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Impacts of Agricultural Irrigation Activities on Water Resources in the Alluvial Plain of Karfiguela, Cascades Region: Burkina Faso

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Abstract :- The Karfiguela alluvial plain, covering an area of 46.496 km², is located in the Cascades region, one of the thirteen regions of Burkina Faso. It has significant surface and groundwater potential. An area of 350 ha is developed for rice cultivation. However, the combined effects of expanding agricultural areas, overexploitation of water resources, and inappropriate agricultural practices are leading to the degradation of water resources. Therefore, understanding the impacts of agricultural practices is essential, which is the focus of this study. The study aims to analyze the impacts of irrigated agriculture on water resources.

The methodological approach is based on both quantitative and qualitative methods, organized into three main phases. The first phase, design, allowed us to define the indicators and data to be collected, develop the tools, and determine the methods for data collection and processing. The second phase involved data collection from thirty-three organizations, the regional agricultural directorate, and PADI. The third phase consisted of processing and analyzing the data, followed by drafting the article.

The study results indicate that proximity to riverbanks and overexploitation of river water are contributing to the physical degradation of the resource. This is manifested through the development of micro-dams and siltation. These practices lead to flooding, premature depletion of water resources, and destruction of the aquatic ecosystem. The use of agricultural inputs has not yet affected the quality of groundwater.

Keywords:- *Karfiguela Alluvial Plain, Groundwater Management, Irrigable Areas.*

I. INTRODUCTION

Agriculture in Burkina Faso, which is predominantly rainfed, faces challenging agro-ecological conditions due to climate degradation and increasing anthropogenic pressure associated with rapid population growth. As a result, the development of irrigated agriculture has become a major issue for achieving food security in the country. In fact, the share of irrigated production in total agricultural output, which was 15% in 2015, is expected to reach 25% by 2020 (PNDS, 2016-2020).

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This favorable political environment for irrigation development has led to the expansion of irrigated agricultural areas, increased water demand, and sometimes improper water resource management, especially exacerbated by competition and conflicts over water use. This expansion is particularly marked in the Karfiguela plain. According to NOMBRE A., 1984 (cited by CNID-B), 75 ha of the Karfiguela plain was developed in 1975. This developed area increased to 150 ha in 1976 and 350 ha in 1977. Additionally, there are non-irrigated operations.

In terms of water demand, agriculture is one of the highest water-consuming sectors worldwide (TIBERGHIEN F., 2012). Food production, and the agriculture it depends on, are by far the largest consumers of water, as the water required to produce our food is a thousand times greater than that we drink and a hundred times more than what is needed for basic personal needs. Irrigation accounts for up to 70% of the water extracted from rivers and groundwater (FAO, 2004). In fact, according to FAO (2019), in Burkina Faso, the agricultural sector ranks first with 51.43% (2005) of total water withdrawals, far ahead of municipal (45.92%) and industrial (2.65%) uses. This growing water demand, observed at the national level, is also evident in some regions of the country, particularly in the Cascades region.

The estimated value of water demand from dams during the dry season varies depending on the author. ORSTOM in 1998 (DEZETTER et al., 1998) prioritized the following needs: potable water for Banfora at 1.1 million m³; for industry at 3.6 million m³; for agriculture (4,000 ha of sugarcane, 350 ha of rice, and 100 ha of vegetable farming) at 49 million m³, totaling 53.9 million m³ with a dam capacity estimated at 51.6 million m³. The Local Water Committee of Cascades in 2009 (AEDE, 2009) estimated the water demand (from December to June) at 52,858,447 m³ for a mobilizable volume of 57 million m³. This demand consists of 588,277 m³ for drinking water, 8,407,584 m³ for the Karfiguela rice plain (350 ha), 9,913,040 m³ for vegetable farming (876 ha), 31,203,026 m³ for SN-SOSUCO, and 2,747,520 m³ for ecological needs.

Analysis of ONEA's data on the evolution of water withdrawals shows that the volumes extracted increased from 754,684 m³ in 2003 to 1,140,184 m³ in 2011. This quantity will continue to rise with the inclusion of Bérégadougou in the Banfora distribution network and the incorporation of gold miners (cited by TRAORE et al., 2016). The estimates did not account for pastoral water demand, which is actually the largest after agricultural demand in the region. In the Comoé basin, the estimated water demand for livestock (682,092 Tropical Livestock Units or UBT) was 11.20 million m³ in 2009, and is projected to reach 15.71 million m³ by 2025 (VREO, 2010).

Regarding water quality, SYLLA M. (2008) examined the challenges of mobilizing, distributing, and managing the impacts of dam developments in Burkina Faso. His study concluded that one of the causes of mobilizing surface and groundwater resources is the level of pollution that these waters may contain. Pollution can originate from various sources (industrial, domestic, agricultural), and depending on the type of pollutant, the water resource could either be reused or lost.

Additionally, the development of dams to address these issues has led to the growth of agriculture, resulting in an increased use of inputs. Mismanagement of these inputs, whether organic or mineral, can be dangerous for aquatic ecosystems when their application to crops is excessive and the soil's retention capacity is low. Indeed, mineral excesses carried by runoff accumulate in surface waters, leading to eutrophication.

Furthermore, eutrophication is responsible for the significant growth of phytoplankton and macrophytes, which increases oxygen consumption and leads to water pollution that can result in the loss of water storage areas[1]. Phosphates, nitrates, and sulfates are the primary causes of eutrophication.

Thus, SIMBORO A. (2016) states that the groundwater of the Karfiguela alluvial plain is overall vulnerable to pollution due to the physical conditions of the aquifer. His study found that areas of high vulnerability include Karfiguela, Banfora North, Tengrela, and Sitiena South, and the risk of pollution is high due to agricultural practices. Similarly, the areas most favorable for induced recharge coincide with those most vulnerable to pollution.

