi Fira Region does not contain a generalised water table. The hydraulic resources are connected with alluvions, alterites and cracked and/or fractured rocks. This refers to aquifers of which potential productivity is high and formations of which productivity is low or null. The major aquifers of which productivity is high are divided into: (i) Cover aquifers, alluvions and river sand. Actually, the ouaddis which are seasonal watercourses provide water to the endoreic water tables located in arid regions; this represents a precious and renewable water resource.

These gradational deposits which are found in the beds of ouaddis are huge sediments such as gravels and sand. They are very porous and enable the recharge and storage of huge quantities of water. (ii) Cambrian continental aquifers containing huge water quantities which flow while in touch with the sandstone basement along the fractures. The low or null productivity formations comprise: (i) the cover series and ancient eolian deposits. Actually, the heterogeneous sands include ancient dune formations coming from erosion and sedimentation of allothogenic matters, which appear as oriented strips ENE-WSW which fall in the ancient valleys. These formations are locally referred to as ''goz'' and have a low storage potential of annual rain water; (ii) the volcanic series which contain light basalt flows of the Miocene Period (Marc-André and Yves, 2005). These basalts have a low water potential. However, the availability of some traditional wells proves that the fractured areas can contain significant water resources which often receive water from the ouaddis beds; (iii) the continental terminal constituted of sandstone flaps which were argillous in the past.

Equipment and methods

Equipment

As part of this study, two types of data were used: (i) data from remote sensing through the analysis and interpretation of satellite images; (ii) geophysical data through the field prospecting. For this study, two scenes (LC81800492016300LGN00.tar; LC81800502016076LGN00) of the satellite Landsat-8, acquired respectively on the 16th March 2016 and 29th March 2016 were used.

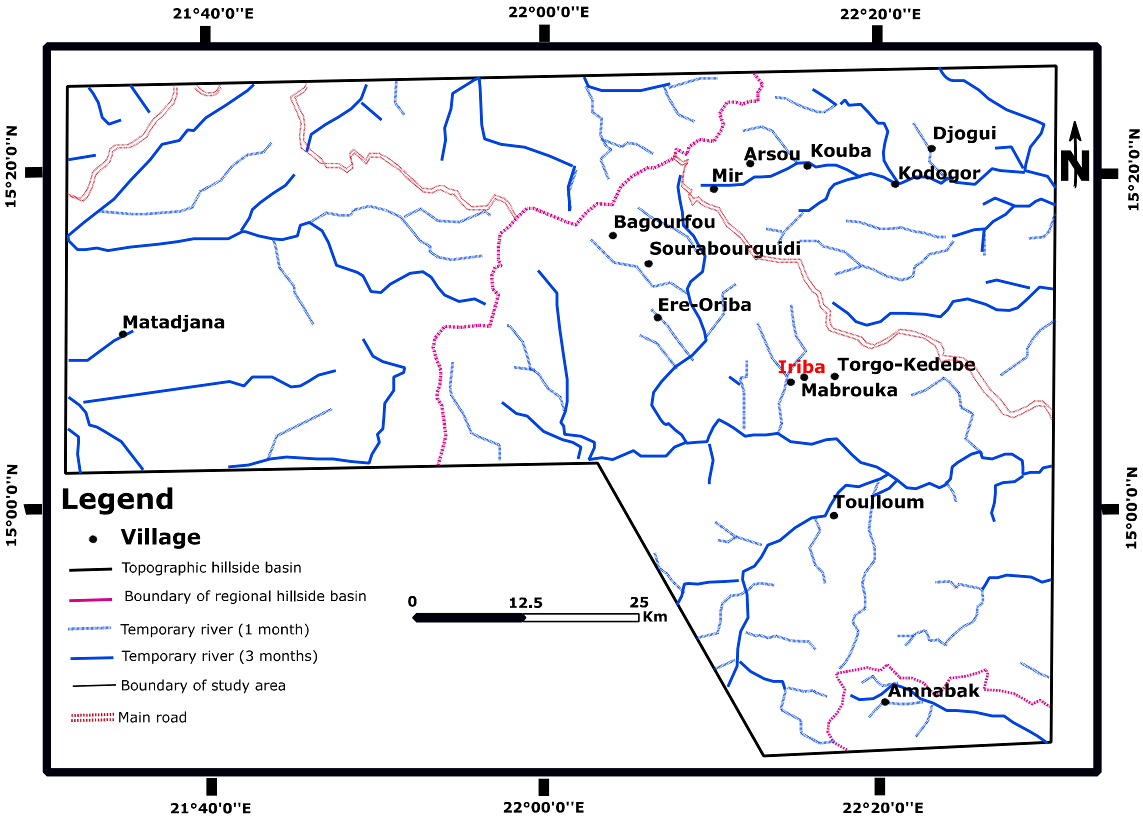

Figure 2. Map of the hydrographic network of the study area

In addition, the scale 1/200,000 topographic, geological and pedologic maps were processed. The fact sheets of ancient boreholes containing information on the static levels, air-lift discharges and depths of boreholes were also used. The acquisition material of geophysical data used in this study is composed of a type Syscal R1 resistivity meter and accessories (connecting coils, electrodes, double decametre, hammers and compasses, GPS, etc.). The data processing material comprises mapping software programmes (QGIS 2.8.2, PCI Geomatica 9.1), for image processing (Envi 5.1) and geophysical processing (WinSev6.3, Ipi2win, IX1Dv3).

MATERIALS AND METHODS

The remote sensing and electric resistivity method greatly contribute to the identification of alteration areas, faults, disharmonic folds which are likely to contain water in the rocks. Indeed, the identification of potential sites for the construction of boreholes in the basement area requires accurate and precise structural maps. The families of discontinuity are defined by their direction, openness, persistence, density as well as their geological origin (Rey, 2007). The study of the fracturing is essential and consists in understanding the hydrogeological functioning of the discontinuous aquifers (Bonn and Rochon, 1992). This is why the remote sensing and geophysics were used as identification tools of potential areas for the construction of boreholes in Iriba.

