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AGRICULTURAL WATER ASSESSMENT: CASE OF OFFICE DU NIGER, MALI

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ABSTRACT

The Government of Mali has been promotingirrigation in Mali in order to meet food needs of the growing population and in the context of climate change. One example of that effort is the Niger office which consists of a vast irrigated area for rice and vegetable production in Mali. More than two decadesago, farmers in the OdN have engaged them selve to apply fertilizer in their field to protect crops. Since then there is speculation to blame usage of fertilizer as main reason of water quality deterioration in Niger office, in order to bring more explanation to the effect of fertilizer to water quality, we have initiated that study to monitoring chemical parameters of water in office du Niger. According to WQI, we found that Sougouninda-Kolongo ville water quality to be poor, Diabali School has good water quality and the remaining 8 sample points have excellent water quality. Principal component analysis (PCA) of 9 chemical parameters result that PC1 explains 62, 66% of variance in data set. Dendrogram of Hierarchical cluster analysis presents 2 clear groups of similarity among sampling points in Niger office.

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INTRODUCTION

The relation between use of fertilizer in agriculture and its implicationsfor human health has been of concern within the context of sustainable agriculture. Increase of fertilizer application in agriculture has improved crop production, but at the same time may cause environmental issues because of unreasonable application (Conant, Bernadier, & Grace, 2013) (GU, JU, & Chang, 2017). Research has shown that only 36-39% of fertilizer is absorbed by the plant. The remain part is transported into the soil and groundwater system andeventually lost in nature through ammonia volatilization and denitrification (GU, JU, & Chang, 2017). TheOffice du Niger (OdN) is a government institution in Mali that manages one of the largest and oldest irrigated areas in West Africa. The intervention zone of OdN is the western part of the central delta of the Niger River. It is fed from a main feeder channel starting from theMarkala dam in the Niger River. OdN covers an area of 100,000 ha, through an irrigated system with a potential of one million hectare to be irrigate. Nowadays, the main missions of the ON are: water management, maintenance of hydro-agricultural infrastructures, land management, train and build capacity of farmers (de Wilde, 1967) (World Bank, 1979) (Walle, 1982) (Wageningen Agricultural University, 1983) (Klinkenberg, Huibers, Takken, & Toure, 2002), (Keita, 2003). (Male, 1991). The removal of the excess irrigation water from rice fields inOdN is done bya gravity-based drainage system. The functionalitythis system is often disturbed by lack of maintenance, which results in the presence of harmful aquatic plants in the beds of drains. The malfunctioning of the drainage favors infiltration of wastewater into the soil and underlying saturated zone and to a rise of thegroundwater table (Vandersypen, et al., 2006). Previous research in water monitoring in the wells in several places along the OdN, show that thegroundwater table is heavily recharged by the surface water (Fala, irrigation and irrigation canals) (Vandersypen, KEITA, COulibaly, Raes, & J Y, 2007). In addition to the irrigation return flow from agriculture, water quality inOdN is affected by solid wastedisposal and domestic wastewater. One needs to take account ofthe demographic pressure and scale of urbanization in OdN, as one of the intensification factors that has negative impacts in water quality in Niger office. Several studies relate water pollution (underground and surface) in the OdNto

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agriculture. Besides crop production and livestock farming and also people's settlements form a potential source of pollution (Carpenter, *et al*., 1998), (Jarvie, Whitton, & Neal, 1998). We noticed that all those 3 sources are severe In OdN all three sources are present. Crop production may pollute by diffusion, runoff, and leaching of excess irrigation water coming from the agriculture field, enriched in chemical products. In OdN, farmersapply 200kg of urea and 125kg of ammonium-phosphate in average per hectare. Additionally they apply pest control products, (rat control, and avian pests). Livestock may lead to water pollutionfrom animal droppings and sometimesfrom sanitary products used to treat insects-infested animals. Human populations may lead to water pollution by domestic wastewater discharge as well as by the residues of the chemicals used in everyday life (oils, detergents, gasoline). The health of humansliving in areasurrounded bypollutedwatermay be negatively affected by water pollution. Also livestock is not immune to the effects of some of these pollutants. Due to the characteristics of the hydrographic networks (surface water and groundwater), these pollutions can also extend to great distances from the sources, and reach the various natural environments parameters of the zone. Several techniques have been applied to monitor water quality around world, among all, water quality index (WQI) is one of the methods with the competence to facilityanalyses of water quality by grouping parameters to a common scale and combining them into a single number. We have decided to choice the method of WQI, because it can be used for both underground and surface water. (Juahir, et al., 2011) (Kim, et al., 2005) (Kowalkowski, Zbytniewski, Szpejna, & Buszewski, 2006). The aim of this study is quantify current pollution due to overuse of fertilizer in OdN and assess sources of water pollution.

