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Relationship between water quality and soil in three Algerian dams (Ghrib, Ledrat and Beni Slimane).

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Abstract :
Dams are seen as essential structures that store water for irrigation and municipal uses. However, the waters in the reservoirs of the dams are influenced by a multitude of environ-mental factors. One of the main factors that influences water quality in reservoirs is the characteristics of the soils in the watershed. The objective of our study is to evaluate the relationship between soil properties and the physicochemical quality of water in three Algerian dams (Ledrat, Beni Slimene, Ghrib), located in the Medea province. Seasonal sampling has been carried out to measure the physicochemical parameters of water and soil with a frequency of three stations for each dam covering the period.(November 2022-Aout 2023).The analysis of water samples focuses on parameters such as temperature (TW), electrical conductivity (COND), dissolved oxygen (DO2), PH (PHW), turbidity (TUR), biological oxygen demand (BOD5), chemical oxygen demand (COD), calcium (Ca), chlorides (CL-), and phosphates.(PO-4).The soil parameters include grain size, electrical conductivity (EC), soil pH (pH), organic matter (OM), active limestone (AL), and total limestone.(TL). The waters of the three dams have been classified based on season and stations using the Water Quality Index (WQI). High WQI values were observed in the Ghrib and Beni Slimene dams, indicating that the Ghrib dam has acceptable quality compared to the Ledrat dam. The interactions between soil parameters and water quality have been highlighted by the model. (GLM). There was a strong correlation between electrical conductivity and active lime-stone and the electrical conductivity of water. Furthermore, factors such as soil organic matter and silt were negatively related to water quality, leading to an increase in turbidity and dissolved organic matter. These conclusions are supported by the results of Monte Carlo tests, which confirmed that electrical conductivity (EC), total limestone (TL), and active limestone (AL) have a direct impact on water quality in the three dams, suggesting their contribution to the increase in mineralization and water hardness. These results highlight the importance of managing water resources in an integrated manner, taking into account the interactions between soil and water, in order to better understand and preserve water quality in these aquatic environments.

Keywords: dams; water quality; soil; water quality index (WQI); GLM; Monte-Carlo tests

Introduction

Water is a natural resource, essential for life on Earth. It represents a major challenge of the 21st century, on par with arable land and energy. This wealth is unfortunately subject to various qualitative and quantitative pressures in terms of health, environmental, socio-economic, financial, political, and geopolitical factors. (Salloum,2013). In Algeria, water is a rare, fragile resource that is unevenly distributed across the territory. The demand for water is continuously increasing, and the use of surface water has become an unavoidable necessity. There are observed conjunctural or structural water shortages. In addition to the tensions related to water resources, there is also the degradation of the ecosystem and biodiversity caused by human intervention, exacerbated by water shortages (Belhadj,2017).

The protection of water resources is one of the most essential concerns of any environmental policy. The chemistry of the surface waters of a river, in every respect, reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions, and anthropogenic contributions (Shertha & kazma ,2017 ; Dellos & sawidis ,2005).

The quantity and quality of water are also important. Water is always considered a universal solvent because it can dissolve many substances, but humans need water with fewer impurities. The main categories of impurities in water are

