International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 5|| May 2017 || PP. 15-20

Aptitude of Ground waters for Irrigation in the South-East Coastal Region of Côted'Ivoire (From Abidjanto Aboisso)

Oulai Jean Gautier Kpan[1], YéiMarie Solange Oga[1], Franck Maxime Gnamba[2], Jean Biemi[1]
(1) Laboratory of Water and Environmental Sciences and Techniques, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire
(2) Department of Geosciences, Paleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire

***Abstract*:** *Development of agricultural areas pressures on the availability of water resources in the South-East coastal region of Côte d'Ivoire (from Abidjan to Aboisso) require farmers to use groundwater for irrigation food and industrial crops. The objective of this study is to assess the aptitude of groundwater for irrigation in this region by using methods that take into account the Sodium Adsorption Report (SAR) and the Permeability Index (PI). The different results show that the SAR values range from 0.03 to 9.90 with an average of 1.83 while the PIs range from 5.11 to 210.77 with an average of 91.40. The C1S1 and C2S1 classes, corresponding to the water suitable for irrigation, represent 95% of the water sampled. In general, therefore, the sampled waters quality is suitable for irrigation except the boreholes waters of Memni (No. 59) and Palmafrique (No. 64).*
***Keywords*:** *Groundwater, irrigation, crops, southeast coastal, Côte d'Ivoire.*

I. INTRODUCTION

The southeastern coastal region of Côte d'Ivoire (Abidjan-Aboisso) has been under intense agricultural activity since the early 1980s. Traditional food crops include cassava, yam and plantain. However, people are increasingly turning to rice, maize, and groundnuts.In addition to this list of food crops, there is the market gardener whose dominant crops are eggplant, tomato, cabbage, lettuce, okra and especially chilli. The region is renowned for its pineapple practice although production is declining today. Industrial crops are at the forefront of agricultural activities in the region. To this end, several agro-industrial units (AGRIVAR, PALMAFRIQUE and PALMCI) are located. The latter cultivate, process and market their products, such as hevea and/or palm trees. Other companies, such as IVOIREFLEUR and SCB, are involved in the production of flowers, pineapples and bananas, all of which are destined for European markets. The culture of the coffee-cocoa couple is also important. The intense agricultural activity observed in this region causes strong pressure on the availability of water resources. The latter increasingly forces farmers and agro-industrialists, particularly those whose plantations are far from watercourses, to use groundwater (via boreholes and wells) for irrigation of crops. This constraint is accentuated by the decline in rainfall and depletion of surface water in the Abidjan-Aboisso region (Kpan et *al*., 2016, Oga et *al*., 2016) [1,2]. Irrigation water supply is a determining factor in agricultural production, both in crop intensification and in the extension of irrigated areas (Benziane et *al*., 2012) [3]. However, nearly half of the irrigated areas in the world are threatened by secondary salinization (Lahlou et *al*., 2000) [4]. On the other hand, the degree of salinization of an irrigated area depends on several factors, mainly the quality of the irrigation water, the nature of the irrigated soil, the climatic conditions and the level of the water table in question. Therefore, the use of these waters must be based on the type of plant, the soil and the chemical quality of the water (Oga et *al*., 2015) [5]. Indeed, if the water used for irrigation has high Na^+ concentrations (greater than 60%, a value representing the maximum permissible threshold for agricultural use, and low in Ca2 +, the exchangeable ion complex (adsorbent complex of Soil) can be supersaturated with Na +, thus degrading the soil structure due to the dispersion of clay particles (Todd, 1980; Benziane et *al*, 2012) [3, 6]. At 200 µS.cm-1 have a strong tendency to rapidly mobilize soil calcium, which promotes the dispersion of particles and the filling of porous spaces (Ayers and Westcot, 1988) [7].The aim of this work is to study the ability of groundwater in the Ivoirian coastal region of Abidjan-Aboisso to irrigate agricultural areas.