Tableau 1. WHO standard value to calculate WQI

Parameter	Who Standards (mg/l)	Weight (wi)	Relative
K+	12	2	0.056
Na+	200	4	0.111
Mg+	50	3	0.083
Ca+	75	3	0.083
HCO3-	120	1	0.028
CL-	250	5	0.139
SO4	250	5	0.139
PH	8.5	3	0.083
T.D.S	500	5	0.139
NO3	11	5	0.139
		∑Wi = 18	∑Wi=1

MATERIALS AND METHODS

Description of study area: OdN (14018' N; 5059'W) is characterized by arid climate, annual rainfall is from 300 to 650mm (Haefele, Wopories, & Kropff, 2003). Soils is dominated by fluvisols combine with clay. OdN cover an area of 80,000 ha divided into 5 administrative zones and mainly cultivated by smallholders. Niger office is hierarchic irrigation which get water from Niger river at Markala dam. It is a network composed of primary, secondary and tertiary canals. The primary canal reaches 10 m wide and 5 m deep. The primary canal feeds secondary canalswhich can reach 4 m of wide and 3 m of deep.Secondary canals feed tertiary canals which deliver water to rice fields and also evacuated it to drainage network (Haefele, Wopories, & Kropff, 2003).

Sampling methodology: Samples for chemical analysis and turbidity analysis were taken during day time and collected between 15 to 30 cm under the surface of the water. In case, the depth of the pond is less than 30 cm, sample is taken in midway between the surface of the water and the bottom of the pond. Samples were taken in anarea not frequented by people at the time of sampling and between the exit of the filtration system and the return of water. In this study, water from 10 sampling points include underground and surface water were sampled in December 2016. Water was filtrated through a 0.40 Um sieve and then kept in clean bottles. We measured physical parameters in the field and then transported the samples into laboratory where they were kept sample at 4oC to prevent contamination.

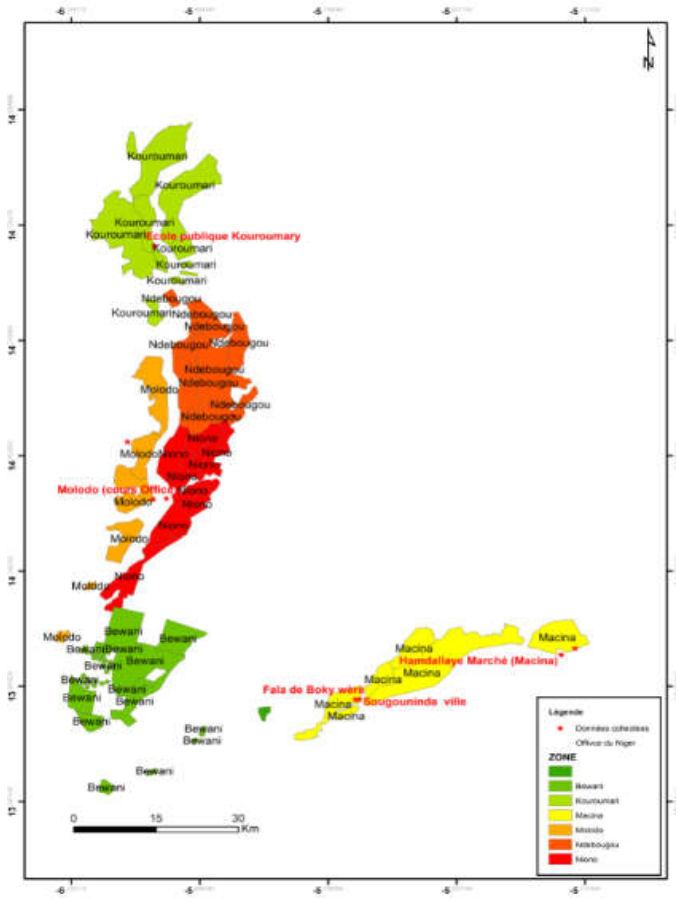

Figure 1. Map of Niger office

Data analysis

Water Quality Index (WQI) is a well-knownindicator to evaluate the quality of drinking water developed by (Brown, McClelland, A, & G, 1970). WHOstates that WQI clarifies composite effects of each parameters and it is considered as a reliable tool to assess the quality of water.