microorganisms, pyrogens, dissolved mineral salts, dissolved organic compounds, suspended particles, and dissolved gases. In general, the quality of drinking water is determined based on the appearance, taste, color, and smell of the water (Ola et al., 2019).
Currently, surface water pollution is attracting particular attention worldwide. The main causes of the degradation of surface water quality are natural and anthropogenic activities, such as hydrological characteristics, climate change, precipitation, agricultural activities, and wastewater discharges from industries (Ravichandran,2003 ; Gantidis et al.,2007). As a result, the quality of freshwater depends on the concentration of a number of elements that are present in solution or in suspension. Thus, water in its natural state can contain organic matter, dissolved substances from the terrains it passes through (calcium, magnesium, sodium, potassium, bicarbonates, sulfates, chlorides, heavy metals), suspended particles, and other elements of anthropogenic origin (Touhari, 2015).
The soil has a complex function that is beneficial for humans and other living organisms (Sumithra et al.,2013).
The physicochemical characteristics of different soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables (Paudel and Sah ,2003).
The assessment of soil quality distinguishes between the static and dynamic properties of the soil. The static properties of the soil reflect the inherent characteristics of a particular site, such as soil texture, mineralogy, and classification, all influenced by his-tory. geological and climatic conditions. Moreover, topography, hydrology, and climate are factors that affect the productivity and environmental quality of a site (Alan J. Franzluebbers,2008).
Severe soil erosion that leads to excessive sediment export to waters or reservoirs causes disruptions to life in water bodies as well as a reduction in environmental quality (Zhai,2010. Kronvang et al., 2003 ; Steiger et al., 2005). Water is considered the most significant agent of soil erosion in most regions of the world. Due to population growth and the increase in water pollution activities, soil erosion has become a global environmental issue, primarily for developing and underdeveloped countries (Abdulkareem et al., 2019 ; Borrelli et al., 2017). Limited research (Sthiannopkao et al., 2007, 2006) has examined the relationship between soil erosion and water quality parameters.
During transfers, water acquires its chemical composition through exchanges and biogeochemical reactions within the soil, particularly thanks to the action of numerous microorganisms. When the soil contains potentially polluting elements (metals, phosphorus, pesticides...), water becomes contaminated with these elements upon contact. The soil thus plays a third role in relation to water, that of regulating its chemical quality (Nathalie et chantal,2014).
During its runoff and infiltration into the soil, water comes into contact with the terrains it encounters, picking up various elements that will affect its quality. Some of these elements are naturally present in the soil and will define the natural quality of the raw water (Berner and Berner, 1987 ; Bricker and Jones, 1995).
The fight against the eutrophication of freshwater and coastal waters, that is to say their enrichment in nutrients, the adherence to water quality standards for drinking water supply, and the protection of aquatic ecosystems from toxic and ecotoxic contamination are essential issues in terms of water quality. The soil retains and stores potentially polluting elements; it is the site of biotransformation's that allow for the creation of non-polluting forms. It limits leaks and preserves both groundwater and surface water. This regulatory role of the soil has limits due to the characteristics and quantity of the pollutants involved, the nature of the soils, the hydric state of the watershed, and the targeted water quality objectives. (Nathalie and Chantal ,2014).
The present study is conducted in three water dams (Ledrat, Beni Slimene, Ghrib) located in the Medea province, which are designed for both consumption and irrigation.
The objective of this study is to characterize the relationship between water quality and the physicochemical properties of the soil in the three dams in order to understand their effects on a spatiotemporal scale.

Materials and Methods

Presentation of the study area:

The wilaya of Medea is located in the heart of the Tell Atlas. (Fig 1). Its capital is located 88 km south of Algiers. It covers an area of 8,700 km², and the climate of the Medea region is of the Mediterranean type, characterized by hot, dry summers and mild, wet winters. Temperatures range between 10°C in winter and 35°C in summer, with an average annual rainfall of about 800 mm. The present study is conducted at the level of three dams located in the province.
The Ghrib dam is part of the Cheliff - Zahrez watershed, which represents more than 22% of the area of northern Algeria (ABH,2004).
The Beni Slimane and Ledrat dam, located in the watershed of the Oued Isser, is situated about 100 km southeast of Algiers. With an area of 4,149 km², it has an elongated shape running from the southwest (Ain Boucif/Beni Slimane) to the northeast towards the Mediterranean Sea. It originates from the mountain of Djebel Serane in Barouaghia (1327 m) and collects the waters from the rivers. (Hammam, Yaggour, Zeroua, Mellah Est et Ouest, Bouhamoude et oued djemaa). The basin of the Isser River is of the mountainous type with an average altitude of 750 m. It is characterized by fairly erodible lithological formations, which are composed of 60% marl and marl-limestone formations belonging to the Lower, Middle, and Upper Cretaceous (Hebal,2013 ; Deffaf et al .2020).

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Table 1. Geographical situation of the dams.

Dams	Oued	Geographical coordinates
Ghrib	Chellif	X :401019.45E Y :3999070N
Ledrat	Ledrat	X :506022,36 E Y :4011256
Beni Slimane	Isser	X :530709.13 E Y :4001678 N