This context frames the present study, which aims to analyze the impacts of irrigated agricultural activities on the water resources of the Karfiguela alluvial plain in the Cascades region.

II. METHODOLOGICAL APPROACH

The methodological approach of the study is based on four essential components: (i) the characterization of the study area, (ii) the definition of the operational framework, (iii) data collection, and (iv) data processing and analysis.

A. Characteristics of the Study Area

The Karfiguela alluvial plain is located in the extreme southwest of the country, approximately 10 km northwest of Banfora in the Comoé province. The plain lies between longitudes 4°50' and 4°42' West and latitudes 10°44' and 10°28' North. It covers an area of 46 km² and extends 28 km in length (COMPAORE N.F, 2012), spanning the localities of Karfiguela, Tangréla, Nafona, Lémouroudougou, Kribina-Lèna, Tiékouna, Niankar, Bounouna, Kossara, Diarabakoko Sitiéna, and Banfora. It is accessible from Ouagadougou via National Route No. 1 (RN1) from Ouagadougou – Bobo –

[1] http://www.2ieedu.org/forum_crepa_07/Theme1/Com_Koussao.pdf

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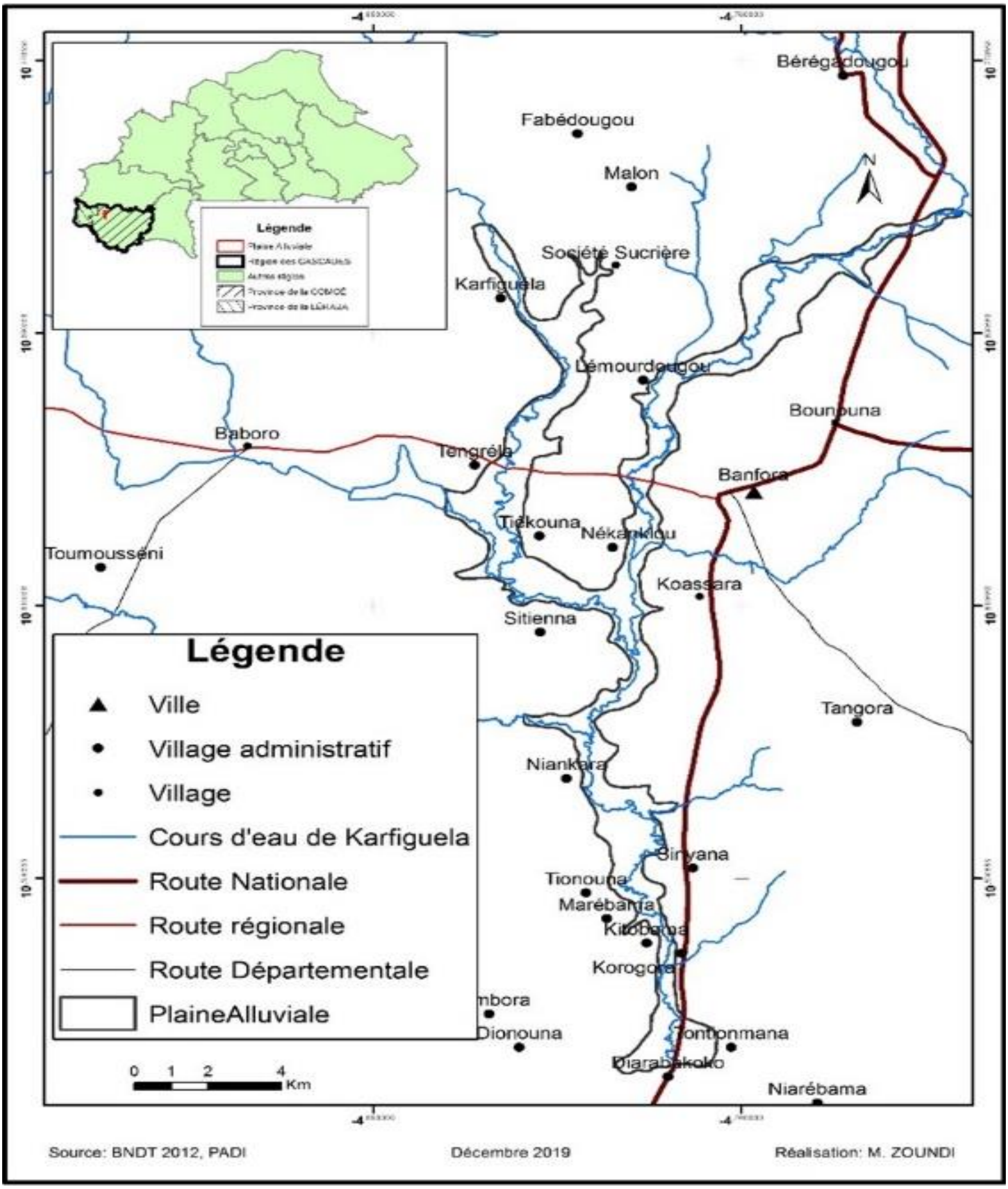
Banfora, a 445 km route that is passable year-round, and then via the Banfora – Karfiguela road, which becomes difficult to navigate during the rainy season.



Map 1: Geographical Location of the Alluvial Plain of Karfiguela

B. Operating framework

The operational framework is the conceptual model of the study. It allowed for the definition and interrelation of the objective, variables, data, sources, and tools for data collection, processing, and analysis. The table below presents the conceptual framework of the study.