- Based on the effect of a parameter, one can determine the relative weight of each (out of 10) qualitative parameters which are present in qualitative analysis.

$$\mathrm{Wi} = \frac{Wi}{\sum Wi}$$

- The quality rating of each parameter obtained through dividing the concentration of each parameter (ci), by their standard values (S1), extracted from either WHO released information. I1is ideal value of each

Table 1. Water Quality Index results in 10 samples OdN

Name of the sampling points	Sample type r	WQI	Appreciation
Sougouninda-Kolongo ville	Groundwater	119.9	Bad
Hamdallaye Marché, ville Macina	Surface water	17.52	Excellent
Quartier A centre Tara BOUARE -Niono ville (marché)	Geoundwater	19.67	Excellent
Cour Office du Niger -Molodo ville	Groundwate	11.70	Excellent
Ecole publique-Diabaly ville (Kouroumari)	Groundwater	49.05	Good
Fala de Boky Wèrè 1er Bief à Kolongo Amont Canal	Surface water	13.92	Excellent
Fala de Molodo 1er Bief au point B	Surface water	12.25	Excellent
Drain Collecteur du Kala Inférieur Ouest (KIO) au Début	Surface water	13.92	Excellent
Drain Collecteur du Kala Inférieur Est (KIE) à N'Dilla	Surface water	12.25	Excellent
Drain principal de Ké-Macina à l'embouchure (Aval canal	Surface water	13.92	Excellent

chemical parameter which is equal to zero except PH=7.

$Q1=\frac{(Ci-I1)}{(Si-Ii)}$ X 100

- Sub-quality index of parameters need to calculate by multiplication of their specific relative weights to their quality rating scale.

  SIi = Qi X WI

- Where Wi is the relative weight of a parameter, Qi the quality rating and SIi is value of sub-quality index related to each parameter.
- Water quality index of each sample is computed by summing the sub-indices.
  WQI= ∑ SIi
- We use principal component analysis to assess new factorsand structure of data set of chemical parameter and cluster analyze was applied to find similarity among of sampling stations.

RESULTS AND DISCUSSION

Temperature and pH: Water temperature ranged from 19.9 to 30.3oC, which is in the standard value of WHO and that of Mali. Temperature is important because it influence chemical and biological reaction in the water body. Variability of sample temperature is due to the time and weather duringcollection. PHvaries from 7.13 - 5.98; we noticed that the samples harvestedfrom channels (drain) are slightly alkaline, that may be due to human activity in those places.

Lithium and Malathion: Lithium and Malathion are parameters used to attest the presence of pesticide in water. They have negative effect on human health and impact badly on fish in river. Lithium and Malathion are absent in underground water, but present in surface water; the range of concentration of lithium and Malathion range from 0.003 to 0.006. According to Malian standard concentration of Lithium and Malathion didn't reach pollution level in Niger office.

WQI: Pollution Index give suggestion to water qualitycontrol officers to take action to improve water quality in Niger office. According to pollution analyses index of different sample stations (table below) in Niger officewe found that Sougouninda-Kolongo ville water quality is poor, Diabali School has good water quality and the remaining 8 sample points have excellent water quality according to WQI (see below table). Based on WQI the general condition of water in OdN is good.

Principal Component Analysis of chemical parameter in office du Niger: Principal Component Analysis (PCA) of 9 chemical parameters result that PC1 explains 62, 66% of variance in data set. PC1 and PC2 associated explain 81, 04% of variance. Chemical parameter Ca, Mg, Na, K, HCO, NO3 have highest loading value in PC1, which suppose that those parameter varied together. Parameter of CL and Fe have highest loading value in PC2, that fact mean that those 2 parameter varied together. Plot of PC1 versus PC2 show strong coloration between NA, NO3 and K, which mean that those parameters are from same source in ON. Likely that is due to fertilizer applied by farmers, because Na, NO3 and K can come directly or indirectly from fertilizer applied in ON. Parameter HCO and MG have strong coloration according to Plot of PC1 versus PC2, this imply that those parameters have same source in Niger Office, which source also can be different pesticide and fertilizer applied byfarmers.