Sampling and Physico-Chemical Analyses :
After exploring the three sites and based on their accessibility, we selected three stations for each site to carry out water and soil sampling. The sampling was conducted at the three dams throughout the four seasons of 2023, with a frequency of one sample per season. Water samples were collected using polyethylene bottles with caps and were kept refrigerated at 4˚C. This measure aimed to enable a quick analysis in order to avoid unexpected changes in water characteristics, according to standard procedures (Rodier et al, 2009). At the same stations and using a auger, we collected soil samples from the first surface horizon (0-20 cm), as it is at this level that the most significant ionic exchanges occur (Jolivet C,2006). The physicochemical analyses of the waters were carried out at the laboratories: Algerian Water Laboratories (ADE) in Ghrib and Djelfa, Ghrib station, and the National Agency for Water Resources (ANRH) in Ledrat. The parameters considered in this study are : Temperature (TW) in °C ; PH (PHW) ; Electrical conductivity (Cond) in µS·cm– ; Dissolved oxygen (DO2) in mg/l; Biochemical oxygen demand (BOD5) in mg/l; Chemical oxygen demand (COD) in mg/l; Total dissolved solids (TDS) in mg/l; Organic matter (OMW) in mg/l; Phosphate (PO-4) in mg/l; Chloride (Cl-) in mg/l; Turbidity (TUR) in NTU; and Calcium (Ca+2) in mg/l.
For the soil, the samples were air-dried, ground, and sieved to 2 mm to obtain fine earth. The analyses of the soil samples were conducted on the fine earth. The parameters used in this section are : granulometry (texture); total limestone; active limestone; PH; electrical conductivity; organic matter; and assimilable phosphorus. These analyses were conducted at the National Institute of Soils, Irrigation, and Drainage (INSID) in Ksar
Chellala-Tiaret. The parameters considered in this study are : grain size (sand, clay, silt); electrical conductivity (EC); total limestone (TL); active limestone (AL); organic matter (OM), expressed as a percentage (%); and assimilable phosphorus (AP) expressed in mg/kg, as well as PH. (PHS).

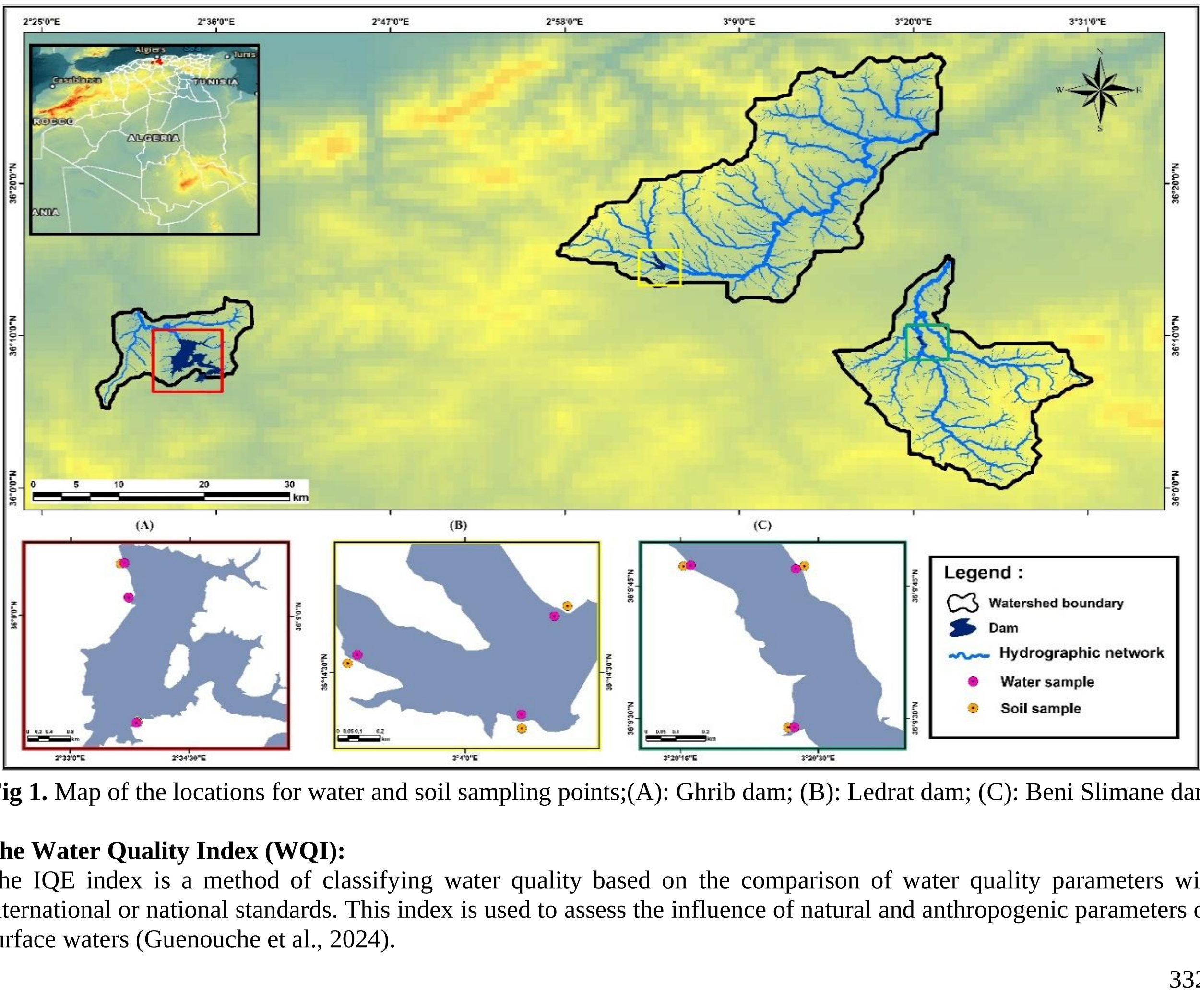

Fig 1. Map of the locations for water and soil sampling points;(A): Ghrib dam; (B): Ledrat dam; (C): Beni Slimane dam