Table 1: Conceptual Framework

Assumptions	Objectives	Variables	Verifiable indicators	DATA			Collection approach
				Type	Tools	Spring	
The quality of water resources is degraded by irrigation activities.	Analyze the impacts of irrigation activities on water resources.	Water quality	- Respect for the easement strip - Use of phytosanitary products - Presence in the water, at an extraordinary rate, of molecules from phytosanitary products used by farmers - degradation of the watercourse by agricultural activities	Data from analytical laboratories - Standards on the levels of chemical elements in water for irrigation - the chemical composition of the phytosanitary products -the chemical composition of the water used for irrigation in the alluvial plain of Karfiguela Physical and observational data: - Physical and ecological degradation observed - geographical position of the plots in relation to the banks	- documentation -survey sheet - questionnaire -Chemical analysis of water	- field (for sample collection, GPS survey) -Analysis report/result -documents	-Survey of producers -Observation of the environment and GPS survey -Spatial analysis - Water sampling and analysis

Source: ZOUNDI Mahamadi 2022

C. Data Collection

The data collected come from different sources and are therefore grouped into three (03) types: physical data, sociological data and data from analysis and observation laboratories in the field.

Physical data are essentially the geographical position of the farms. To this end, the crop areas were georeferenced using a GPS (Gamin map 64S) and documented.

Sociological data are made up of producers' perception of the use of the phytosanitary products used, operating practices and their impact on water resources.

These data were collected by a sociological survey based on a reasoned survey oriented towards the farming populations of the alluvial plain, the agricultural council and the decentralised administration. These include farmers' cooperatives, individual farmers, members of the agricultural council and decentralised technical services.

Laboratory data are those relating to the chemical quality of the water according to the drinking water guide values of the World Health Organization's Drinking Water Quality Directive (WHO 2011). To this end, water samples were taken from the structures and the watercourse to be analysed in the laboratory. Also, information on the products (pesticides and herbicides) used was collected from producers. In addition, field observations on water management practices and the physical degradation of water resources completed the need.

D. Data Processing and Analysis

At the end of the data collection, we first proceeded to the pre-processing of the data, then to the processing and in order to analyze and interpret the results obtained.

The pre-processing consisted of the analysis, entry, sanitation and grouping of the data collected by study variable and by source.

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Then, processing with the help of Microsoft EXCEL made it possible to create tables and graphs for analysis and interpretation

Several methods of analysis were used depending on the verifiable indicators of the hypotheses. The analyses carried out are broken down by the following table:

Table 2: Method of Analysis of the Variable Water Resources Quality

Variables	Verifiable indicators	Data	Method of Analysis
Quality of water resources.	Distance of the plots from the banks	- Geographical coordinates of the plots. -Geographical boundaries of the easement area.	Spatial and statistical analysis method: $Ratio\ d = \frac{Dp}{100}$ If Ratio d > 1, then there is respect for the easement area so no likely impact If Ratio d ≤ 1, then the easement area is not respected and therefore there is likely impact.
	Use of phytosanitary products.	The chemical composition of phytosanitary products.	Inventory of plant protection products used List of the chemical composition of the plant protection products used
	Presence in the water, at an extraordinary rate, of molecules from phytosanitary products used by irrigators.	-Standards on Chemical Elements of Water for Irrigation -The ratio of chemical elements in the water for irrigation.	$Ratio\ E = \frac{Valeur\ E}{Norme\ E}$ If Ratio E ≤ Norm E, then there is no impact. Si ratio e > norme e, alors il y a impact.

Source : ZOUNDI M. 2022, ONEA, Laboratoire Central 2014

III. STUDY RESULTS

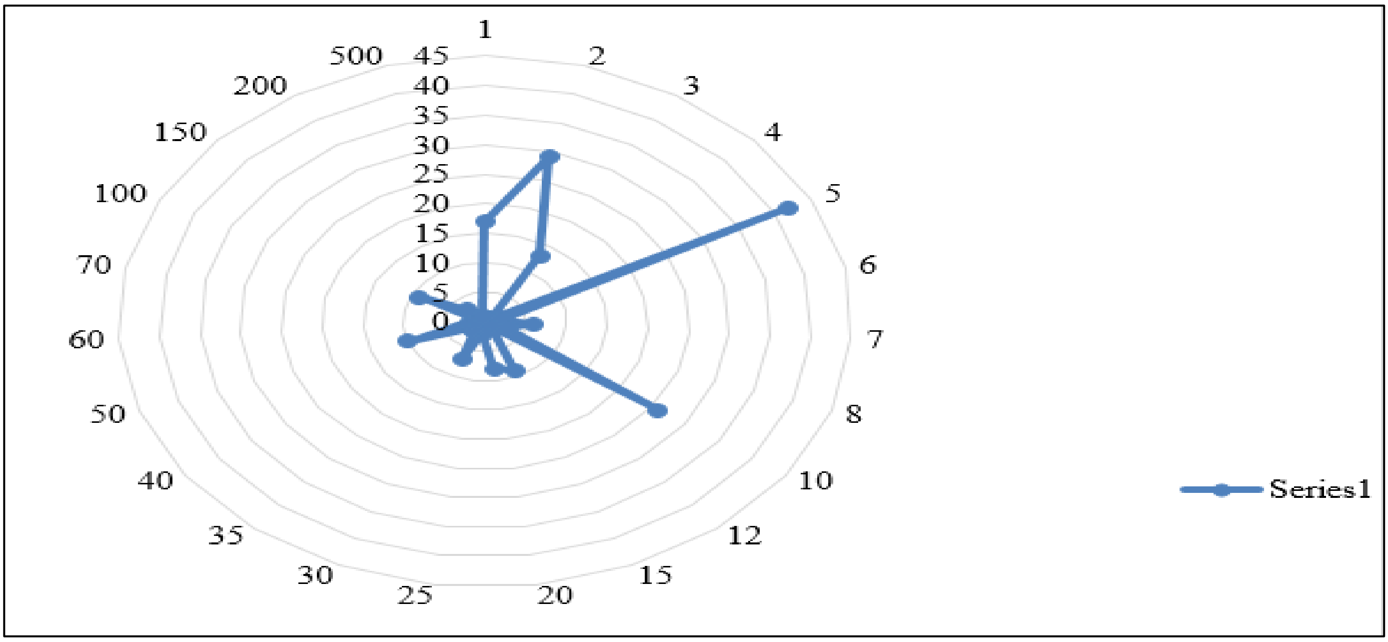
The results focus on analyzing the impacts of irrigated agricultural practices on the water resources of the plain. It identifies and describes the agricultural factors contributing to water resource degradation and analyzes the physicochemical impacts of agricultural activities on the water resources of the Karfiguela plain.