Mapping of lineament structures by remote sensing

Several hydrogeological studies were conducted in the basement using the remote sensing techniques (Savané *et al.*, 1997; Savané and Biémi, 1998; Kouamé *et al.*, 1999; Ta *et al.*, 2008; Ngo *et al.*, 2010; Koita, 2010; Koita *et al.*, 2010; Kouamé *et al.*, 2010; Koussoubé *et al.*, 2003).

These studies mostly aimed at proposing the characterisation methodology of tectonic accidents and the determination of their role in the underground runoffs. These studies target the identification and characterisation of lineaments on the satellite images. Actually, according to (Chapellier, 2000), the study of lineament has two objectives: (i) the definition of the exploratory programme identifying the favourable areas ; (ii) the selection of potential sites for the construction of boreholes.

The upward techniques which include the principal component analysis (ACP) and spatial filtering were used to process the images. The ACP is a mathematical transformation which consists in computing the values and vectors of the variance and co-variance matrix, which is computed based on a series of images and the key components of the digital account of the multispectral bands (Bonn and Rochon, 1992). This enables to separate the maximum information so as to secure a specific canal for high frequencies. The spatial filtering is directional (Sobel 7×7 and 3x3). As part of our study, the extraction of lineaments was done automatically by using an algorithm through the software programme ''PCI Geomatica''. The lineaments and structural elements which are mapped out are validated by the field knowledge and the existing geological, hydrogeological and topographic maps. The map of the productive direction and hydrographic network was used to validate the fracturing map of the Division of Kobé (Iriba). During the validation phase, the lineaments which do not have any tectonic origin are cancelled. This refers to roads, pathways, energy transportation lines, etc. The selected lineaments have a fracturing value.

Geophysical prospecting

The geophysical prospecting through the electrical resistivity method used in this study comprises two research phases: (i) the first one is about the geomorphologic analysis and the implementation of electrical methods (electrical trolling and sounding) in the field; (ii) the second phase is the interpretation and selection of the boreholes sites. A geomorphologic study based on the identification of natural hydrogeological indicators, was conducted in a bid to determine the directions of the geophysical profiles. Indeed, the fractures are presented through their signatures, which are located as abnormalities on the geomorphology: alignment of vegetation, alignment of epigeous termites, hydrographic network, trough, lodes, fractures in the outcrops, etc. (Koussoubé *et al*., 2003). The geophysical methods include the electrical trolling and sounding according to the Schlumberger approach. They measure the underground physical parameters based on the ground surface. The electrical resistivity methods consist in setting a direct current in the soil using electrodes A and B and measuring the difference of potentials between the two other electrodes M and N , including between A and B. The electrical trolling is the preliminary method to any geo-electric study and is the basis for the activation of other electrical implementations (Kouassi *et al*., 2014). In this study, the electrical profile (electrical trolling) was used to monitor the lateral continuity of layers in a given position, and enabled to confirm the presence or absence of abnormalities (Bakkali and Bouyalaoui, 2004). In this case, the electrical trolling was conducted according the Schlumberger mechanism with the following geometric features: AB = 300m, MN = 20 m with a 10m measurement step.

The vertical electrical sounding (SEV) was used according to the Schlumberger mechanism following the apparent resistivity abnormalities determined by the electrical profile. The SEV enables to determine the thickness, the nature of vertical structures and the depth of the abnormality under the measurement station. Its implementation requires the use of four electrodes, which are deviated regularly from the central point (sounding centre) so as to take into account more space in the field. The Schlumberger mechanism was used with AB/2 varying from 1 to 150 m and MN/2 from 0.5 to 10 m. The distance between the electrodes A and B varies while maintaining the distance between M and N. At times, during the declutching, MN is changed. As such, the declutching is done with the respective values of MN, which are 0.5, 5, 10m. The modelling of the sounding data was conducted using the software programme WinSev 6.3 of GEOSOFT. It is a repeated interpretation using the geo-electrical model 1D (horizontal layered medium), which leads to the setting of models providing the features of crossed field. This refers to the estimation of the depth where the resisting formation is found and the depth of its substratum to the vertical axis of the SEV. After each modelling exercise, the soundings which highlight interesting depths were selected for the location of boreholes to be constructed. These locations were demarcated in the field by the stones, iron posts and coloured in red following the geophysical prospecting order or hydrogeological location order. In order to facilitate the identification of sites, trees were used as benchmarks and painted in red colour. The GPS coordinates of those locations and benchmarks were collected.

RESULTS AND DISCUSSION

Results

The aim of this study is to extract satellite images, necessary geological and structural information to enable the mapping of lithologic and lineament units in Iriba. These data were the fundaments of geophysical studies, which made easier the locations of boreholes**.**

Role of the remote sensing

The principal component analysis was conducted on the raw image in a bid to avoid redundancies and improve the image contrast. This analysis enabled the decorrelation of bands and compilation of information on the first band of the ACP or ACP1. Actually, this neo-canal contains alone 99% of the information. This was instrumental in identifying most of the lineaments (Fig. 3).