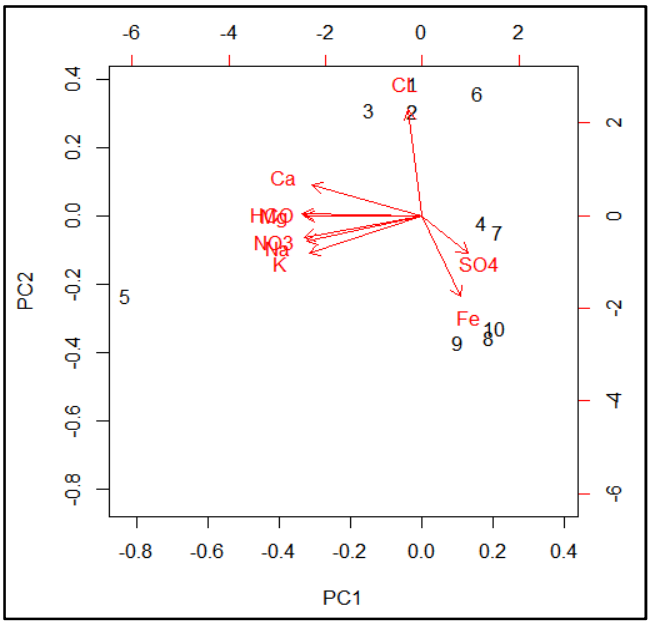

Figure 2. Biplot of water chemical parameters in Niger office

Hierarchical cluster analysis of sampling point: Dendrogram of Hierarchical cluster analysis presents 2 clear groups of similarity among sampling points in Niger office. The first class is constituted of samples Number 9 and 10. Those 2 samples are the waste water is collected from rice field. The second class is constituted of sampling numbers 1,2,3,4,5,6,7 and 8 in that group. The second group is divided into 3 sub-groups, first sub-group is a stand out of sample number 5.Second sub-group is consist of sample numbers 2 and 3, and the last sub-group is sample numbers 1, 4, 6 and 8.

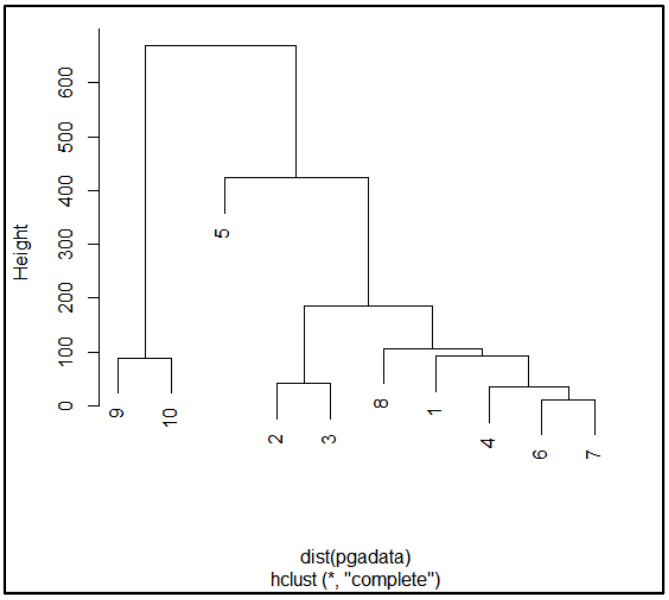

Figure 1. Cluster analyze of sample points

Legendre:
Kolongo ville Sougouninda ----------1
Macina ville, quartier Hamdallaye marché----------2
Niono ville quartier A- Centre Tara BOUARE----------3
Molodo ville dans la cour de l'Office----------4
Diabaly (zone Kouroumari)-Ecole publique----------5
Kolongo réseau d'irrigation Fala de Boky Wèrè 1er Bief-amont canal----------6
Fala de Molodo 1er Bief au point B----------7
Molodo Drain Collecteur du Kala Inférieur Ouest (K.I.O.) au début- jonction des 2 drains----------8
N'Débougou Drain Collecteur du Kala Inférieur Est (K.I.E.) à N'Dilla----------9
Drain principal de Ké-Macina déboucher coté Est----------10

DISCUSSION

Although fertilizer use by farmers in OdN has been generally increasing over the past years, results ofWater Quality Index (WQI) shows that water quality is good.It means that chemical pollution is not severe in ON.That is explained by the fact that fertilizer has diluted by huge amount of water which cross farm lands in Niger office. Sampling point of Sougounida kologo has poor quality, that is due to human activities. It is a place where waste from market is pour down and there is no protection to prevent it from contaminating surface water in Sougounida kologo. This collaborate with finding of previous research which conclude that human health issues in ON is due to the fact that, mostiquo anopheline larva use rice field as breeding area.(Nafomon, *et al*., 2007). Water borne diseases vectors animals like snails, fly and bacteria are spread in rice fields, associated with social life style and environment conditions can be consider as main reason of human health in ON. (Klinkenberg, Takken, Huibers, & Toure, 2003). Na, K and NO3 are components of type of fertilizer applied by farmers in ON; which means more they applied fertilizer the more the water will receive more Na, K and NO3. In another way that means main source of Na, K, and NO3 in water is from fertilizer in ON.Cluster analyses result can be explained by the fact that water from drain are directly coming from rice fields in ON, which explains why concentration of chemical parameters is high in drain compare to other sampling points.

Conclusion

Analysis results show it is clear that the use of fertilizer by farmers is the main reason for chemical parameters levels increase in the surface water bodies in OdN. However, the WQI analysis shows that the water quality levels remain in acceptable limits. One common way to treat liquid waste is to dilute it with water. In OdN huge amount of fertilizer is diluted by water from Niger river and rainfall during rainy season. Therefore another study to investigate the impacts of use of fertilizer on presence of bacteria and insects that infect people living near rice field in ON is required. Agricultural techniques applied in OdN stagnant waters for a long time in the field, therefore it is of interest to further explore the impact of stagnant water on level of waterborne disease in OdN.

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