II. STUDY FRAMEWORK AND GEOLOGICAL CONTEXT

The study area is located in the southeast of Côte d'Ivoire between longitudes 3 ° 00 and 4 ° 00 West and latitudes 5 ° 00 and 5 ° 30 North. Covering an area of 5056 km2, it leaves from Gonzagueville (Municipality of Port-Bouët) to Aboisso. It includes in its northern part the department of Alépé, in the North-East the department of Aboisso, in the east the department of Adiaké and the sub-prefecture of Assinie, in the west the sub-prefecture of Bingerville And the Atlantic Ocean (Figure 1). According to the latest census (INS, 2014) [8], the population of the study area is estimated at 803500 inhabitants with a density of 158 inhabitants / km2 and a growth rate of the population of 1.59%.

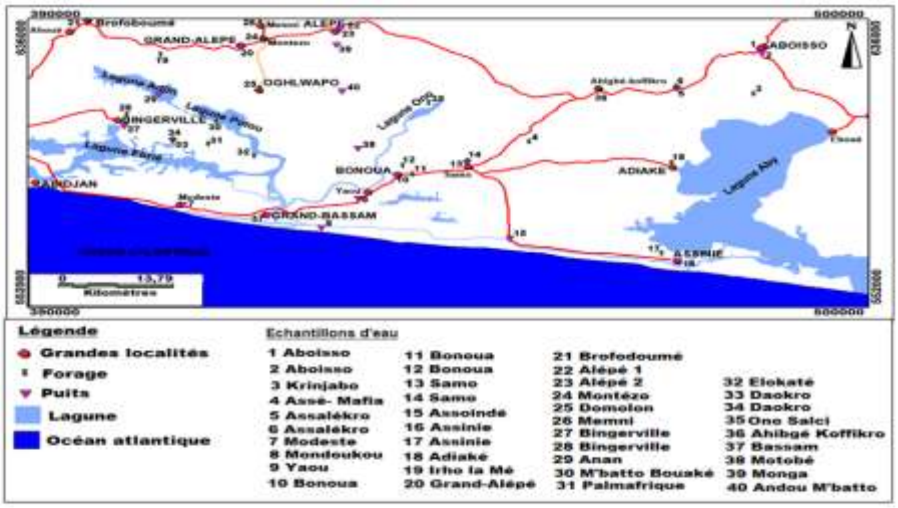

Figure 1: Location of the study area

On the geological level, 90% of the investigated area is composed of a secondary-tertiary-sedimentary basin and a Precambrian base covering 10% of the region. The sedimentary basin is composed of 80% of the Mio-Pliocene formations. The deposits corresponding to this transition in the geological era are also called "Continental Terminal". The soils encountered are an alternation of coarse sands and variegated clays, later ferruginous lateritic clay sands of various colors (red on rust) and ferruginous sandstones. In addition, Quaternary soils are formed at the base by lagoon deposits with black clays intercalated with sand and peat, with marine sands (Yacé, 2002) [9] and with the "Terre de barre", a rube formation. The series ends with vases and fluvio-lagoon sands of the Holocene. The geological map of the region is shown in figure 2

Figure 2: Geological map of the Abidjan-Aboisso region

III. METHODOLOGY

3.1 Data

For the purposes of this study, 54 water points (boreholes and wells) spread over the whole region were inventoried (Figure 2). These waters were selected to constitute the sampling network. The database is the result of a project called UEMOA / PAES 2010 funded by the African Development Bank (ADB) and the West African Economic and Monetary Union (UEMOA). The water sampling campaign took place in the period from 23/12/2013 to 14/06/2014. Physico-chemical parameters such as temperature, pH, salinity and electrical conductivity were measured in situ, while the major components (dry residue, chloride anions Cl^-, sulfate SO_4^{2-}, bicarbonate HCO_3^-, nitrate NO_3^- And calcium cations Ca^{2+}, magnesium Mg^{2+}, sodium Na^+, potassium K^+) were assayed in the laboratory.

3.2 Calculation of agricultural water parameters

The dissolved salts expressed by the dry residue or electrical conductivity, potential salinity, relative sodium concentration and the quantity of toxic elements (boron and chlorine) present in the water are the cause of the degradation of the quality of Water for irrigation (Rouabhia and Djabri, 2010) [10]. The salinity generally expressed by the global mineralization or by the electrical conductivity (CE) is related to the dry residue (RS) and to the osmotic pressure π. Equations 1 and 2 show these different relationships:

RS ($mg.L^{-1}$) = 0, 7*CE ($\mu S.cm^{-1}$) Éq. 1

π (*atm.*) = 0, 00036*CE Éq. 2

According to (Doneen, 1961) [11], the salinity of the soil contains all the salts of sodium chlorides and sulphates of magnesium. Thus the potential salinity (Sp) can be estimated by Equation 3:

$$SP = Cl + \frac{1}{2(SO_4^{2-})}$$ Éq. 3

where all terms are expressed in milliequivalents per liter.