The Water Quality Index (WQI):
The IQE index is a method of classifying water quality based on the comparison of water quality parameters with international or national standards. This index is used to assess the influence of natural and anthropogenic parameters on surface waters (Guenouche et al., 2024).

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To calculate the water quality index, which is based on the comparison of water quality parameters with the Algerian national standards (Official Journal of the Algerian Republic No. 18 2011). In the context of this study, we have:
Wi = k/si
Where:
K: the constant of proportionality, which can also be calculated using the following equation:
K=1/∑(1/si)
si : maximum value of the Algerian standard norm for surface water for each parameter.
Then, a quality assessment scale (Qi) is calculated for each parameter by dividing the concentration by the standard of that parameter and multiplying the result by 100, as shown in the following formula :
Qi= (Ci/Si) *100
Qi: evaluation scale for the quality of each parameter.
Ci: the concentration of each parameter in mg/l.
Finally, the overall water quality index is calculated using the following equation:
IQE = ∑(Qi*Wi) / ∑Wi
Five quality classes can be identified according to the values of the water quality index (WQI). (Table 2).

Table 2. Classification and possible use of water according to the IQE

IQE class	Type of water	Usage possible
0-25	Excellent quality	Drinking water, irrigation and industry
>25 - 50	Good quality	Drinking water, irrigation and industry
>50 - 75	Poor quality	Irrigation and industry
>75 - 100	Very poor quality	irrigation
> 100	Non potable water	Appropriate treatment required before use

Statistical analysis:
The non-parametric analysis of variance represented by the Kruskal-Wallis test is used to discuss the significance of temporal variability (years, months, and seasons) and spatial variability (dams and stations) on the variation of different physicochemical parameters of water and soil.
Multidimensional analyses : Principal Component Analysis (PCA), Hierarchical Ascending Classification (HAC), and a numerical correlation matrix are used to describe the relationships between (and within) the physicochemical parameters of water and soil in relation to the factors of dams, stations, and seasons.

To assess the spatial and seasonal variability of the physico-chemical factors of water and soil, we used the Generalized Additive Model. (GAM). A generalized linear model (GLM) was used to highlight the variability of the WQI index and the effect of the physicochemical parameters of the soil. A redundancy analysis (RDA) was conducted to assess the effect of soil parameters on the physicochemical parameters of the water in the three dams. The significance was tested using the Monte Carlo permutation test. The various analyses were conducted using the R language. (Cran, 2024).

Results and discussion
Results
Variation of physicochemical parameters of water and soil :
According to (Table 3), the variability of the physicochemical parameters of the soil at the stations of the three dams is remarkable. This shows significant differences according to these factors (p-value < 5%, Table 3). The same observations were recorded for the physicochemical parameters of the water, except that these variations are not significant for TW, DO2.d, PHW, and COD (p-value > 5%, Table 3). On the other hand, the results of the seasonal variations at the three dams show that there are significant fluctuations that are statistically very significant (p-value < 5%, Table 4).

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Table 3. Statistical summary of the physicochemical parameters of water and soil based on dams and stations, along with the results of the statistical test