A. Agricultural Factors Contributing to the Degradation of Water Resources in the Karfiguela Plain

Inappropriate agricultural practices are a significant source of water resource degradation. Two major agricultural factors contributing to the degradation of water resources in the Karfiguela plain are identified and analyzed in this study. These are: (i) proximity to riverbanks and (ii) inappropriate use of agricultural inputs.

➢ *Proximity to Riverbanks*

The location of farming areas relative to the riverbanks influences the sustainability and quality of water resources. Farming near riverbanks contributes to the physical degradation of the watercourse and the deterioration of water quality. In the Karfiguela plain, farmers are settled along the riverbanks and irrigation canals. They are situated at varying distances from the riverbanks (see Graph 3).



Graphic 1: Stock Market Diagram on Radar Showing the Distances of the Farms from the Banks of Karfiguela
Source: 2022 Field Data

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The blue lines labeled "Series1" represent the number of farmers. These lines point to numbers along the outer circle, which indicate the distances from the Karfiguela riverbanks.

From the analysis of the graph, we deduce a significant pressure on the Karfiguela riverbanks. The number of farmers is concentrated in the short-distance range from the riverbanks. In fact, only 9% of the farmers are located more than 100 meters from the Karfiguela riverbanks, while 91% are situated between 1m and 100m. This situation calls for an analysis of the impacts of farming practices along the riverbanks on water resources.

According to a census conducted by the Cascades Water Agency in 2016, there were 1,367 market gardeners settled within the river's buffer zone along the Comoé River in the Karfiguela alluvial plain (the area within 100 meters on either side of the riverbed). The photos below illustrate irrigated farming operations that are located next to the Comoé riverbanks.

Photo 1: Occupation of the Banks by Producers
Cliché : ZOUNDI Mahamadi, November 2022

The red line marks the boundaries between the banks of the river and the farms.

- *Use of agricultural inputs*

- *The Different Types of Agricultural Inputs*

- Fertilizer : Fertilizers are substances, most often mixtures of mineral or organic elements intended to increase or maintain soil fertility. They provide plants with additional nutrients to improve their growth and increase crop yield and quality. There are two (2) types of fertilizers:
- chemical or synthetic fertilizers: e.g. NPK (N, P2O5, K2O), NPKSB
- Organic fertilizers: e.g. compost, organic manure

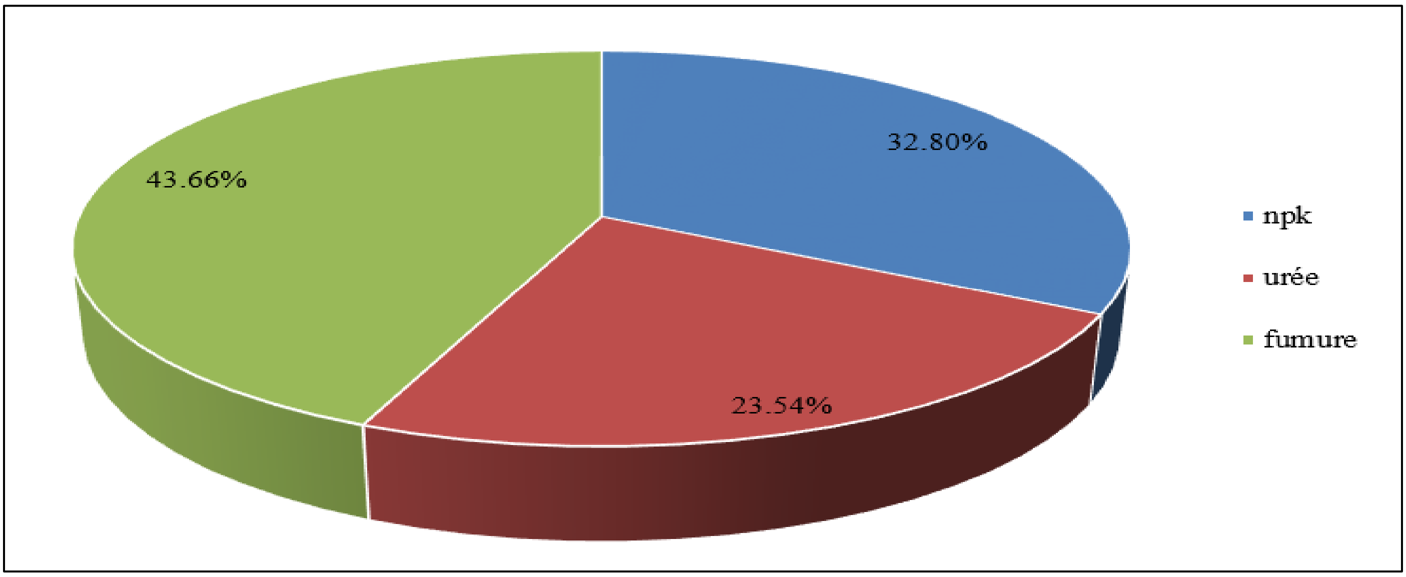
- *Fertilizers Provide Plants with:*

- the major fertilisers needed in large quantities: nitrogen (N), phosphate (in the form of P2O5) and potassium (in the form of K2O);
- secondary fertilising elements such as calcium (in the form of CaO), sulphur (S), magnesium (Mg), sodium (Na),
- small quantities of trace elements required: boron(B), iron (Fe), copper (Cu), zinc(Zn), molybdenum (Mo) and cobalt (Co).
- Pesticides: According to *DANIDA* cited by KAM A, 2007, pesticides can be defined as chemical substances aimed at repelling, combating or destroying pest vectors, diseases or nuisances that may cause damage or alteration during the production, processing and storage of agricultural products.