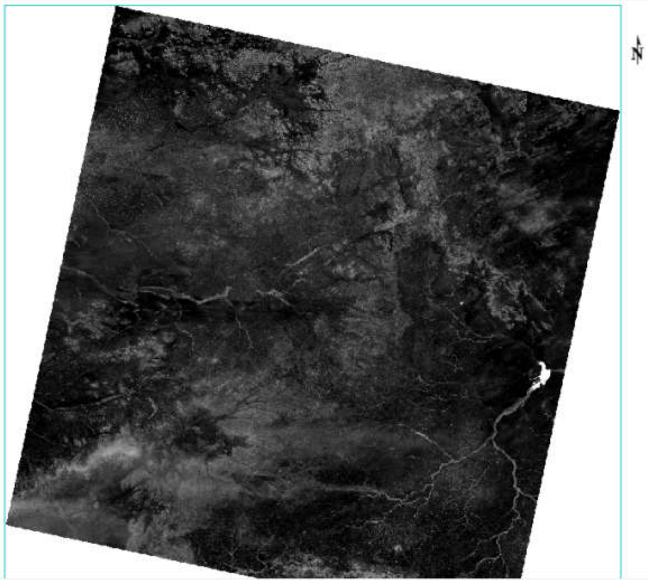

Figure 3: Result of the image application ACP

The coloured composition was conducted on the images which were previously improved. It enabled to determine the image contrasts drawing the difference of the colour of the vegetation-free surface and water courses. As such, the false colours (764 RGB) were secured allocating the red colour to the mid infrared 2, the green colour to mid infrared 1 and the blue colour to the red band (Fig. 4).The application of the directional filter 60° of type Sobel, matrix 7x7 and 3x3 on APC1 in the four directions N-S, NE-SW, NO-SE and E-W enabled to raise the discontinuity on the images (Fig.5) corresponding to structural lineaments (Table 1).

Table 1. Directional Sobel filters, matrix 7x7

			N-S							E-O			
1	1	1	2	1	1	1	-1	-1	-1	0	1	1	1
1	1	2	3	2	1	1	-1	-1	-2	0	2	1	1
1	2	3	4	3	2	1	-1	-2	-3	0	3	2	1
0	0	0	0	0	0	0	-2	-3	-4	0	4	3	2
-1	-2	-3	-4	-3	-2	-1	-1	-2	-3	0	3	2	1
-1	-1	-2	-3	-2	-1	-1	-1	-1	-2	0	2	1	1
-1	-1	-1	-2	-1	-1	-1	-1	-1	-1	0	1	1	1
		NE -	SO						NO -	SE			
0	1	1	1	1	1	2	-2	-1	-1	-1	-1	-1	0
-1	0	2	2	2	3	1	-1	-3	-2	-2	-2	0	1
-1	-2	0	3	4	2	1	-1	-2	-4	-3	0	2	1
-1	-2	-3	0	3	2	1	-1	-2	-3	0	3	2	1
-1	-2	-4	-3	0	2	1	-1	-2	0	3	4	2	1
-1	-3	-2	-2	-2	0	1	-1	0	2	2	2	3	1
-2	-1	-1	-1	-1	-1	0	0	1	1	1	1	1	2

The extraction of lineaments was conducted automatically on the transformed bands from the ACP1 through the module ‘‘extraction line’’ of the software ‘‘PCI Geomatica’’. Only the structural lineaments are interesting as part of this study.