To understand the effects of the presence of Na^+ on soil structure, several interpretations are made on the basis of several parameters, including SAR:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$$ Éq. 4

The percentage of sodium is given by:

$$Na(\%) = 100 \times \frac{Na^+ + K^+}{Ca^{2+}+Mg^{2+}+Na^+ + K^+}$$ Éq. 5

The percentage of sodium exchange is:

$$ESP = 100 \times \frac{[b(SAR) - a]}{1 + [b(SAR) - a]}$$ Éq. 6

Where a = 0, 0126 et b = 0, 01475

The first three terms were combined in a single formula giving the so-called permeability index (IP) defined by (Doneen, 1961):

$$IP(\%) = 100 \times \frac{Na^+ + \sqrt{HCO3}}{Ca^{2+}+Mg^{2+}+Na^+}.$$ Éq. 7

Where all terms are in milliequivalent per liter.

This method is only applicable when the permeability index (PI) is greater than 3.

All these calculations make it possible to establish two characteristic diagrams used to determine the suitability of groundwater in the Katiola region for irrigation:

- the conductivity sodium absorption rate diagram, which provides information on the salinity and risk of soil alkalization (USSL, 1954) [12];
- The Doneen diagram (1961) using potential or actual salinity, soil permeability index and concentrations of toxic substances in water.

IV. RESULTS

4.1 Result of physicochemical analyzes

The results of analysis of groundwater samples (boreholes and wells) in the Abidjan-Aboisso region are presented in Table 1. This table shows that the groundwater in this region is characterized by a Low salinity. Indeed, their electrical conductivities (CE) vary from 15.3 (minimum) to 1550 µS.cm-1 (maximum) r with an average of 209.16 µS.cm-1. It should be noted that 70% of the well water samples have conductivities between 100 and 500 µS.cm-1, while the drilling water in most cases (62.5%) has an electrical conductivity less than 50 µS.cm-1. The pH values are acidic with an average of 4.94. The average contents of the chemical elements are generally low. The values of the sodium adsorption ratio (SAR) are all less than 15 (considered dangerous) insofar as they are between 0.03 and 9.90%. The permeability index calculated for the analyzed waters is between 5.11 and 210.77%. Waters with IP values above 80% are considered to have good permeability. Below this value, the waters are considered intermediate or poor permeabilities. However, for the projection in the Doneen diagram, only samples of water with an IP of less than or equal to 120% are represented.

Table 1: Chemical composition of groundwaterin the Abidjan-Aboisso region

Parameters	Units	Average	Minimum	Maximum
pH		4,94	1,57	6,66
CE	$\mu S.cm^{-1}$	209,16	15,3	1550
Ca^{2+}	$mg.L^{-1}$	11,47	0,60	68,80
Mg^{2+}		3,84	0,14	58,10
K^+		5,35	0	51,56
Na^+		16,85	0,30	138,65
Cl^-		23,40	1,10	214
HCO_3^-		22,53	0	101,48
SO_4^{2-}		15,10	0	167,50
NO_3^-		18,69	2,10	81,20
SAR	%	1,83	0,03	9,90

IP	%	91,40	5,11	210,77

4.2 Sodium Adsorption Ratio (SAR)

The USSL diagram (1954) relates the SAR to groundwater conductivity (CE) and places the samples in irrigation water categories (Figure 3). Examination of the figure reveals that all the samples are positioned in the S1 part, the low alkalizing power class (SAR) and in the C1, C2 and C3 conductivity domains. Thus, the water classification of the Abidjan-Aboisso region gives three classes of water:

- Class C1S1: these are SAR water with low conductivity and low conductivity. It includes 23 samples (42.59%);
- class C2S1: it comprises 29 samples (53,70%) and represents the SAR waters with low and medium conductivities;
- class C3S1: it is the least represented with only samples 39 (Gbagba 1) and 41 (Gbagba 3). These are waters with high conductivities and low SAR. The water of the last class (C3S1), in general, can be used for irrigation only after previous dilution with low salinity water.