Parameters	Stations	Station 1			Station 2			Station 3			K-S P-value
	Dams	B	G	L	B	G	L	B	G	L	
	Physico-chemical parameters of the soil										
CLAY	mean	27,94	30,25	39,66	29,28	29,82	37,5	29	29,95	38,43	0,001
	se(mean)	0,92	0,683	0,37	1,305	0,423	1,494	0,865	0,696	0,705	
SILT	mean	29,47	16,07	25,01	30,97	15,59	24,14	29,96	16,9	23,9	7E-05
	se(mean)	0,674	0,271	0,365	0,339	0,319	0,368	0,098	0,195	0,875	
SAND	mean	47,36	50,99	32,83	47,4	49,68	30,44	48,84	50,4	32,37	6E-04
	se(mean)	1,455	0,873	1,849	0,729	0,518	1,188	1,012	0,184	0,752	
AL	mean	4,973	3,83	3,363	5,31	3,528	3,518	5,153	4,08	3,683	0,006
	se(mean)	0,359	0,157	0,443	0,31	0,184	0,544	0,355	0,18	0,347	
TL	mean	17,82	11,35	9,818	17,97	11,69	10,45	18,83	11,62	10,89	9E-04
	se(mean)	0,616	1,051	0,278	0,631	0,943	0,329	0,51	1,298	0,134	
CE	mean	1,323	1,035	0,457	1,255	1,008	0,391	1,25	1,018	0,411	1E-04
	se(mean)	0,141	0,047	0,02	0,098	0,063	0,022	0,091	0,047	0,017	
OMS	mean	1,15	1,353	0,72	1,103	1,365	0,82	1,123	1,278	0,825	7E-04
	se(mean)	0,033	0,187	0,092	0,01	0,246	0,066	0,042	0,039	0,04	
PHS	mean	7,925	8,035	7,748	7,98	7,988	7,218	7,875	8,04	7,73	0,009
	se(mean)	0,107	0,036	0,05	0,041	0,104	0,063	0,131	0,105	0,024	
AP	mean	187,5	195,2	115,2	184,7	195,6	128,4	186	195,1	125,9	4E-04
	se(mean)	5,678	1,263	4,364	6,28	1,12	1,885	6,121	1,992	2,507	
Physico-chemical parameters of the water											
TW	mean	20,4	20,15	21,03	20,18	20	21,1	20,33	19,68	20,98	0,997
	se(mean)	2,982	2,939	2,733	2,996	3,189	2,575	3,029	3,015	2,52	
DO_2	mean	8,424	8,735	7,733	8,694	9,008	7,598	8,669	8,633	7,615	0,186
	se(mean)	0,179	0,413	0,48	0,304	0,707	0,475	0,266	0,622	0,435	
PHW	mean	7,855	7,973	7,895	7,648	8,065	7,653	7,685	8,095	7,893	0,668
	se(mean)	0,119	0,253	0,232	0,139	0,185	0,254	0,212	0,123	0,331	
COND	mean	2360	2326	973,5	2388	2259	981,5	2340	2224	1006	0,002
	se(mean)	260,9	47,53	24,54	220,2	64,74	16,68	241,4	73,8	4,939	
TUR	mean	9,855	4,45	16,9	10,61	4,215	16,7	10,23	4,288	16,43	1E-04
	se(mean)	0,271	0,245	2,411	0,251	0,163	1,675	0,593	0,177	1,919	
OMW	mean	4,8	5,1	7,125	4,878	4,95	7,375	4,575	5,05	7,225	0,005
	se(mean)	0,245	0,248	0,789	0,282	0,222	0,972	0,461	0,21	0,788	
DR	mean	1429	1457	643,5	1431	1405	684,3	1435	1423	671,8	0,003
	se(mean)	72,9	33,36	25,94	87,16	83,1	24,96	52,56	73,23	23,11	
Ca^{+2}	mean	186	223,3	112	190	220,8	115,5	189	218,3	115,3	1E-04
	se(mean)	2,483	4,732	3,697	1,08	10	1,848	4,378	6,981	6,625	
Cl^-	mean	291,8	392,2	123	304,5	372,8	129	306,4	365	124,5	2E-04
	se(mean)	26,06	19,94	7,842	22,64	38,13	4,708	9,423	15,98	7,879	
BOD5	mean	8,25	3,5	13	7,75	3,75	12	9	3,75	13,5	1E-04
	se(mean)	0,629	0,289	0,707	0,479	0,25	1,225	0,408	0,25	1,443	
COD	mean	29	26	29,5	27,75	25	30,5	27,5	25,25	26,5	0,97
	se(mean)	2,38	1,08	4,992	2,016	1,732	5,299	1,848	0,946	4,406	
PO^{-4}	mean	0,031	0,008	0,167	0,071	0,015	0,218	0,075	0,005	0,245	0,002
	se(mean)	0,03	0,005	0,023	0,042	0,003	0,032	0,04	0,003	0,014	

Note : se(mean) : standard error of the mean; B: Beni Slimane; L: Ledrat; G: Ghrib

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Table 4. Statistical summary of the physicochemical parameters of water and soil ac-cording to the dams and seasons, along with the results of the statistical test.

