Journal of New Technology and Materials (JNTM)
J. New Technol. Mater.
Vol. 09, N°01 (2019)47-51

OEB Univ. Publish. Co.

Hydrochemical characterization of Gareat-El-Tarf plain groundwaters, northeastern, Algeria

H. Ouldammar* and B. Houha

Department of Ecology and Environment, Abbes Laghrour University, Khenchela 04004 ,Algeria.

*Corresponding author, email: *Ouldhanane@hotmail.fr*

Received date: Jan. 31, 2018 ; revised date: March 17, 2019 ; accepted date: Apr. 24, 2019

Abstract

A hydrochemical study has been conducted on groundwaters of Gareat-El- Tarf plain in order to discriminate the salinity origin. Achieved findings indicate that waters are of medium salinity, with a conductivity of 1618µS/cm. A spatial variation in chemical facies suggests that waters chemistry is influenced by a number of factors such as geology, climate and anthropogenic activity. Waters are bicarbonate-calcic type upstream of the basin and near calcareous outcrops, sulfate-calcic type in the Mio-Plio-Quaternary filling and ultimately become chloride-sodic type on the borders of the Sebkha. Chloride ion crossing with major ions on binary diagrams suggests that waters salinity would be attributed to water-rock interaction characterized by mineral dissolution and precipitation, as well as cation exchange. Chemical tracing by trace elements such as strontium suggests that evaporites dissolution contributes to waters salinity of Gareat-El-Tarf plain. Statistical approach is another tool allowing to classify processes responsible for hydrochemical variability, in function of their significance. The increase in salinity is mainly due to climate aridity.

Keywords: Hydrochemistry, salinity, dissolution, Sebkha, Algeria

1. Introduction

Water resources are increasingly scarce and are of poor quality in Saharan Atlas, where semi-arid climate prevails; with hot and dry winds (sirocco) originating from Sahara. Climate aridity, successive dry periods, precipitation irregularity and anthropogenic activity are factors having reduced waters amount of Gareat-El-Tarf basin and degraded their quality.Gareat-El-Tarf plain is located in the region of Khenchela northeast of Algeria; at the extreme east of the steppe upper plains stretching on an area of nearly 1378 km^2, between 35°56' of latitude north and 7°34' of longitude east. it is bordered to the southeast by DjChettaia, DjTafrent, DjBoutakhma, to the southwest by DjRasSerdoune, DjAures, to the east by F'kirina (ouedNini), to the west by Remila plain (ouedGuiss) and to the north a closed depression of 200 km^2, Gareat-El-TarfSebkha. Climate is characterized by the annual temperaturemean is of +16°C. The precipitations are of the order of 370 mm. A semi-arid region subject to ground waters salinity. It is a center of intensive agricultural activity. Most water needs derive and will keep deriving from groundwaters [1]. The aim of this work is to better understand the physicochemical state of the plain groundwaters in order to comprehend their hydrochemicalbehaviour to obtain data on their order and their salinity origin.

2. Experimental details

2.1. Geological setting

Geology is made up of Cenomanian marls at the base, surmounted by cracked limestones of Lower Cretaceous, on which deposit in discordance Miocene sandstones of limited extension. The whole is covered by Mio-Plio-Quaternary, consisting of sand and gravel conglomerates, with a set-up of visible Triassic in Khenchela and DjKroumaa [2]. Gareat-El-Tarf plain is replenished by rainwaters and wadis flood waters during flooding periods. Waters output occurs only by evaporation and intensively during dry seasons. The plain is characterized by a dense drainage system of small streams and wadis, the most important of which are El Guiss, Baghai, Aïssour and Niniwadis, which transport waters until the site [3]. The climatic conditions play a major role in the regime of these streams, particularly precipitations that are directly involved in the pluvial recharge of the catchment [4].