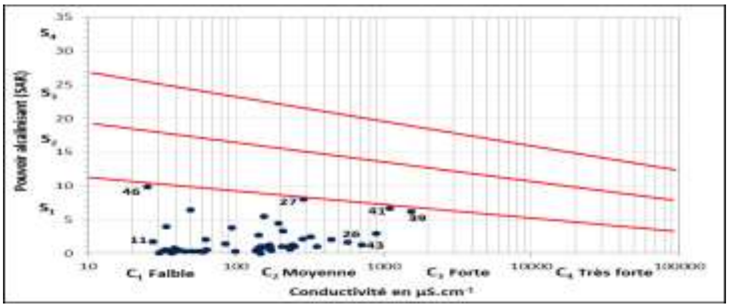

Figure 3: Abidjan-Aboisso Region Groundwater Classification Chart for Irrigation (USSL, 1954)

4.3 The Permeability Index (IP)

Figure 4 is the representation of the data on the Doneen diagram. Projected IPs range from 5% to 118%. Based solely on the permeability index, class III of water represents the types of water of poor quality for irrigation. It brings together 18 points (2, 3, 10, 12, 21, 23, 27, 28, 34, 35, 36, 37, 41, 42, 45, 51 and 54). Class II represents the water category of an intermediate quality and is likely to be used for irrigation but with certain precautions. It contains 23 points (1, 4, 5, 6, 7, 8, 9, 11, 13, 14, 15, 16, 17,19,20,26,29,38,39,40,43,48,53). As for class I, it represents the category of water of excellent quality for irrigation with a single sample (18). The analysis shows that approximately 2% of water samples are in Class I, 42.59% in Class II and 33% in Class III.

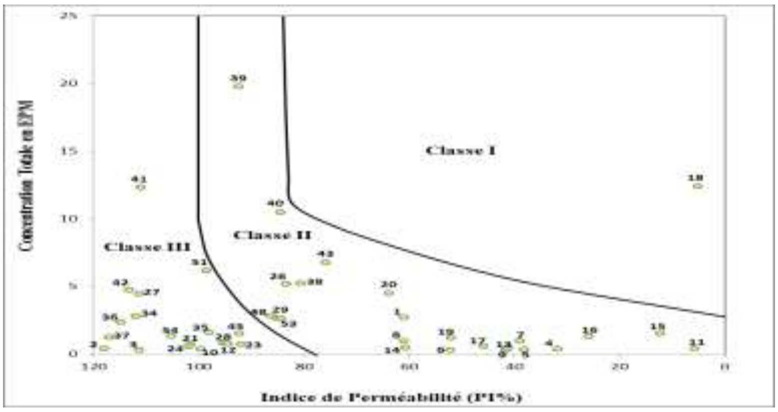

Figure 4: Groundwater Doneen Diagram of the Abidjan-Aboisso Region.

4.4 Mapping the Abidjan-Aboisso groundwater capacity for irrigation

Figure 5 illustrates the spatial distribution of the region's water suitability for SAR irrigation and permeability index (PI). The first map highlights three areas. Water of excellent quality for agriculture (C1S1) located in the Center and South-West of the region precisely between the curves of isovaleurs 100 and 200µS.cm-1 of conductivity. Acceptable or intermediate-quality waters (C2S1) occupying most of the region and encompassing the Aboisso, Adiaké, Bonoua, and other localities. Finally, the highly mineralized (C3S1) waters are located to the west in the Bingerville region (Gbagba 1 and 3). The second map drawn up according to the interpretation of Doneen (IP) confirms more or less the observations from the first. The waters of the south-east Côte d'Ivoire are 95% acceptable for irrigation of the crops of the region.