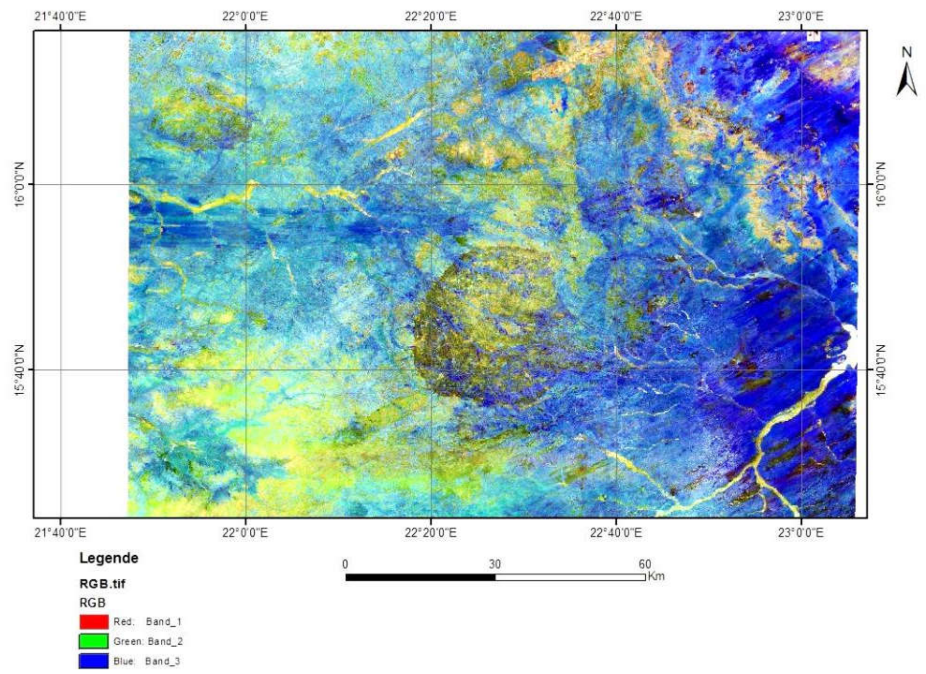

Figure 4. Result of the coloured composition RGB from the ACP image

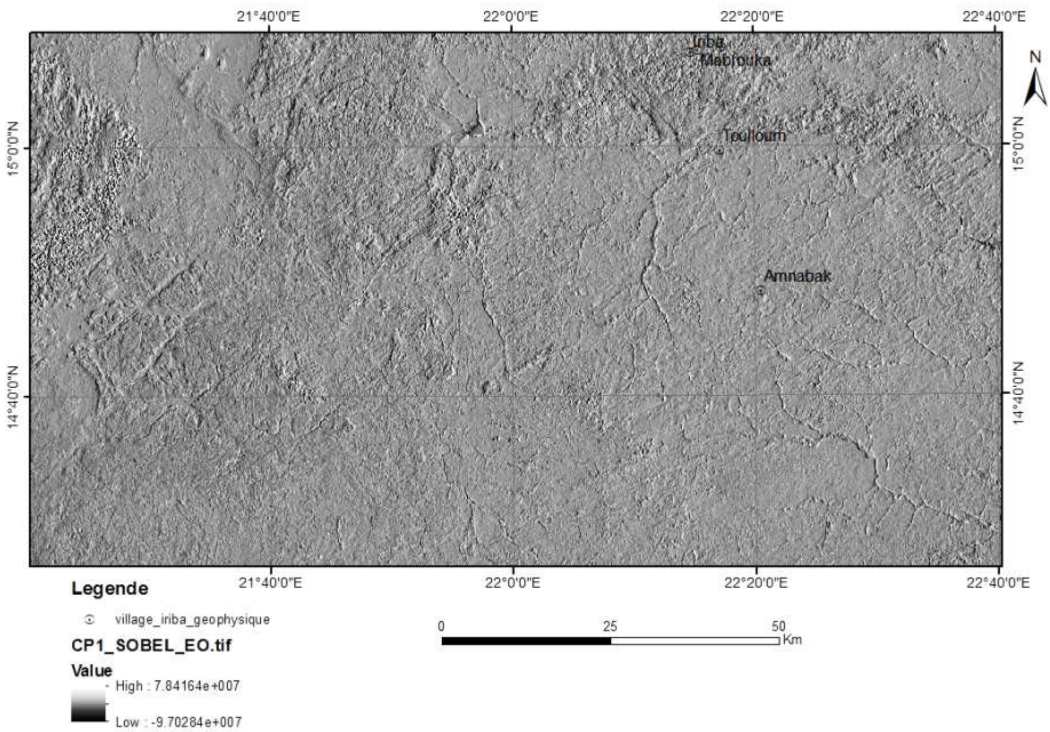

Figure 5. Image derived from the application of the SOBEL_EO filter on ACP1

The lengths and density of lineaments which were extracted by this module depend on the values of input parameters, which are optional (Fig.6). The validation of results presented in the map of lineaments (Fig. 7) was visually conducted by comparing them with different existing maps in the field. The result is quite satisfactory as the final map highlights structural accidents from this study and the accidents of the previous studies.

Results of the geophysics

The volume of works performed as part of this study is as follows:

- 11 sites analysed;
- 3,340 ml of electrical trolling;
- 22 electrical soundings (SE) ;
- 22 potential sites for boreholes.

Table 2 provides the summary of geophysical locations identified by the study. For the electrical profiles, the resistivity values measured for each point are recorded in a semi-logarithm paper where the position of points is recorded in abscissa (*normal scale)* and the resistivity is recorded in ordinate (*log scale*). On the profiles of electrical trolling, the lowest resistivity value points are the most conducting locations.