2.2. Sampling and Analytical Techniques

To characterize hydrochemistry of the aquifer system of Gareat-El-Tarf plain, 45 boreholes were sampled; sampling was performed in October 2014. All analyses were carried out at the LACIP laboratories of AinM'lila. Field measurements were carried out by means of multi-parameter Consort C931, version 2.4. In order to be able to quantitatively determine the elements that evolve after sampling, such as temperature, pH, electrical conductivity

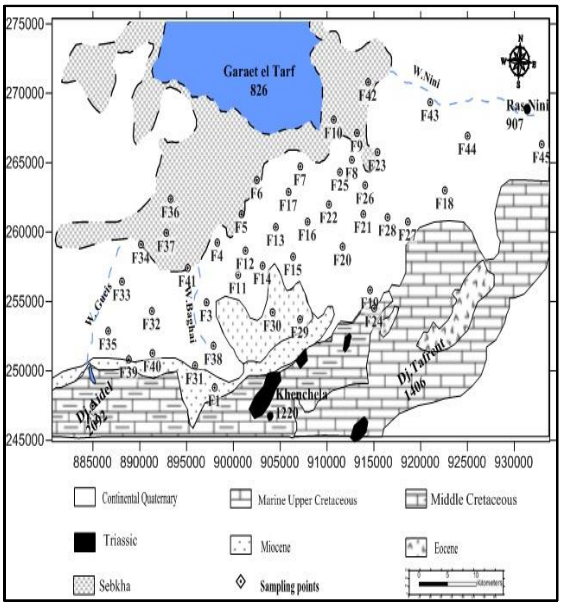


Figure 1. Geological map and inventory of water points –Gareat-El-Tarf plain.

3. Results and discussion

3.1. Physical parameters

Measured temperatures in situ on Quaternary aquifer groundwaters are fairly homogeneous and vary between 16° and 25°C, with a mean of 21°C.

In all sampled waters, measured pH are homogeneous, varying between 6, 5 and 8 with a mean of 7, 15.

The global fluctuations of chemical water load can be reflected by water electrical conductivity, which is a linear function of dissolved ions [5, 6]. Variation in electrical conductivity can have both an anthropogenic (groundwater pollution) and a natural origin (dilution by meteoric waters, infiltration of less mineralized surface water [5]. Conductivity values in the plain groundwaters are very dispersed, ranging between a minimum value of 580µS/cm and a maximum value of 2780µS/cm, exhibiting abnormalities in the area located on the borders of the Sebkha, northeast and southwest of the plain being subject to a great anthropogenic influence as agricultural activity.

3.2. Hydrochemistry

So we have plotted the 45 samples on Piper diagram that show chemical facies evolution upstream/downstream. It is seems obvious that, following the flow direction, the hydrochemical evolution of the system occurs from bicarbonate calcic pole in the carbonate outcrops south towards chloride-sodic type brines on the borders of the Sebkha, going through an intermediate chloride-sulfate-calcium-magnesium facies. Outside this general trend, certain points indicate a notable influence of sulfate pole or chloride-sodic pole (Fig.2). These are waters local contaminations and saliferous minerals dissolution contained in the Triassic inclusions.

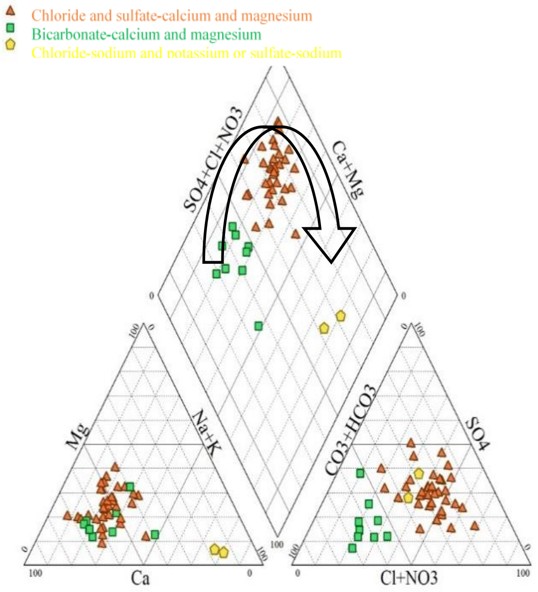


Figure 2. Piper diagram for groundwaters.

To better understand the groundwater mineralization process, we have plotted major elements in function of chlorides (Fig.3). This latter is a conserved element, does not contribute to water-rock interaction, characterizes the waters salinty origin and constitutes a mixing tracer[5, 6].

The disposition of different analyzed water points in relation to mixing line freshwater-saltwater (rainwater-seawater) can be of great significance to identify other phenomena associated with the mixing process.