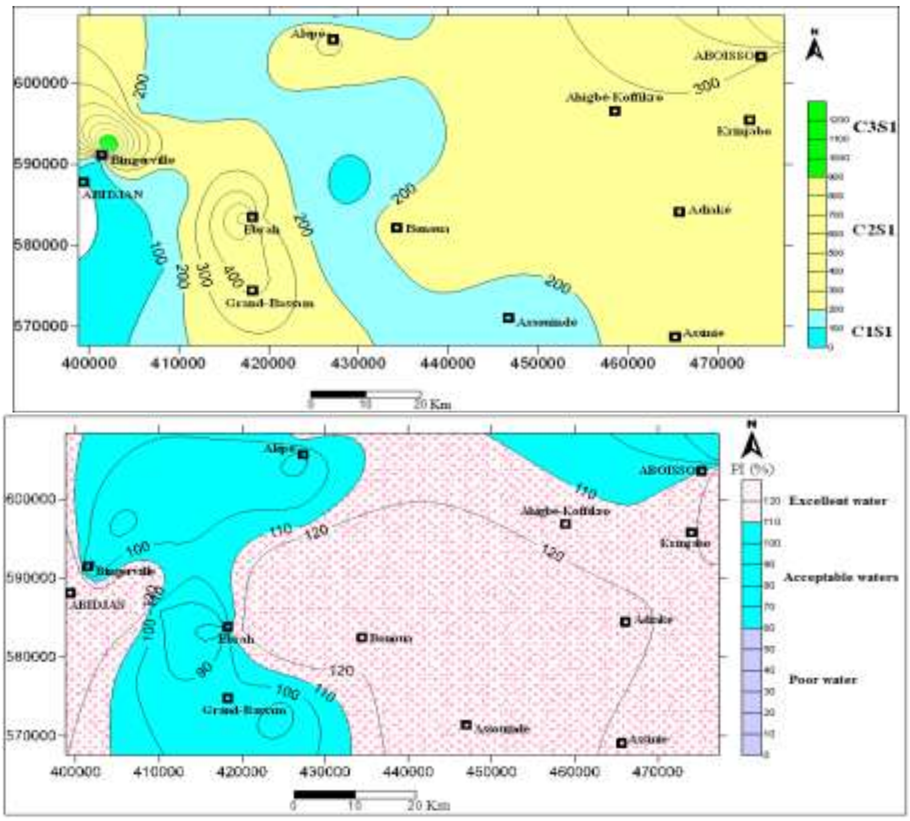

Figure 5: Abidjan-Aboisso Area Groundwater Ability Map for Irrigation (SAR: IP)

V. DISCUSSION

The context of climate change, in particular the decline in rainfall recorded in Côte d'Ivoire since the 1970s, is pushing the populations of the coastal South-East to irrigate their plantations to meet the water needs of plants. Irrigation water criteria depend on the type of plant, the soil and the chemical quality of the water (Soro, 2002) [13]. Indeed, soils containing high levels of sodium can delay the growth of the plant (Devadas et *al*., 2007) [14]. The region is 80% clay soil of the Continental Terminal (Moi-Pliocene age). It has weakly mineralized acid waters. These waters are encrusting and can be dangerous from the point of view of alkalization (Oga et *al*, 2015) [5]. These characteristics (acidity and low water mineralization) could lead to a rapid mobilization of soil calcium, which would favor the dispersion of particles and the filling of porous spaces according to Ayers and Westcot (1988) [7]. However, the sodium adsorption ratio (SAR) diagram as a function of conductivity has shown that there is no risk of soil alkalization in the study area because the levels of sodicity obtained These results are consistent with those obtained in Côte d'Ivoire by Biémi (1992), Soro (2002), Oga et *al* (2015) and Orou et *al* (2016) [5, 13, 15, 16] respectively in the Haute Marahoué region , Grand Lahou, Katiola and Agboville and by Ncibi et *al* (2016) [17] in the plain of Sidi Bouzid in Tunisia. The waters are mostly classified in the C1S1 and C2S1 classes, which correspond respectively to low and medium salinity waters, and thus to low risk of alkalization. Class 1 waters pose no risk to most crops. Class 2 is suitable for plants with low tolerance. On the other hand, core fruit trees can accumulate dangerously sodium (Soro, 2002) [13]. Two points (Gbagba 1 and 3) are located in class C3S1, representing poorly mineralized mediocre waters presenting significant risks of soil salinization, likely to be suitable for the irrigation of certain species that are well tolerant to salt and soil Drained and leached areas (FAO, 2003) [18]. These waters have conductivities greater than 1000 µS.cm-1. Climatic factors such as the drop in rainfall and especially the rise in temperature (Oga et *al*., 2016) [2] do not favor the dilution phenomenon. On the contrary, they cause a high evapotranspiration and consequently an increase in the salinity which can explain the degradation of the water quality. This would explain the degradation of the quality of these two water points. In the absence of an adequate drainage system, any use of this type of resource, which does not provide for frequent leaching of irrigated soils, would lead to progressive salinization and would lead to a significant decline in agricultural productivity or even a loss Irreversible fertile soils. Falling yields of some crops at the study area level (Ayers and Westcot, 1988) [7] can be expected. To address this problem, in the absence of another water resource, the replacement of sodium by calcium in the form of a gypsum amendment is advised with drainage (Qadir et *al*, 2006) [19]. Another solution, complementary to the chemical amendment, consists in the use of plants in order to reduce the quantity of sodium by phytoremediation; Due to the increased dissolution of calcium carbonate in the soil, this may provide calcium, which can be exchanged with sodium (Qadir et *a*l., 2006 in Rimmer et *al*., 2013) [19, 20]. Thus, depending on the salinity of the irrigation water used, populations can practice some salt-tolerant crops such as onions, lettuce, tomatoes (ANAT, 2003) [21], in order to diversify and improve their incomes. In the Doneen diagram based on the measurement of the permeability index, the waters are distributed according to the three classes. Class I and II waters have acceptable intermediate grades for irrigation. On the other hand, the waters of class III are of poor quality for irrigation. Their poor permeability can impede the supply of water to the crop. It makes farming practices much more difficult. It is responsible for the emergence due to surface crusting caused by soil congestion (Benziane et *al*., 2012) [3]. These phenomena are accompanied by a number of disadvantages, including diseases, salinity, weeds, and aeration and nutrition problems (Maait, 1997) [22]. The groundwater in the Abidjan-Aboisso region is predominantly of a quality suitable for agricultural use. They are therefore suitable for the irrigation of most crops.