Parameters	Seasons	Autumn			Winter			Spring			Summer			K-S P-value
	Dams	B	G	L	B	G	L	B	G	L	B	G	L	
The physico-chemical parameters of soil														
CLAY	mean	28,1	30,28	36,7	28,08	30,92	38,93	30,7	28,28	38,44	28,08	30,54	40,04	0.001452
	se(mean)	1,487	0,04	2,031	1,098	0,401	0,389	0,292	0,175	0,205	1,098	0,223	0,278	
SILT	mean	29,56	16,19	23,91	30,67	15,62	23,88	29,62	16,56	25,29	30,67	16,37	24,33	0.0007146
	se(mean)	0,647	0,613	1,105	0,485	0,396	0,356	0,677	0,099	0,582	0,485	0,472	0,43	
SAND	mean	48,27	50,85	30,89	48,62	50,44	29,33	45,94	50,2	32,93	48,62	49,94	34,37	0.002634
	se(mean)	1,691	1,545	1,419	1,1	0,161	1,415	0,7	0,055	0,662	1,1	0,249	1,034	
AL	mean	5,917	3,597	2,483	5,393	3,707	3,217	4,34	3,743	4,467	4,93	4,203	3,917	0.0008217
	se(mean)	0,12	0,239	0,269	0,087	0,198	0,072	0,203	0,209	0,095	0,045	0,189	0,251	
TL	mean	18,18	8,647	10,63	17,07	11,58	9,857	18,55	12,17	10,53	19,03	13,82	10,53	0.00059
	se(mean)	0,847	0,312	0,389	0,388	0,406	0,534	0,634	0,328	0,29	0,4	0,21	0,29	
CE	mean	1,6	0,881	0,425	1,11	1,11	0,43	1,207	1,023	0,43	1,187	1,067	0,393	0.0004527
	se(mean)	0,07	0,021	0,049	0,01	0,01	0,023	0,012	0,034	0,023	0,013	0,023	0,003	
OMS	mean	1,187	1,14	0,82	1,087	1,143	0,783	1,117	1,253	0,917	1,11	1,79	0,633	0.001189
	se(mean)	0,044	0,032	0,093	0,041	0,043	0,018	0,017	0,043	0,023	0,01	0,218	0,058	
PHS	mean	7,703	7,87	7,547	7,903	8,03	7,597	8,103	8,237	7,547	7,997	7,947	7,57	0.002059
	se(mean)	0,143	0,059	0,236	0,015	0,031	0,213	0,015	0,064	0,153	0,009	0,039	0,097	
AP	mean	194,4	193,9	116,4	190,2	197,3	124,3	168,5	192,9	126,9	191,2	197,1	125	0.001136
	se(mean)	2,396	2,132	6,095	1,207	0,984	1,395	1,782	0,709	2,941	0,125	0,611	6,598	
The physico-chemical parameters of water														
Tw	mean	18,03	18,23	19,1	14,77	14,23	15,3	28,77	28,57	27,67	19,63	18,73	22,07	0.0003157
	se(mean)	0,033	0,233	0,058	0,285	0,233	0,153	0,186	0,233	0,176	0,203	0,145	0,067	
DO_2	mean	8,897	8,177	7,167	8,077	10,27	7,4	9,063	7,98	9,003	8,345	8,74	7,023	0.001145
	se(mean)	0,307	0,072	0,067	0,03	0,521	0,173	0,062	0,333	0,058	0	0,405	0,023	
PHW	mean	7,557	7,833	7,333	7,673	7,673	7,433	7,553	8,267	8,123	8,133	8,403	8,363	0.002905
	se(mean)	0,222	0,148	0,176	0,048	0,114	0,033	0,015	0,12	0,096	0,088	0,047	0,232	
COND	mean	2270	2217	1002	2752	2352	961,7	2703	2374	1004	1725	2136	980,3	0.0005286
	se(mean)	65,33	70,87	3,844	22,24	38,68	30,87	29,06	25,71	6,429	55,89	33,15	24,11	
TUR	mean	9,793	4,707	14,07	10,38	3,907	12,73	11,14	4,49	20,3	9,6	4,167	19,6	0.0003806
	se(mean)	0,365	0,095	0,717	0,079	0,099	0,338	0,488	0,181	0,569	0,252	0,131	1,308	
OMW	mean	3,867	5,6	5,9	4,837	4,733	5,733	5,067	5,167	9,067	5,233	4,633	8,267	0.0005907
	se(mean)	0,34	0,1	0,208	0,185	0,033	0,12	0,088	0,067	0,067	0,133	0,088	0,328	
TR	mean	1535	1321	682,3	1514	1522	610	1449	1500	652,7	1229	1369	721	0.0009351
	se(mean)	19,43	103,8	18,17	9,244	47,79	17,9	24,29	10,04	12,71	31,48	9,171	11,27	
Ca^{+2}	mean	187,7	201,3	111	181,3	222	117,3	192,3	225,3	122,7	192	234,3	106	0.0003713
	se(mean)	2,028	4,91	2,082	2,963	3,215	2,028	2,028	3,18	4,978	1,528	3,756	3,786	
Cl^-	mean	299,6	338	116,3	326,4	359,3	145	325,8	449	123,7	251,6	360,4	117	0.0004903
	se(mean)	5,607	13,94	2,404	14,39	11,18	2,082	6,809	20,86	4,177	22,57	8,727	2,646	
BOD5	mean	7,333	3,667	10,67	8,667	3,333	14,33	8	4	14,67	9,333	3,667	11,67	0.0004901
	se(mean)	0,333	0,333	0,667	0,667	0,333	1,333	0,577	0	0,333	0,333	0,333	0,882	
COD	mean	23,33	23,33	19,33	31,33	24,33	21,67	31,33	26	37	26,33	28	37,33	0.0006542
	se(mean)	0,333	0,667	0,333	1,764	0,333	1,453	0,667	1,528	2,517	0,333	1,155	1,333	
PO^{-4}	mean	0,156	0,003	0,187	0,07	0,007	0,24	0,009	0,01	0,177	0	0,017	0,235	0.001785
	se(mean)	0,018	0,003	0,032	0,036	0,003	0,043	0,004	0,006	0,033	0	0,003	0,008	