The graph Cl$^-$ versus Na$^+$ shows that all water points are located bellow the mixing line. Given that Na$^+$ Content should balance Cl$^-$ content, Na$^+$ deficit is explained by the ionic base exchange phenomenon between water and the aquifer and is reflected by Na$^+$ adsorption and Ca^{2+} release [7]. Calcium input derives also from gypsum dissolution. The relationship between Ca^{2+} and Cl$^-$ is a good illustration of this, indicating that the points are usually above the mixing line freshwater-saltwater.

The relationship between Mg^{+2} and Cl$^-$ shows dolomite dissolution, resulting from water-rock interaction, with a tendency to the balance.

The relationship between SO$_4^{-2}$ and Cl$^-$ shows that the quasi-totality of the points is located above the mixing line freshwater-saltwater. The enrichment of the points in sulfate is associated with gypsum dissolution and/or with agriculture-originating contamination (irrigation return flow).

3.3. Saturation index

The use of PHREEQC software (USGS)[8], has allowed us to calculate the saturation index of anhydrite, aragonite, calcite, dolomite, gypsum and halite [9].

The saturation indices of certain common mineral phases show obviously that groundwaters are generally supersaturated regarding most carbonate mineral phases (Aragonite, dolomite and calcite) that are probably responsible for hydrochemical composition (Fig.4). In contrast, evaporitic minerals (halite, gypsum and anhydrite) are always undersaturated.

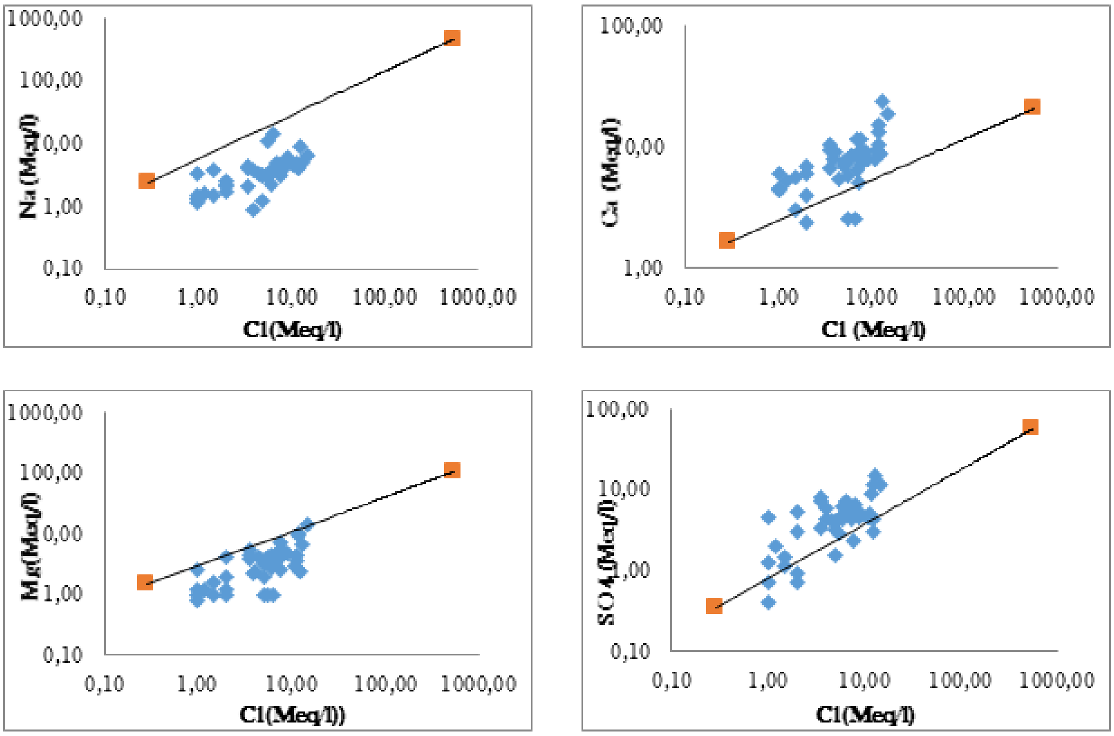


Figure 3. Relationship between Na^+, Ca^{2+}, Mg^{+2}, SO_4^- and Cl^- of groundwaters and rainwater-seawater.