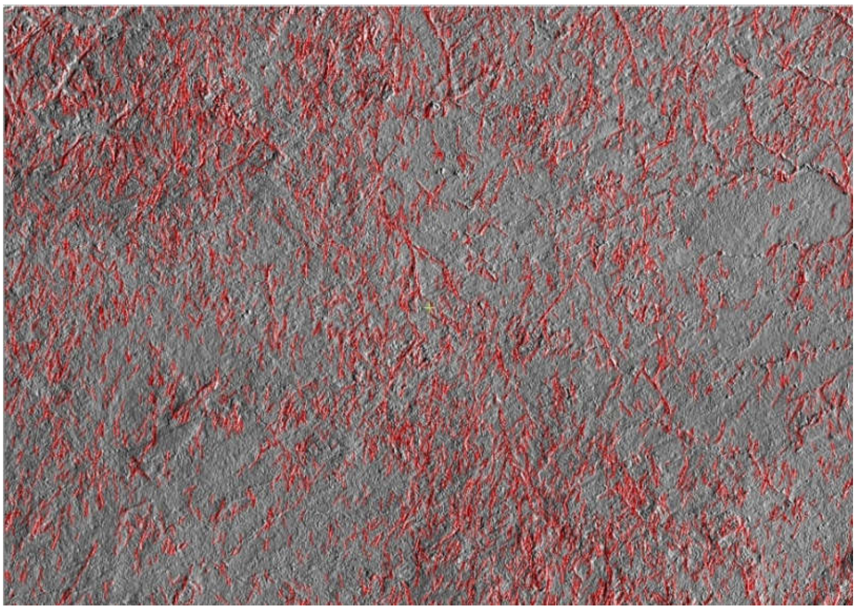

Figure 6: Automatic extraction of lineaments

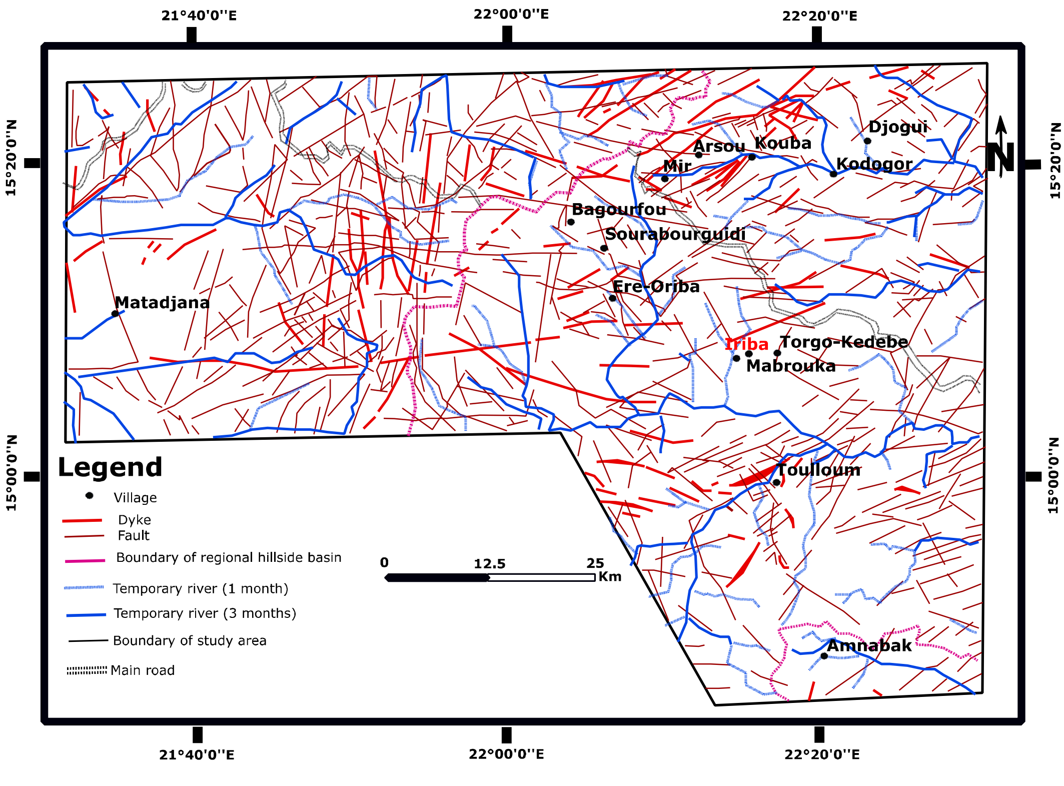

Figure 7. Hydrogeological and lineaments map of Iriba

Table 2. Volume of works performed per site

Region	N°	Division	S/P	Sites	SEV	Profile (m)	Number of locations
	1	Kobé	Amnabak	Amnabak	2	260	2
	2	Kobé	Iriba	Arsou	2	350	2
	3	Kobé	Iriba	Bagourfou	2	340	2
	4	Kobé	Iriba	Djogui	2	160	2
	5	Kobé	Iriba	Erre Oriba	2	290	2
Wadi Fira	6	Kobé	Iriba	Kodogor	2	370	2
	7	Kobé	Iriba	Kouba	2	360	2
	8	Kobé	Iriba	Mir	2	250	2
	9	Kobé	Iriba	Sourabourkidi	2	410	2
	10	Kobé	Iriba	TorgoKedebé	2	430	2
	11	Kobé	Iriba	Toulloum	2	120	2
TOTAL					22	3340	22

The electrical soundings are conducted following the apparent resistivity abnormalities, which are determined by the electrical profile. Figures 8 and 9 represent an example of electrical trolling in the villages of Amnabak and Arsou. The curve of the electrical sounding drawn in bilogarithm coordinates represents the evolvement of the apparent resistivity (ρa) based on AB/2. Its interpretation by the softwares Winsev and IX1D enables to compute the geo-electrical characteristics (thickness and resistivity) of different layers, which are crossed by the current. Table 3 and figures 10 and 11 represent two examples of measurements and SEV curves of Amnabak and Arsou. Table 4 provides the field characteristics secured upon interpretation of sounding curves of Amnabak and Arsou.

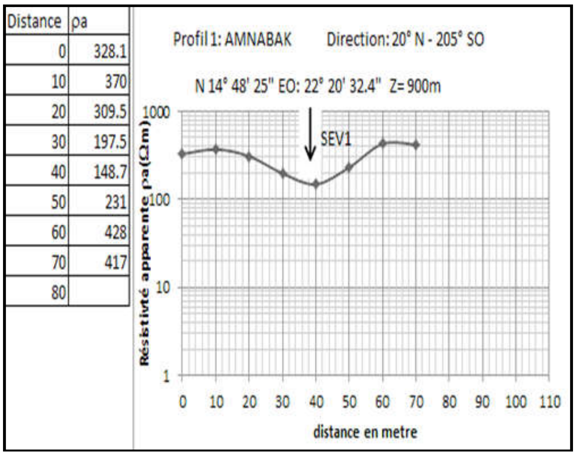

Figure 8. Electrical profile of Amnabak

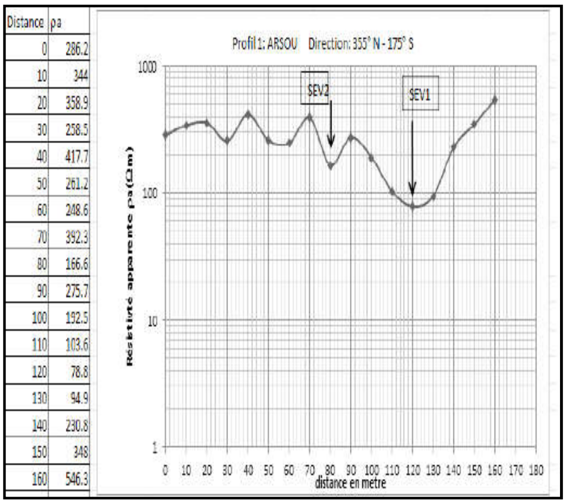

Figure 9. Electrical profile of Arsou

The data which were collected after the geomorphologic and geophysical research works, were compiled in order to draw the ranking of sites by priority for the construction of boreholes taking into account the accessibility of drilling machinery to the selected sites. The geophysical profiles are located perpendicularly to the lineaments, which were recorded on the Landsat8 image in a bid to verify the link between these lineaments and the fractures. Some profiles were located closer to existing boreholes in order to check if these boreholes were constructed as a result of the identification of particular structures. As such, in a bid to optimise the results of boreholes, two developments were planned per village.