Note : se(mean): standard error of the mean; B: Beni Slimane; L: Ledrat; G: Ghrib

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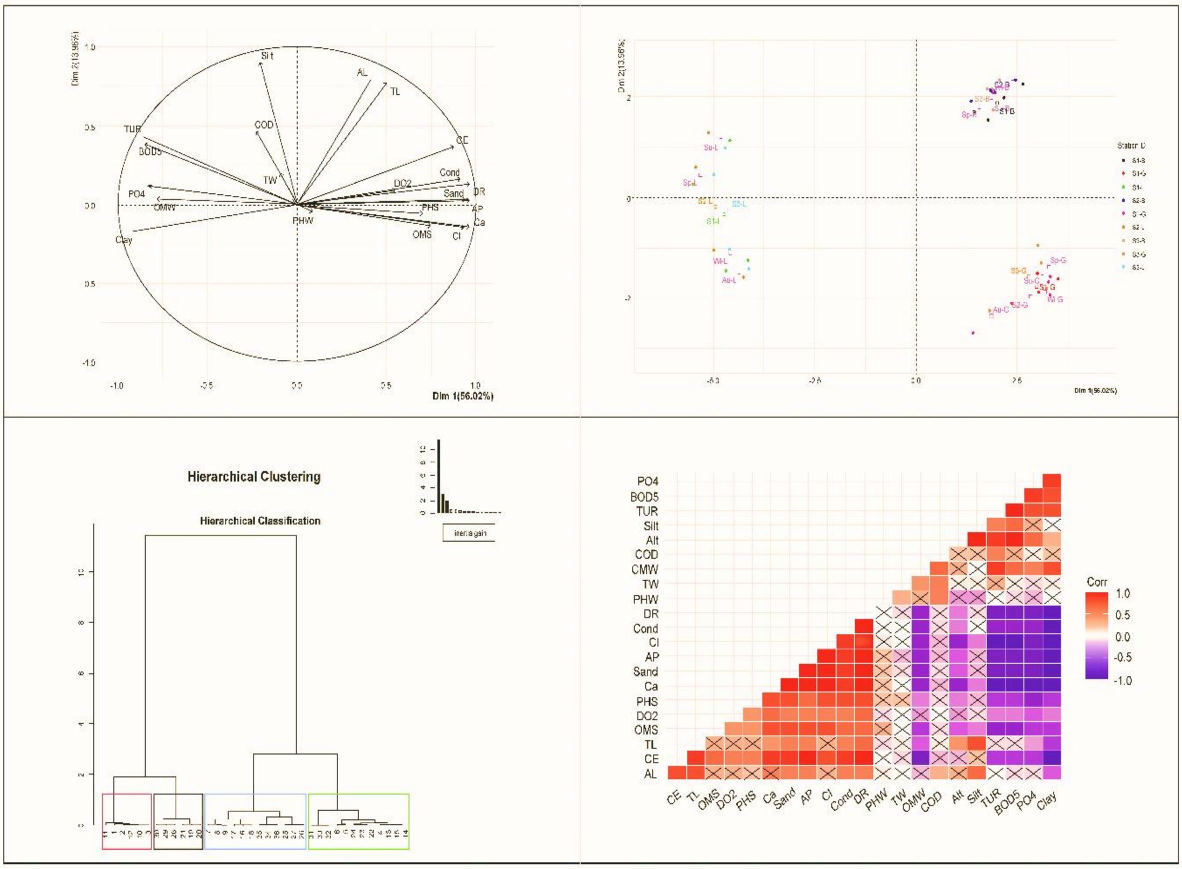

Fig 2. Multidimensional analyses PCA, CA, and correlation matrix of the physico-chemical parameters of water and soil according to stations and Seasons.