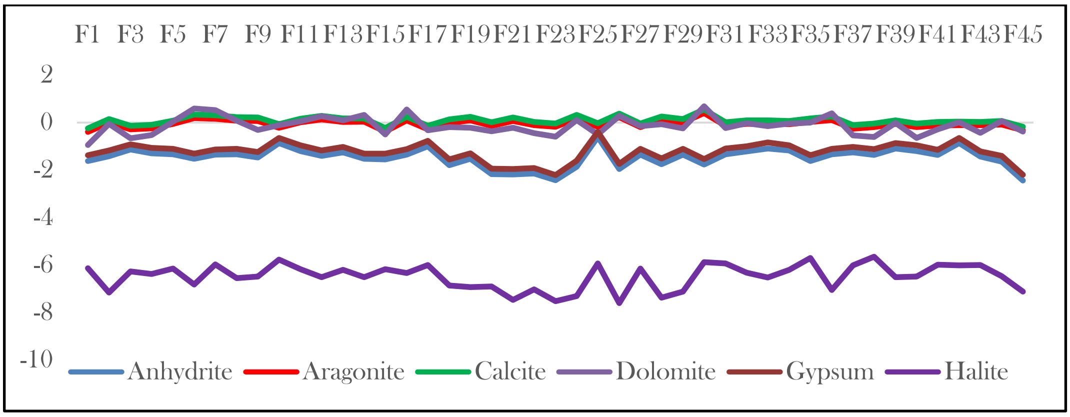


Figure 4. Curve indicating groundwaters saturation index.

3.4. Strontium study

The strontium (Sr^{2+}) is an element linked to evaporites. It is very marginally integrated into carbonates network and is little adsorbed by clays. High Sr^{2+} contents in waters are only explained by celestite($SrSO_4$), a mineral associated with gypsum. So it constitutes a good marker of the evaporites presence [10].

Strontium allows then to distinguish sulfates deriving from sulfurs oxidation (low contents) from those deriving from evaporitic dissolution (high contents) [11].

Sr^{2+} / Ca^{2+}‰ ratio is typical of evaporitic origin, if it is equal or greater than1‰ [12]. It is greater than 5 ‰ in Alpine Triassic evaporites in non-outcropping evaporitic Triassic [11].

All groundwaters of the plain exhibit elevated Sr^{2+} / Ca^{2+} ratios (> 5‰). It seems that Triassic evaporites contribute to groundwaters chemistry [13] and have chemistry of evaporitic origin. This ratio reach a maximum of 23‰ in the center and westward then decreases gradually northward and eastward, where minimum values concentrate (Fig.5).

3.5. Multivariate statistical analysis

The correlation between the physicochemical parameters in groundwaters helps understand certain phenomena resulting from water-rock interaction; it allows to provide an approach on the common origin of certain parameters [14].

3.5.1. Descriptive statistical analysis

The results of the physico-chemicalanalysis of groundwater are presented in Table 1

It is shown from the average of major element levels that the dominant cations are Ca^{2+} and Na^{+} and for the dominant anions are Cl^{-} and SO_4^{2-}.

Table 1: Preliminary findings of physicochemical parameters.

Variable	Min	Max	Mean	Standard deviation
Ca^{2+}	48,100	480,960	161,428	81,501
Mg^{2+}	9,600	177,120	44,496	32,606
Na^{+}	20,470	343,970	92,342	59,452
K^{+}	0,012	4,753	0,912	1,059
HCO_3^{-}	164,700	445,300	283,587	61,948
Cl^{-}	35,500	527,250	217,712	135,740
SO_4^{2-}	20,000	740,000	229,244	145,407
NO_3^{-}	0,800	96,000	33,278	24,206
Sr	1,270	21,180	5,569	3,992
c25°C	580,000	3720,000	1617,778	738,952
PH	6,500	8,000	7,156	0,286
T°C	16,000	25,000	20,711	2,944

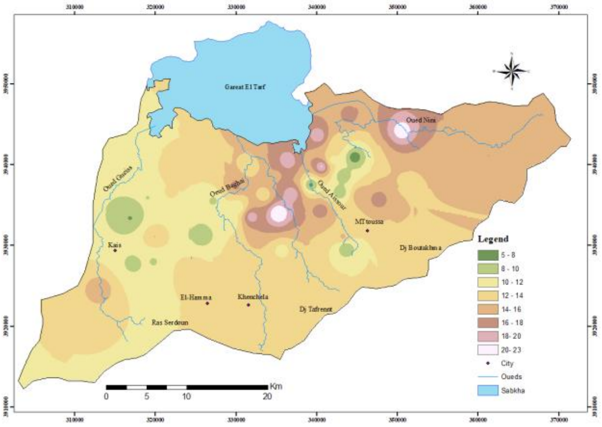


Figure 5. Spatial distribution of Sr/Ca ratio in groundwaters of Gareat-El-Tarf plain.