- *Agricultural inputs used by producers in the Karfiguela plain*

In order to increase production and obtain better yields, fertilizers and pesticides are used in the production of almost all crops in the alluvial plain of Karfiguela.

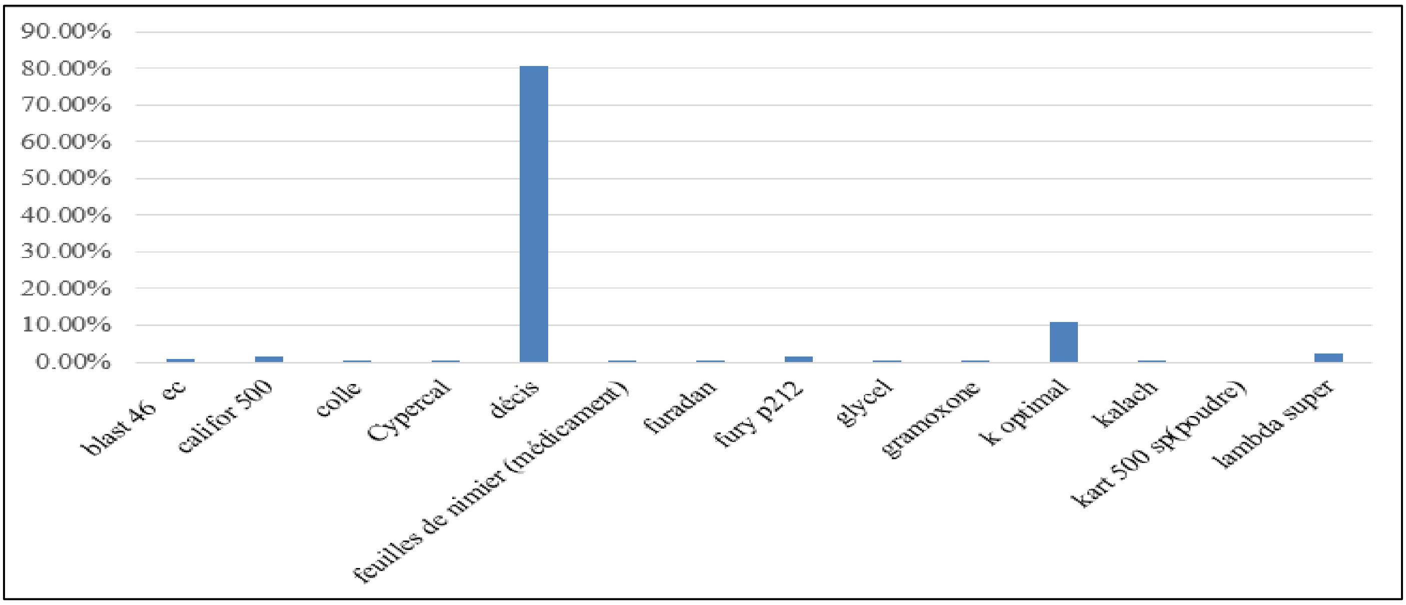
In terms of fertilizers, the most used by producers in the Karfiguela plain are organic manure, NPK and urea. The graph below shows the proportion of fertilizer used by formula by producers in the Karfiguela plain.



Graphic 2: Proportion of Fertilizer Formulas Consumed in Agricultural Production of the Karfiguela Alluvial Plain
Source: Field Survey, 2022

Chemical fertilizers are the most used with 56% of total consumption. The most consumed formulas are NPK (33%), and Urea (23%). Organic manure is also used in the Karfiguela plain.

In terms of pesticides, contact pesticides are used much more, as we can see in the following graph.



Graphic 3: Proportion of Pesticide Consumption
Source: Survey 2022

Of the pesticides, Décis is the most used by producers in the Karfiguela plain. Indeed, 80% of the pesticides used by producers in the Karfiguela plain are Décis.

B. Impacts of Agricultural Practices on Water Resources in the Karfiguela Alluvial Plain

- *Physical Degradation*

Inappropriate agricultural practices lead to the physical degradation of water resources. The territorial expansion of agricultural activities (Jolankai G., 1990) and the exploitation of the Comoé riverbanks have such an extent that their impacts predominantly manifest in phenomena such as sedimentation/siltation, the development of micro-reservoirs, and the early drying up of the river.

Erosion is the primary cause of siltation. River siltation is a natural process that is part of the ecosystem’s dynamic balance. However, this balance can be disrupted by various human activities, including the exploitation of riverbanks and runoff from soils disturbed by agricultural practices, thus accelerating the process of siltation and erosion (VACHON A., 2003).

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On the Karfiguela plain, the occupation of the riverbanks on both sides of the river and its main channel has led to siltation of the watercourse in certain areas (see photo

Photo 2: Silting up of the watercourse
Photo: ZOUNDI M., April 2022

According to a diagnosis by the Kamouraska Watershed Organization, as part of the development of the water master plan for L'Islet and Rivière-du-Loup (May 2014), several impacts result from the sedimentation of watercourses.

5). This has resulted in a reduced flow in the Karfiguela river and recurrent flooding during years of high rainfall.

One of the major impacts of sedimentation is the loss of habitat for aquatic wildlife, such as fish and macroinvertebrates, as the habitat is buried under sediment. Excessive sediment can also lead to changes in the community structure of certain species, resulting in reductions and even extinctions.

An abundance of sediment also increases turbidity, which limits the amount of light entering the waterway, reducing the primary production upon which the rest of the food chain depends. Consequently, food production for aquatic fauna is diminished.