Table 3. Field measurements and values computed

SEV data of Amnabak			SEV data of Arsou		
MN/2 [m]	AB/2 [m]	Resistivity [ohm·m]	MN/2 [m]	AB/2 [m]	Resistivity [ohm·m]
0.5	1	48	0.5	1	62.1
0.5	1.5	44.4	0.5	1.5	62.4
0.5	2	36.6	0.5	2	45.4
0.5	3	28.7	0.5	3	37.6
0.5	4	23.9	0.5	4	36
0.5	5	21.8	0.5	5	33.8
0.5	7	21.1	0.5	7	35.2
0.5	10	25.4	0.5	10	37.6
0.5	15	38.6	0.5	15	27.4
5	15	56.6	5	15	39.4
0.5	20	46.5	0.5	20	37
5	20	69.1	5	20	41.1
5	30	88.7	5	30	43
5	40	107	5	40	53.5
5	50	124	5	50	61.4
5	70	133	5	70	69.6
5	100	148	5	100	80.6
10	100	171	10	100	81.8
5	120	158	5	120	82.1
10	120	189	10	120	84.8
10	150	206	10	150	90

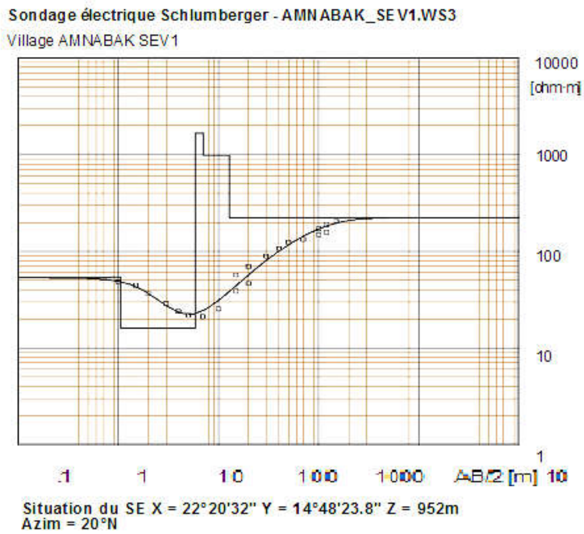

Figure 10: SEV curve of Amnabak

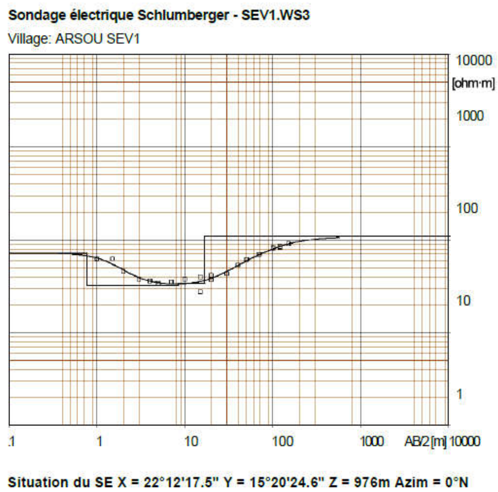

Figure 11. SEV curve of Arsou

Table 4. features of the prospected field

Modèle Résistivité [ohm·m]	Epaisseur [m]	Profondeur [m]	Altitude [m]
53	.82		952
54	.23	.82	951.2
16	4.8	1	951
1664	1.2	5.8	946.2
992	5.9	7	945
225		13	939

Modèle Résistivité [ohm·m]	Epaisseur [m]	Profondeur [m]	Altitude [m]
72	.77		976
32	7.7	.77	975.2
34	8.4	8.5	967.5

Table 5. Summary of the locations of boreholes in the study area

Village	SEV N°	GPS coordinates		Preferential order	Estimated depth
Kouba	SEV3	N 15° 20‘44’’	E 022° 15’06.8’’	F1	55
	SEV1	N 15° 20’35.5’’	E 022° 15’41.4’’	F2	60
	SEV2	N 15° 20’16.2’’	E 022° 15’28.3’’	F3	60
Arsou	SEV2B	N 15° 20‘54.9’’	E 022° 12’35.5’’	F1	70
	SEV1	N 15° 20’24.6’’	E 022° 12’17.5’’	F2	55
Bagourfou	SEV1	N 15° 16‘17.8’’	E 022° 04’05.6’’	F1	55
	SEV2	N 15° 14’57’’	E 022° 03’53.2’’	F2	55
Djogui	SEV1	N 15° 21‘32’’	E 022° 21’01.3’’	F1	65
	SEV2	N 15° 21’32.7’’	E 022° 22’59.8’’	F2	60
Erre Oriba	SEV1	N 15° 10’19.1’’	E 022° 05’55.2’’	F2	55
	SEV2	N 15° 11’24.9’’	E 022° 06’46.1’’	F1	55
Kodogor	SEV1	N 15° 19’09.1’’	E 022° 22’06.1’’	F2	60
	SEV2	N 15° 19’18.5’’	E 022° 20’57.8’’	F1	70
Mir	SEV1	N 15° 19’24.6’’	E 022° 10’11.5’’	F1	65
	SEV2	N 15° 19’11.2’’	E 022° 10’38.2’’	F2	55
Sourabourkidi	SEV1	N 15° 14’41.2’’	E 022° 06’12.4’’	F1	65
	SEV2	N 15° 14’51’’	E 022° 06’48’’	F2	60
TorgoKedebé	SEV1	N 15° 07’56.5’’	E 022° 17’21.3’’	F2	55
	SEV3	N 15° 07’09.1’’	E 022° 16’57.8’’	F1	65
Toulloum	SEV1	N 14° 59’41.6’’	E 022° 17’10.3’’	F1	70m
	EV2	N 14° 59’41.6’’	E 022° 17’09.6’’	F2	70m
Amnabak	SEV1	N 14° 48’23.8’’	E 022° 20’32’’	F1	55
	SEV2	N 14° 48’11’’	E 022° 19’47’’	F2	55