3.5.2. Correlation matrix

Correlation matrix from this PCA (Table.2) shows that EC exhibits a significant link (0,564 to 0,914) with Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-} ,SO_4^{2-} and Sr^{2+}; this reflects the contribution of these elements to waters saline recharge acquisition. Ca^{2+}andMg^{2+} exhibit a high positive correlation between them (0,755), indicating a common origin. The same is true for Ca^{2+} and SO_4^{2-} (0.84), SO_4^{2-} and Mg^{2+} (0.772), Ca^{2+} and Sr (0,752) that also have very good positive correlation. Na^{+}, Cl^{-}, Ca^{2+} and SO_4^{2-} high contents detected in certain samples can suggest chlorides and sulfates salts dissolution such as gypsum, anhydrite and halite. The close link existing between sulfates and calcium highlights this trend.

3.5.3. Principal component representation

Principal component analysis PCA highlights the links that seem to exist between chemical elements [15]. Principal component analysis was performed on the observations made on the area waters:

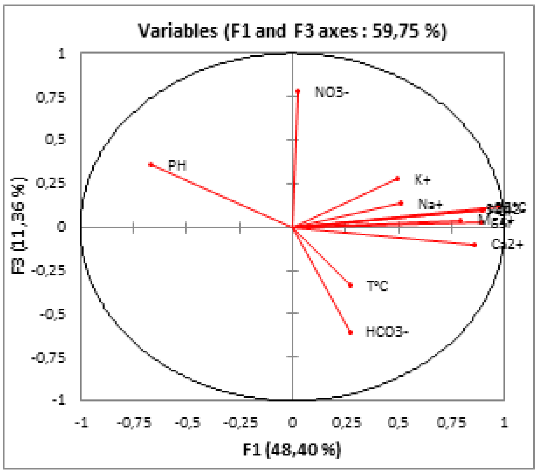
The F1 factorial design and F2 provide 66,51 % of total data (Fig.6), the F1 axis (45,86 %) is positively determined (CE, SO_4^{2-}, Cl^{-}, Ca^{2+}, Mg^{+2},Sr^{2+}) The F1 axis is a mineralization axis and accounts for the main part of mineralization due to water-rock interaction.

The F2 axis, accounting for 20, 65 % of total variance, is determined by Na^{+} K^{+}associated with HCO_3^{-} as opposed to NO_3^{-} it reflects the influence of clay fraction, and Pontian red clay in cation exchange processes.

The F3 axis, accounting for (12, 38 %) of total variance (Fig.7), is determined by NO_3^{-} it is an agricultural pollution axis in a cracked area.

The projection of individuals on the F1-F2 design revealed that the F1 axis indicates opposition between marginally mineralized waters upstream of the plain in the calcareous outcrops, and highly mineralized waters on the borders of the Sebkha.The F2 axis indicates alkaline-rich waters, as a result of water-rock interaction recorded in the center of the plain in the Mio-Plio-Quaternary filling.

The PCA was performed usingXLSTAT2016 software.



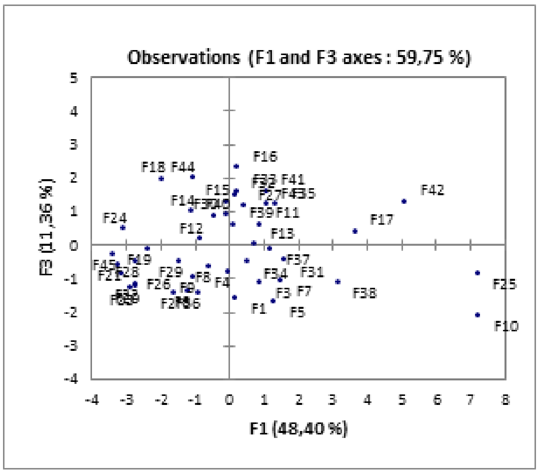


Figure 6: F1-F2 factorial design. Figure 7. F1-F2 factorial design.