VI. CONCLUSIONS

This study assessed the suitability of groundwater in the south-eastern coastal region between Abidjan and Aboisso (agricultural zone) for irrigation. At the end of this study, it should be noted that the majority of the groundwater in the area, with the exception of those in the Bingerville area, is of suitable quality for the irrigation of most cultivated species. These waters are generally mineralized with sodicity levels below 10%, without danger of alkalization or sodium fixation on the adsorbent complex of the soil. In terms of permeability index, more than 50% of water has an intermediate to acceptable permeability index for irrigation. The highly mineralized mediocre waters in the Bingerville area, which pose significant risks of soil salinization, are likely to be suitable for the irrigation of certain species that are well tolerant to salts and to well-drained and leached soils. In the absence of an adequate drainage system, any use of this type of resource, which does not provide for frequent leaching of irrigated soils, would lead to progressive salinization and would lead to a significant decline in agricultural productivity or even a loss Irreversible fertile soils.

VII. REFERENCES

[1] O. J. G Kpan., Y. M. S. Oga, K. T. Yao, A. F. Yapi, D. Baka, T. Lasm and J. Biemi, Impact of climate variabilty on water ressources and population health in the South Eastern coastal area of Côte d'Ivoire.*European Scientific Journal, edition vol.12, No.35,* 2016, pp 319-341

[2] Y.M.S Oga., M Adja, A.F. Yapi, J.G. Kpan, D. Baka, K.T Yao, et J. Biemi, Projection de la variabilité climatique à l'horizon 2050 dans la zone côtière au Sud-Est de la Côte d'Ivoire (d'Abidjan à Aboisso). *Larhyss Journal, ISSN 1112-3680, n°25*, 2016, pp. 67-81

[3] A. Benziane, N. Boualla, Z. Derriche, Aptitude des eaux du bassin de la Grande Sebkha d'Oran à l'irrigation. *Journal of Applied Biosciences,N0 56,*2012, 4066– 4074.

[4] M. Lahlou, M. Badraoui et B. Soudi, Modélisation de l'évolution de la salinité et de l'alcalinité dans les sols irrigués. *Séminaire « Intensification agricole et qualité des sols et des eaux »,* Rabat, 2-3 Novembre 2000; p : 135-151.