According to the same diagnosis, a decrease in reproductive success in fish can also be observed, as eggs cannot attach or breathe when covered by sediment.

Furthermore, according to the Water Framework Directive (WFD, 2012, cited by the MEDE), the consequences include habitat homogenization, loss of biodiversity, and the decline of the river's self-purification capacity. In fact, it asserts that the river is becoming biologically poorer and increasingly vulnerable to pollution, discharges, and inputs from various sources. Sand, for example, does not allow the presence of beneficial organisms, particularly "filter feeders," which play a role in absorbing pollution.

Another phenomenon of water resource degradation that is prevalent in Karfiguela is the development of micro-water reservoirs in the riverbed (see photo 3). According to some farmers, during water shortages, they fetch water from the riverbed to ensure the final phase of crop irrigation. Some of them say, "When there is a lack of water, we dig in the river to get it." These practices have led to modifications in the river's profile, consequently disrupting its flow regime.

Photo 3: Development of Micro-Reservoirs in the Bed of the Comoé by Producers
Photo: ZOUNDI M., April 2022

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In addition, there is an overexploitation of the river in favour of irrigation. Thus, the environmental flow is used in irrigated agricultural production (see photo 4). These practices have led to the drying up of the river and an ecological tragedy, including the destruction of the aquatic ecosystem. Indeed, dead mussels following the early drying up of Karfiguela have been identified in Niankar (Cf. photo 5).

Photo 4: Drying up of the Watercourse due to Poor Cultural Practices

Photo 5: Dead mussels following the early drying up of the river in the Niankar area
Cliché : DRAAH – Cascades, 2016 ; ZOUNDI M., 2022

In light of the impacts of agricultural activities, particularly those related to the exploitation of riverbanks and environmental flow, it is necessary to understand the logic behind the settlement of farmers in the Karfiguela plain.

Managing the pressure resulting from the exploitation of the Karfiguela riverbanks requires an understanding of the reasons behind their use. Several factors explain why farmers exploit the riverbanks.

First, the need for easy access to water at a low cost leads farmers to settle closer to the river. Some farmers, unaware of the potential damage their actions may cause, believe that exploiting plots near the river or the irrigation canal requires less physical and financial effort. In fact, 56% of farmers agree that their proximity to the riverbanks provides easy access to water with reduced physical effort and cost. This is reflected in some of the farmers' statements: "We are close to the river because it's less tiring and less expensive." Thus, in an effort to satisfy their water needs, farmers prefer to settle near the riverbanks.

Second, the proximity of certain farmers to the riverbanks can be explained by the allocation of land for farming. It is near the riverbanks that landowners have granted them access to land. As such, 20% of farmers in the plain are forced to farm the land allocated to them by landowners.

Next, tradition plays a role, with some farmers citing the habit of the area as an explanation for their current position relative to the riverbanks. Among the farmers surveyed, 8% justify their proximity to the riverbanks by the habit of the area. These farmers have been farming the same plots for years and have developed an attachment to the land. It is therefore difficult for them to leave these areas.

Additionally, land tenure is a key factor explaining the agricultural occupation of the Comoé riverbanks. The analysis results reveal that 6% of the farmers surveyed own the land, with 92% of them farming within the servitude zone, compared to only 8% situated outside of this zone. Furthermore, 3% of the farmers have inherited their land, with over 70% of them farming within 10 meters of the riverbanks.

Finally, a lack of available land explains why some farmers occupy the riverbanks. Indeed, 7% of the farmers surveyed justify exploiting the riverbanks by the lack of usable land. Among these farmers, 85% have their plots within the servitude zone.
In the traditional land tenure systems, which remain widespread, access to arable land is particularly problematic for women, who often only have precarious usage rights (typically annual) and generally work on degraded land.

- *Degradation of the Chemical Quality of Karfiguela's Water Resources*

The analysis of chemical degradation was based on the available data. In this regard, the PADI-BF101 project already had groundwater analysis data (see Appendix 3), which were used for this study. The data consist of water samples from 13 piezometers distributed across the Karfiguela plain.

The sampled data were analyzed. The parameters that were analyzed are presented in the following table.

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Table 3: Water Quality Analysis Parameters

Parameter	Unit	Parameter	Unit
TOCK	meq/L	Calcium	mg/L
Turbidity	NTU	Magnesium	mg/L
Chloride	mg/L	Total Hardness	mmol/L
Fluoride	mg/L	Cyanide	mg/L CN
Sulphate	mg/L	Carbonate	mg/L
Nitrite	mg/L N	Bicarbonate	mg/L
Nitrate	mg/L N	Arsnic (As)	ug/L
Sodium (Na)	mg/L	Lead (Pb)	ug/L
Potassium (K)	mg/L	Mercury (Hg)	ug/L
Fer total	mg/L	Zinc Zn)	mg/L

Source: PADI Water Analysis Sheets

The results of the analysis of these parameters allowed us to interpret the degradation of groundwater quality in relation to drinking water quality and irrigation standards.

- *Degradation compared to drinking water quality standards*

The data were interpreted with reference to the drinking-water guideline values of the World Health Organization's Drinking-Water Quality Guideline (WHO, 2011). The standards of analysis are recorded in the following table.

Table 4: Drinking Water Quality Standards

Parameter	Unit	WHO Standards
TAC	meq/L	
Turbidity	NTU	5.0
Chloride	mg/L	250
Fluoride	mg/L	1.5
Sulfate	mg/L	250
Nitrite	mg/L N	0.9
Nitrate	mg/L N	11.4
Sodium (Na)	mg/L	200
Potassium (K)	mg/L	
Fer total	mg/L	0.3
Calcium	mg/L	
Magnesium	mg/L	
Total Hardness	mmol/L	
Cyanide	mg/L CN	
Carbonate	mg/L	
Bicarbonate	mg/L	
Arsnic (As)	ug/L	10
Lead (Pb)	ug/L	10
Mercury (Hg)	ug/L	1
Zinc Zn)	mg/L	3

Source: WHO, 2011 (from the 2015 PADI report)

Reading the table, we note that the standards of certain parameters have not been mentioned. This is due to the fact that the WHO does not take these parameters into account in the estimation of drinking water quality.