Table 2: Preliminary findings of physicochemical parameters

Variables	Ca2+	Mg2+	Na+	K+	HCO3-	Cl-	SO42-	NO3-	Sr	c25°C	PH	T°C
Ca^{2+}	1											
Mg^{2+}	0,755	1										
Na^{+}	0,083	0,132	1									
K+	0,106	0,162	0,847	1								
HCO$_3^-$	0,098	0,094	0,438	0,275	1							
Cl$^-$	0,709	0,662	0,470	0,462	0,130	1						
SO$_4^{2-}$	0,840	0,772	0,410	0,393	0,152	0,652	1					
NO$_3^-$	0,081	0,199	-0,211	-0,096	-0,468	0,098	0,086	1				
Sr	0,753	0,592	0,504	0,450	0,203	0,808	0,761	-0,036	1			
c25°C	0,786	0,714	0,596	0,564	0,228	0,914	0,863	0,069	0,881	1		
PH	-0,761	-0,573	0,041	0,047	-0,258	-0,615	-0,516	-0,011	-0,481	-0,563	1	
T°C	0,327	0,335	-0,183	-0,145	-0,149	0,286	0,166	-0,111	0,223	0,178	-0,310	1

4. Conclusion

Geology is depicted as a sedimentary set made up of Cenomanian marls at the base, on which deposit Maastrichtian limestones; the whole is covered by sand, clay and gravel detrital filling. The plain groundwaters display significant mineralization variations. Electrical conductivity ranges between 580 to 2780µS/cm, presenting abnormalities, with elevated values located northeast and southwest and on the borders of the Sebkha. The chemical approach use, namely, major elements and trace element (Sr^{++}), allowed us to understand the waters mineralization process. The waters chemical facies evolves from carbonate-calcic in the calcareous outcrops towards chloride-calcic downstream of the plain. Waters salinity would be attributed to water-rock interaction by the dissolution of Triassic evaporitic formations. The thermodynamic approach highlighted carbonates precipitation and halides dissolution. Chlorides- major ions binary ratios highlighted cation exchange process with sodium absorption and alkaline-earths desorption.

References

[1] B. Houha, Doctorate thesis, 2007, university of Annaba (Algeria).

[2] B. Houha, N. Kherici, S. Kachi, V. Valle., Am J Appl. Sci(2008) 891 -895.

[3] B. Houha, magister thesis, 1996, university of Annaba(Algeria).

[4] N. Dali, D. Zouini, N. Bougherira, J Hydrocarb Mines Environ Res (2013)61-65.

[5] A. ElAchheb, J. Mania, J. Mudry, P. Chauve, Proceedings First International Conference on Saltwater Intrusion and Coastal Aquifers Monitoring and Management, Essaouira, Morocco 2001.

[6] C. Fehdi, A. Boudoukha, A. Rouabhia, E.Salameh, AfrSci J (2009)217-231.

[7] N. Belkoum, B. Houha, Sciences J Mater Environ Sci(2017)3262- 3268

[8] L N B F.Plumme, Jones A H., Truesdell., WATEQF : à Fortran IV version of WATEQ, a computer program for calculating chemical equilibrium of natural waters. – In: US Geological Survey. Water Research Investigation Report(1976).

[9] S. Amrani, S. Hinaje, Eur Sci J, (2014)174-189.

[10] J. Carre, Thesis 3^{erd} cycle,1975 , Univerity of Paris(France) .

[11] M. Abdesselem, J. Mania, J. Mudry, J-P. Gelard, P.Chauve, H. Lami, C. Aigoun, Rev Sci Eau (2000)155-166.

[12] M. Bakalowicz, thesis, 1988, La formation des travertinsespects géochimiques, Univerity of Provence (France).

[13] M. Meyrbek, thesis, 1984, Univerity of Paris (France).

[14] N. Brinis, A. Boudoukha, A. Ahmed Hamel, Larhyss J (2015) 123 -137.

[15] Y. Travi and J. Mudry, Méthode pour l'évaluationet la gestion du risque nitrate dans les aquifères de socle de la zone sahélienned'Afrique de l'Ouest (1997).