DISCUSSION

The study of the fracturing enables to assess the hydraulicity of the prospected field. Actually, the area is more fractured as the interconnection of fractures is secured and there are more opportunities to discover a productive fracture (Lasm, 2000). This study aims to demarcate the different geological formations and underscore their hydrogeological role. The methodology used for the processing of satellite images enabled to map out the major lineaments in Iriba. This map presents an important density of lineaments of different sizes ranging from hundreds of metres to several kilometres. This huge density of lineaments highlights the various fracture knots. These knots are composed by the junctions of fractures and present precious hydric potentials. The processing and analysis of satellite images in combination with the geological and geomorphologic data enables to: (i) determine the favourable areas by drawing fitness maps and sidelining the unfavourable areas ; (ii) select the sites of boreholes by demarcating the potential infiltration areas , which are likely to provide water to the fracture networks (those which are planned to be cut by the boreholes) ; (iii) reduce the geophysical prospecting highlighting the areas of major accidents, which may hinder the underground runoffs.

The localisation of these geological structures enables to gear the geophysical exercises towards the study of major structures. The analysis of the network of lineaments reveals that the four (4) classes NS, NE-SW, EW and NW-SE constitute the major directions. On this file, we superposed the data base of the structures on the lineament map after designing a thematic map, which represents the distance of any point of the study area with respect to the closest lineament. We determined the distance between each structure of the study area of the closest fracture in each of the four above-mentioned directions. The analysis of the results of the geophysical research works is recorded on the apparent resistivity values and contrasts observed through the resistivity profiles set on the bi-logarithm diagram for the electrical trolling and electrical sounding. The resistivity ρ of a medium is the physical property which determines the capacity of this medium to channel the electrical current (Chapellier, 2000). On the profiles of electrical trolling, the lowest resistivity points are the most conducting locations. The geophysical prospecting targets the research of underground contrasts which is being analysed. At the geophysical level, the analysis of the results of the geophysical research works is recorded on the apparent resistivity values and contrasts observed through the resistivity profiles set on the bi-logarithm diagram for the electrical trolling and electrical sounding. The resistivity ρ of a medium is the physical property which determines the capacity of this medium to channel the electrical current (Chapellier, 2000). In the case of electrical trolling, the conduct of the SEV on a prospecting line takes into account the shape of the abnormality, which was identified. Actually, a study conducted by (Dieng *et al*., 2004) enabled to highlight seven possible abnormality shapes. The U, H or V shapes are the best as the boreholes constructed based on these categories of abnormalities generated the best discharges. For the SEV, the contrast which emerges from the resistivity profile is characterised by the availability of an in-depth abnormality. In this vein, the presence of in-depth cracks is proved by the surge of a hanging outlet. The analysis of the sounding curves enables to identify four (4) major trends in the area of Iriba: (i) the type H curve like the bilge of the boat, which presents a surface cover which is not resisting, the conducting areas and a safe resisting substratum, which is partially cracked; (ii) the curve with a single rising branch of type 2P, which characterises the surface formations presenting sandy clays with different resistivity values due to the variation of the clay or sand content.

Other soil horizons correspond to the sub-outcropping resisting basement; (iii) the type KH hanging curve which reveals a dry argillous and sandy horizon raised by a thick resistivity horizon, which is slightly low ; (iv) a stair curve of type HKH characterised by resisting and conducting levels. The geophysical prospecting highlights the presence of discontinuities while in touch with the convergence area of the drainage network thus favouring the potential recharge of the aquifer. There are hydric resources in very peculiar geological conditions (fractures areas, draining levels, etc.). In this vein, the selection of the locations of boreholes was done according to the combination of geophysical, geomorphologic and hydrogeological parameters. As regards the geophysical parameters, the parallel electrical profiles to the outcrops revealed fractures of diverse directions of which orientation influences the construction of the borehole. As such, the directions of fractures present imprecise hydraulic features because some of them are open while others are closed. The open fractures are likely to store the quantity of waters, which favours the productivity of structures while those which are closed cannot play a hydrogeological role. In addition to the orientation criteria of fractures, the electrical soundings present indexes of the presence of fracturing (Koussoube *et al*., 2003; Sombo *et al*., 2011): hanging surge, change of the dip on the final backoff, huge thickness of the conducting complex. As concerns the geomorphologic and hydrogeological aspect, there are morphological potentials such as the structural saddles, escarpments, ouaddis and slopes) and runoff areas including the springs or alluvions deposits, alignments in the vegetation.

Conclusion

The identification process of lineaments through satellite imaging followed by the electrical geophysical validation (electrical trolling and soundings) seems to be adapted to the study of aquifers of the fracture basement. Actually, the use of this technique on research works and prospecting of the underground waters enabled to design the map of the major geological units and the map of fractures and lineaments of Iriba. It also enabled to determine the exact location of potential sites for the construction of boreholes through conducting abnormalities and fractures oriented on the directions NS, NE-SW, EW and NW-SE. As such, the area of Iriba could be considered as a hydrogeological area where the fractures are likely to be adequate water reservoirs for the construction of boreholes. These reservoirs are an alternative to meet the potable water needs of populations and cattle in the area of Iriba. Finally, this study revealed that the electrical resistivity method is an undeniable and very precious tool for water supply to people living in the basement areas if it takes into account the morphologic and hydrogeological potentials.

REFERENCES

Bakkali, S. et Bouyalaoui, J. 2004. Prospection géophysique appliquée à l'évaluation des eaux souterraines de Médiouna (Tanger, Maroc). *Journal des Sciences pour l'Ingénieur,* N°4/2004, PP 13-22.

Bonn, F. et Rochon, G., 1992. Précis de Télédétection. Principes et méthodes. Presse de l'université de Québec / AUPELF, vol. 1,485 p.

Chapellier D., 2000. Prospection électrique de surface. Cours *online* de géophysique-résistivités électriques. Université de Lausanne, Institut français de géophysique appliquée, 102 p.