The results of the analysis of the samples and the interpretation of these results are given in Table 20.

Table 5: Water Quality Results and Interpretation based on WHO Drinking-Water Standards

Place	Turbidity	Chloride	Fluoride	Sulfate	Nitrite	Nitrate	Sodium (Na)	Fer total	ARSENIC	LEAD	MERCURY	ZINC
ANALYSIS RESULTS												
KARBR1	1.3	1	-1	15.6	1.7	4.8	2	0.05	-1	-1	-0.1	-0.02
KARFPA3	128.4	7	-1	21	7.1	3.5	0	0.12	-1	-1	-0.1	-0.02
KARPA1	136.8	7	-1	43.9	10.1	0.7	2	0.2	-1	-1	-0.1	-0.02
P2RG16	113.6	1	-1	18.5	4.6	4.8	0	0.2	-1	-1	-0.1	-0.02
PZ RG 36	10.3	2	-1	11.5	3.1	2.1	0.1	0.25	-1	-1	-0.1	-0.02
PZ RG X1	0.5	7	-1	7.6	1.9	2	1	0.35	-1	-1	-0.1	-0.02
PZK03	135.6	2	-1	26.7	10	7.7	0	0.4	-1	-1	-0.1	-0.02

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PZK04	192.1	2	-1	54.6	18.5	2.8	0	0.85	-1	-1	-0.1	-0.02
PZKO2KD19	157.1	1	-1	37.8	24.8	91.5	0	97	-1	-1	-0.1	-0.02
PZKO7		3	-1	14.9	4.1	12.5	0	0.2	-1	-1	-0.1	-0.02
PZRD15	122.5	8	1	23.3	7	4.4	0	0.3	-1	-1	-0.1	-0.02
PZRD31	124.3	4	-1	19.5	5.5	4.9	0	0.4	-1	-1	-0.1	-0.02
PZRDX3	0.5	5	-1	8.1	3.2	5.3	1	0.4	-1	-1	-0.1	-0.02
STANDARDS	5	250	1.5	250	0.9	11.4	200	0.3	10	10	1	3
INTERPRETATION DES ANALYSES												
KARBR1	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
KARFPA3	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
KARPA1	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
P2RG16	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZ RG 36	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZ RG X1	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZK03	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZK04	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZK02KD19	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZKO7	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZRD15	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	gradient	Not degraded	Not degraded	Not degraded	Not degraded
PZRD31	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded
PZRDX3	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded	Not degraded

Source : PADI 2016, ZOUNDI M., 2022

The results of the laboratory analyses of the water samples revealed that substances deteriorating the water quality were observed (see Table 17). These results were interpreted by chemical parameter for each micropiezometer. This consisted of comparing the results of the analyses to the quality standards defined by the WHO. To do this, the "If" function of Microsoft Excel was used. Thus, the state of each quality parameter has been classified as "degraded" if the normative values are not respected. On the other hand, if the normed value is respected, then the state of the parameter is "not degraded".

All the parameters of all the structures have been classified as "not degraded". We then deduce that the water of the alluvial plain of Karfiguela is of good quality. Therefore, agricultural activities in the Karfiguela plain have not affected groundwater to the point of degrading its qualit

The results reveal the presence of chemical elements in the water that can degrade water quality. However, these substances are of low quantities according to WHO standards and can therefore affect human and animal health.

- *Degradation Compared to Irrigation Water Quality Standards*

The assessment of the quality of the water for irrigation was carried out according to the parameter class values defined by MAYNARD D. N. et al.; 1997 (see Table 6).

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Table 6: Degradation Severity Class According to Irrigation Water Quality Analysis Parameters

Type of problems	**Severity of the problem**		
	No	**Light**	**High**
Salinity Conductivity (dS/m) Dissolved Solids total (mg/litre)	- 0,75 - 700	0,75 – 3,3 700 - 2000	+3 +2000
RAS (Ration d'Absorption du Sodium)	+3	3 – 9	+9
Alkalinity or hardness (CaCO3 equivalent)	80 – 120		+200
pH (risk of clogging)	<7.0	7 – 8	+8
Iron mg/l (risk of clogging)	0,2	0,2 – 1,5	+1,5
Manganèse mg/L (risk of clogging)	<0,1	0,1-1,5	>1,5

Source2 : Maynard D. N. et G . J. Hochmuth, 1997. Knott's Handbook for Vegetable growers. 582p. ; Peterson, H.G. Water quality Fact Sheet: Irrigation and Salinity, Agriculture et Agroalimentaire Canada (http://www.agr.gc.ca/pfra/water/microirr_htm), 4p. ; Rogers Danny H., Freddie R. Lamm et Mahbub Alaam. Irrigation Management Series, subsurface drip irrigation Systems (SDI) Water Quality Assessment Guidelines. Kansas State University. (http://www.oznet.ksu.edu/library/ageng2/mf2575.pdf), 8p.

In the context of this study, due to the unavailability of certain analytical data, the water quality analysis for irrigation focused on the Sodium Absorption Ratio (SAR), hardness, total iron, and magnesium.

The concentration of sodium in irrigation water is estimated by the Sodium Absorption Ratio (SAR). The SAR describes the amount of sodium in excess relative to calcium and magnesium cations, which can be tolerated in relatively large amounts in irrigation water.