[5] M. S. Oga, F. M. Gnamba, B. AdiaffI, T. Soro, K. Oulai and J. Biemi, Aptitude of Groundwaters for Irrigation in Katiola Area. *Asian Review of Environmental and Earth, Vol. 2, N° 3,*2015, pp. 54-60.

[6] K. Todd, Groundwater hydrology, *J. Wiley & Sons, 2nd Edition*, New York, USA, 1980.

[7] R. S. AyersetD. W. Westcot, La qualité de l'eau en agriculture. *Bulletin FAO d'irrigation et de drainage. 29 Rév. 1*, 1988, 165 p.

[8] INS, Recensement générale de la population et de l'habitat de la Côte d'Ivoire, 2014, 22 p, /http : ins.ci

[9] I. Yacé, Initiation à la géologie. L'exemple de la Côte d'Ivoire et de l'Afrique de l'Ouest(Edition CEDA, Abidjan, Côte d'Ivoire, 2002).

[10] E. K. Rouabhia et L. Djabri, L'irrigation et le risque de pollution saline.Exemple des eaux souterraines de l'aquiferemiocene de la plaine d'el ma el abiod. *Larhyss Journal, ISSN 1112-3680, n° 08, 2010, pp. 55-67.*

[11] L.D Doneen,The influence of crop and soil on percolating water. Proc. 1961 *Biennial Conf. on groundwater recharge.*1962, P10.

[12] USSL. Diagnosis and improvement of saline and alkali soils. USDA, Handbook 60, 1954, p. 147.

[13] N. Soro. *Hydrochimie et géochimie isotopique des eaux souterraines du degré carré de Grand-Lahou et ses environs (Sud-Ouest de la Côte d'Ivoire). Implication hydrologique et hydrogéologique*. Thèse de Doct ès Sc. Nat Univ. de Cocody-Abidjan, Côte d'Ivoire, 2002.

[14] J. D. Devedas,R. B. Thirupathi, R. N. Subla, A. Subrahmanyam, andR. K. V,Scinivasa. Hydrochemistry of the sarada river basin, Visakhapatnam district, Andhra Pradesh, India, *Environ. Geol., vol. 52*, 2007, pp. 1331-1342.

[15] J. Biémi. *Contribution à l'étude géologique, hydrogéologique et par télédétection des bassins versants subsaheliens du socle précambrien d'Afrique de l'Ouest : Hydrostructurale hydrodynamique, hydrochimique et isotopie des aquifères discontinus de sillons et aire granitique de la Haute Marahoué (Côte d'Ivoire)*. Thèse de Doctorat ès Sciences Naturelles, Université de Cocody, Côte d'Ivoire, 1992.

[16] K. R. Orou, G. Soro, T. D. Soro, A. Traoré, N. R. M. Fossou et N. Soro, Aptitudes à l'agriculture des eaux souterraines du département d'Agboville (Sud-Est De La Côte d'Ivoire). *European Scientific Journal, Edition vol.12, No.21*, 2016, pp 81-100.

[17] K. Ncibi, N. Gaaloul, etA. Gasmi, Contribution de l'analyse multivariée et des SIG pour la caractérisation hydrochimique de la nappe phréatique de la plaine de Sidi Bouzid (Tunisie centrale). *International Journal of Innovation and Applied Studies, Vol. 15 No. 3*, 2016, pp. 667-684.

[18] FAO, Gestion intégrée des ressources naturelles eaux et sols de l'Afrique du Nord - Synthèse et propositions. *Bureau sous régional pour l'Afrique du Nord. Tunis, 2003*, 91 p.

[19] M. Qadir, A. D. Noble, S. Schubert, R. J. Thomas and A. Arslan, Sodicity-induced land degradation and its sustainable management: problems and prospects *.Ed Land Degrad. Develop. 17*; 2006, 661–676.

[20] D.L Rimmer, G. J. D. KirkandG. Bourrié,-land mark Papers: N°2. Quirk J.P et Schofield R.K.1955- the effect of electrolyte concentration of soil permeability. *Ed-journal of Soil Science, Vol; 6, N°.2*. 2013,pp163-178.

[21] ANAT.Étude Schéma directeur des ressources en eau W. de Biskra dossier Agro-pédologique. 2003, 53p.

[22] J. Maait,. La réutilisation des eaux usées en irrigation. Synthèse bibliographique. *ENGREF de Montpellier*, 1997.