Dieng B., Kouassi A.H. et Bakyono B.A., 2004. Optimisation de l'implantation géophysique des forages en zone de socle au Nord du Burkina Faso. Sud Sciences et Technologies, N°12 – juin 2004, pp 21-30.

Gachet, A et K. Foreste., 2005. Carte hydrogéologique de l'Est du Tchad au 1 :350 000. Edité par UNOSAT/UNHCR, Genève.

Koita, M., 2010. Caractérisation et modélisation du fonctionnement hydrodynamique d'un aquifère fracturé en zone de socle. Région de Dimbokro-Bongouanou (Centre Est de la Côte d'Ivoire)", Thèse de doctorat, Université Montpellier II, 220 p.

Koita, M., Jourde, H., Ruelland, D., Koffi, K., Pistre, S. and Savane, I., 2010. Cartographie des accidents régionaux et identification de leur rôle dans l'hydrodynamique souterraine en zone de socle. Cas de la région de Dimbokro-Bongouanou (Côte d'Ivoire). *Hydrological Sciences Journal, 55*(5), 805-820.

Kouamé K. F., T. Lasm, J. R. De Dreuzy, G. A. Akaffou, O. Bour and P. Davy., 2010. Contribution d'un modèle hydrogéologique à fractures discrètes à l'étude des aquifères fracturés du socle Archéen de Touba (Nord-Ouest, Côte d'Ivoire)", *Revue desSciences de l'Eau,* 23 (1) : pp.41-56.

Kouamé, F., Gioan, P., Biémi, J. and Affian, K., 1999. Méthode de cartographie des discontinuités-images extraites d'images satellitales: exemple de la région semi montagneuse à l'Ouest de la Cote d'Ivoire. *Télédétection, 1*, 139-156.

Kouassi Eric Germain Kouakou, Théophile Lasm, Boko Célestin Sombo, Marc Youan Ta, Derving Baka, and Konan Emmanuel Kouadio., 2014. Contribution de la géophysique à l'étude structurale et à l'identification des aquifères de fissures dans le Département de Dabakala (Centre-Nord Côte d'Ivoire). *International Journal of Innovation and Applied Studies.* ISSN 2028-9324 Vol. 8 No. 4, pp. 1752-1769.

Koussoubé Y., Savadogo A.N. et Nakolendoussé S., 2003 - Les différentes signatures des fractures de socle cristallin en zone sahélo-soudanienne du Burkina Faso (bassin versant de Bidi, province du Yatenga). Télédétection, 2003, vol. 3, n° 5, p. 419–427.

Koussoube, M Y., S. Nakolendousse, P. Bazie, A. N.savadogo., 2003. Typologie des courbes de sondages électriques verticaux pour la reconnaissance des formations superficielles et leur indice en hydrogéologie du socle cristallin du Burkina Faso, *Sud sciences et technologie* n°10, (2003) 26-34.

Lasm .T., 2000. Hydrogéologie des réservoirs fracturés de socle : Analyse statistique de la fracturation et des propriétés hydrodynamiques. Application à la région des montagnes de Côte d'Ivoire (domaine archéen)", Thèse de doctorat, Université de Poitiers, France, 274p.

Marc-André Bünzli et Yves Haeberlin., 2005. Carte Hydrogéologie de l'Est du Tchad : Notice Explicative Unhcr/Unosat, Genève, Septembre 2005, 88P.

Ngo, A. Y., Lasm, T., Koita, M. and Savané, I., 2010. Extraction par télédétection des réseaux de fractures majeures du socle Précambrien de la Région de Dimbroko (Centre Est de la Cote d'Ivoire). *Revue Télédétection, 9*(1), 33-42.

Rey, F. 2007. Ressources en eau souterraine dans les chaînons béarnais. Géométrie et fonctionnement hydrogéologique de quatre aquifères carbonatés", Thèse de doctorat, Université de Bordeaux 1, p 178 p.

Savané, I. and Biémi, J. 1998. Télédétection et SIG pour l'étude des aquifères du socle cristallin d'Odienné (Nord Ouest de la Cote d'Ivoire). *Télédétection, 1*, 47-64.

Savané, I., GOZE, B. and Gwin, Q., 1997. Evaluation de la productivité des ouvrages dans le socle par l'étude des fractures et le GIS dans la région nord-ouest de la Côte d'Ivoire. *Hard Rock Hydrosystems (Proceedings of Rabat Symposium S2, May 19)* (241).

Sombo A. P., F. W. Kouassi, B. C. Sombo, L. N. Kouame, E. G. K. Kouakou., 2011. Contribution de la prospection électrique à l'identification et à la caractérisaton des aquifères du socle du département de Sikensi (Sud de la Côte d'Ivoire), *European Journal of Scientific Research*, Vol. 64, N° 2 - 206-219.

Ta, M., Lasm, T., Jourda, J., Kouamé, K. and Razack, M. 2008. Cartographie des accidents géologiques par imagerie satellitaire Landsat-7 ETM+ et analyse des Réseaux de fracture du socle Précambrien de la région de Bondoukou (Nord-Est de la Cote d'Ivoire). *Revue Télédétection, 8*(2), 119-135

Yao, K. T., F. Grogbla, M. S. Oga and T. Assoma., 2012. Extraction de linéaments structuraux à partir d'images satellitaires, et estimation des biais induits, en milieu de socle précambrien métamorphisé. *Télédétection*, 10(4) : pp.161-17.

Youan, M. Ta, T. Lasm, J. P. Jourda, K. F. Kouamé and M. Razack., 2008. Cartographie structurale par imagerie satellitaire ETM+ de Landsat-7 et analyse des réseaux de fractures du socle précambrien de la région de Bondoukou (Nord-Est de la Côte d'Ivoire). *Télédétection*, 8(2) : pp.119-135.

****