Here is the formula for calculating the SAR (sodium, calcium, and magnesium are expressed in meq/L):

The following is how the RAS is calculated (sodium, calcium, and magnesium are expressed in meq/L):

$$RAS = \frac{\text{Na}+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

Sodium is one of the most undesirable elements in irrigation water. It is responsible for the alteration of rocks, soils, treated waters, and irrigation systems.

The main issue with a high concentration of sodium is its effect on soil permeability and water infiltration. Sodium replaces calcium and magnesium adsorbed on clay particles, causing soil particles to disperse. This leads to the disintegration of soil aggregates, resulting in a hard and compact soil when dry, which becomes excessively impermeable to water. Sandy soils may not deteriorate as quickly as heavier soils when irrigated with water high in sodium; however, a potential problem still exists (AGRI-VISION 2003-2004).

According to COUTURE I. (2004), sodium also directly contributes to the total salinity of water and can be toxic to sensitive crops such as carrots, beans, strawberries, raspberries, and onions, to name a few. The same author states that high sodium combined with chloride gives the water a salty taste. If the water passes through a sprinkler system and the levels of calcium and magnesium are low, moderate to high levels of sodium can cause defoliation in sensitive plants. He further argues that water with a SAR (Sodium Absorption Ratio) greater than 9 should not be used, even if the total salt content is relatively low. Continuous use of water with a high SAR leads to soil structure degradation. Water with an SAR between 0 and 6 can generally be used on any type of soil with little risk of sodium accumulation. When the SAR is between 6 and 9, the risks related to soil permeability increase.

Alkalinity is a measure of water's ability to neutralize acids, similar to its "buffering capacity" (MAYNARD D. et al., 1997). In other words, alkalinity measures the resistance to any changes in pH. The neutralizing power of water is primarily attributed to the presence of dissolved calcium and magnesium bicarbonates (and to a lesser extent, hydroxides, organic bases, borates, ammonium ions, phosphates, and silicates). Water alkalinity is typically expressed in ppm (mg/L) of calcium carbonate ($CaCO_3$).

Alkalinity prevents calcium and magnesium from being available to plants. Carbonates trap calcium and magnesium, which must be released by neutralizing the alkalinity with acid. Otherwise, the carbonates automatically transform into calcium and dolomitic lime, leaving behind limestone deposits that can clog sprinkler or drip irrigation systems, or cause white streaks on leaves if watering is done via sprinklers.

The results of the analysis, along with the interpretation of these results, are recorded in the following table.

[2] From the document "WATER ANALYSIS FOR IRRIGATION PURPOSES" by Isabelle Couture

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Table 7: Results and Interpretation of Water Quality for Irrigation of the Alluvial Aquifer of Karfiguela

Place	Fer total	Magnesium	Total hardness	RAS
KARBR1	0.05	35	1.3	0.36214298
KARFPA3	0.12	2	1	0
KARPA1	0.2	35	1.6	0.4417261
P2RG16	0.2	6	0.4	0
PZ RG 36	0.25	15	0.7	0.03244428
PZ RG X1	0.35	20	1	0.2773501
PZK03	0.4	14	0.7	0
PZK04	0.85	10	0.4	0
PZKO2KD19	97	3	0.3	0
PZKO7	0.2	2	0.2	0
PZRD15	0.3	3	0.3	0
PZRD31	0.4	2	0.3	0
PZRDX3	0.4	4	0.4	0.40824829
RESULTATS D'INTERPRETATION				
KARBR1	No	High	No	No
KARFPA3	No	High	No	No
KARPA1	No	High	No	No
P2RG16	No	High	No	No
PZ RG 36	High	High	No	No
PZ RG X1	High	High	No	No
PZK03	High	High	No	No
PZK04	High	High	No	No
PZKO2KD19	High	High	No	No
PZKO7	No	High	No	No
PZRD15	High	High	No	No
PZRD31	High	High	No	No
PZRDX3	High	High	No	No

Source : ZOUNDI M., 2022

The results show that no water sample falls within the high severity class for total hardness and SAR (Sodium Absorption Ratio) parameters. However, all samples fall within the high severity class for the magnesium parameter. Furthermore, eight (8) samples (PZ RG 36, PZ RG X1, PZK03, PZK04, PZKO2KD19, PZRD15, PZRD31, and PZRDX3) are classified in the high severity class for total iron. A high level of iron can lead to clogging of the irrigation network, especially in sprinkler or drip irrigation systems.

IV. CONCLUSION AND DISCUSSION

The analysis results indicate that agricultural practices have a physical impact on surface water resources. These impacts are manifested through sedimentation, the development of micro-water reservoirs, the premature drying of the river, and the loss of aquatic biodiversity. However, these impacts are not exclusively attributable to agricultural practices, particularly to the exploitation of riverbanks. Indeed, the sedimentation of rivers is a natural process linked to land erosion at the watershed scale. According to GUYON F. (2016), the sediment input in the filling of water reservoirs is much higher at the watershed scale than at the riverbanks.

Regarding the quality of groundwater, the analysis was based on WHO drinking water quality standards and irrigation water standards defined by MAYNARD D. et al. (1997). No impact was identified based on the WHO standards. However, according to irrigation water standards, a slight impact of agricultural practices on groundwater resources was observed. The analysis standards are inappropriate for the context and irrigation technologies in the Karfiguela plain. Indeed, the irrigation water quality standards developed by Maynard were applied in Canada, which likely uses highly refined irrigation technologies. Therefore, applying these standards in the Karfiguela context is inappropriate.

Moreover, the estimation of parameters often lacks precision due to insufficient or non-existent data in certain areas of the study zone. Indeed, in the Karfiguela site, from Niankar to the western tip of Tangora, there are no piezometers. As a result, water sampling did not cover this part of the plain. Additionally, out of the 49 piezometers, only 13 were sampled.

The results obtained from this study should therefore be considered with a margin of error. They represent a relative evaluation of the impacts of agriculture on water resources and serve as a decision-making tool for better management of the Karfiguela plain.

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