Relationship between the parameters : PCA, CHA, and Correlation Matrix :
The multidimensional analyses (PCA, CHA, and correlation matrix) describe the relationships between (and within) the physicochemical parameters of water and soil in relation to the factors of dams, stations, and seasons. The PCA accounts for a total explanation of 70.37% of the information. (Fig 02). According to axis 1 (56.02%), there is a positive relationship between Cond, DO2, Ca+2, Cl-, DR, Sand, PHS, CE, MOS, AP, which characterize the stations of the Ghrib and Beni Slimane dams. On the other hand, TUR, PO-4, BOD5, and clay are negatively correlated with this axis 1, which marks the stations of the Ledrat dam. Axis 2 (13.96%), DCO, silt, TL, AL. The former positively mark the stations of the Beni Slimane dam and negatively mark the stations of the Ghrib dam.
Effect of spatial and seasonal variability on water and soil parameters :
According to the results of the GAM model, it is generally observed that spatial factors (dam, station, altitude) as well as the seasonal factor have a significant effect on the physicochemical parameters of water (p-value < 5%, Table 05). On the other hand, the edaphic parameters are more stable compared to these factors (p-value > 5%, Table 05).

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Table 5. Effect of spatial and seasonal variability on water and soil parameters : results of the p-values from the General Additive Model. (GAM).

GAM	Dams	Seasons	Stations	Altitude	Latitude	Longitude
TW	7.882e-06	5.413e-10	5.033e-10	0.014414	0.1265018	0.2165005
PHE	4.333e-12	7.006e-05	5.507e-06	2.727e-10	1.771e-10	3.573e-08
Cond	<2.2e-16	0.2739421	0.0002112	5.648e-11	0.0001389	<2.2e-16
DO_2	3.798e-08	0.0081924	0.0016562	1.483e-06	1.017e-05	0.5905548
TUR	2.726e-15	0.0710035	0.7659472	4.652e-14	5.053e-14	5.289e-11
Ca^{+2}	4.653e-06	0.0432867	0.0137371	0.435138	0.0543027	1.582e-07
Cl^-	0.0051851	0.4456021	0.3506919	2.212e-07	3.759e-08	0.0372727
OMW	2.370e-08	0.8859769	0.4225212	1.891e-10	7.772e-11	0.0009655
DR	0.1524796	0.0006358	0.0006581	0.395852	0.0007783	0.0001968
PO^{-4}	0.5532751	0.5712842	0.9371224	0.058944	0.0006276	0.0017544
BOD5	2.388e-06	0.0009901	0.0013007	6.809e-08	1.861e-08	0.8319777
DCO	0.0224483	0.0026707	0.0050379	0.032618	0.2522522	0.1275007
CLAY	0.4244510	0.3151166	0.3222467	0.003837	0.0002915	0.0072286
SILT	0.0001376	0.8780891	0.8937564	1.663e-07	1.494e-08	0.0073626
SAND	0.0001942	0.0116871	0.0199815	0.062474	0.9344183	0.0077624
PHS	0.7817731	0.0524830	0.0505860	0.990323	0.8626502	0.2988649
CE	0.4255967	0.0628712	0.0122039	0.607497	0.2156193	0.1102109
OMS	0.1072695	0.0564666	0.0308059	0.029380	0.9358213	0.1115225
TL	0.0081520	0.0117122	0.0068800	0.012396	0.0209228	0.7675643
AL	0.3605353	0.9745540	0.5452973	0.346537	0.4571282	0.2213764
AP	0.1674323	0.7711886	0.8038936	0.882888	0.4422970	0.1694174

Variability of the WQI index and the effect of soil physicochemical parameters (GLM model) :
The spatial (Fig 3a) and seasonal (Fig 3b) variations of the WQI indicate that the Ledrat dam reflects a situation of very severe pollution, classified as non-potable water and requiring pretreatment before use. The Beni Slimane dam is in a very poor condition intended for irrigation. Finally, the water from the Ghrib dam is classified as excellent quality and can be used for drinking, irrigation, or industrial purposes.
According to the results of the GLM model (Fig 3(c) and Table 6), the effect of edaphic parameters on the WQI quality index is statistically significant (p-value < 5%, Table 6) except for the clay factor (p-value > 5%, Table 6). This effect is positive for Clay, AL, TL, and CE. She is negative for Silt, WHO, AP, PHS, and sand.

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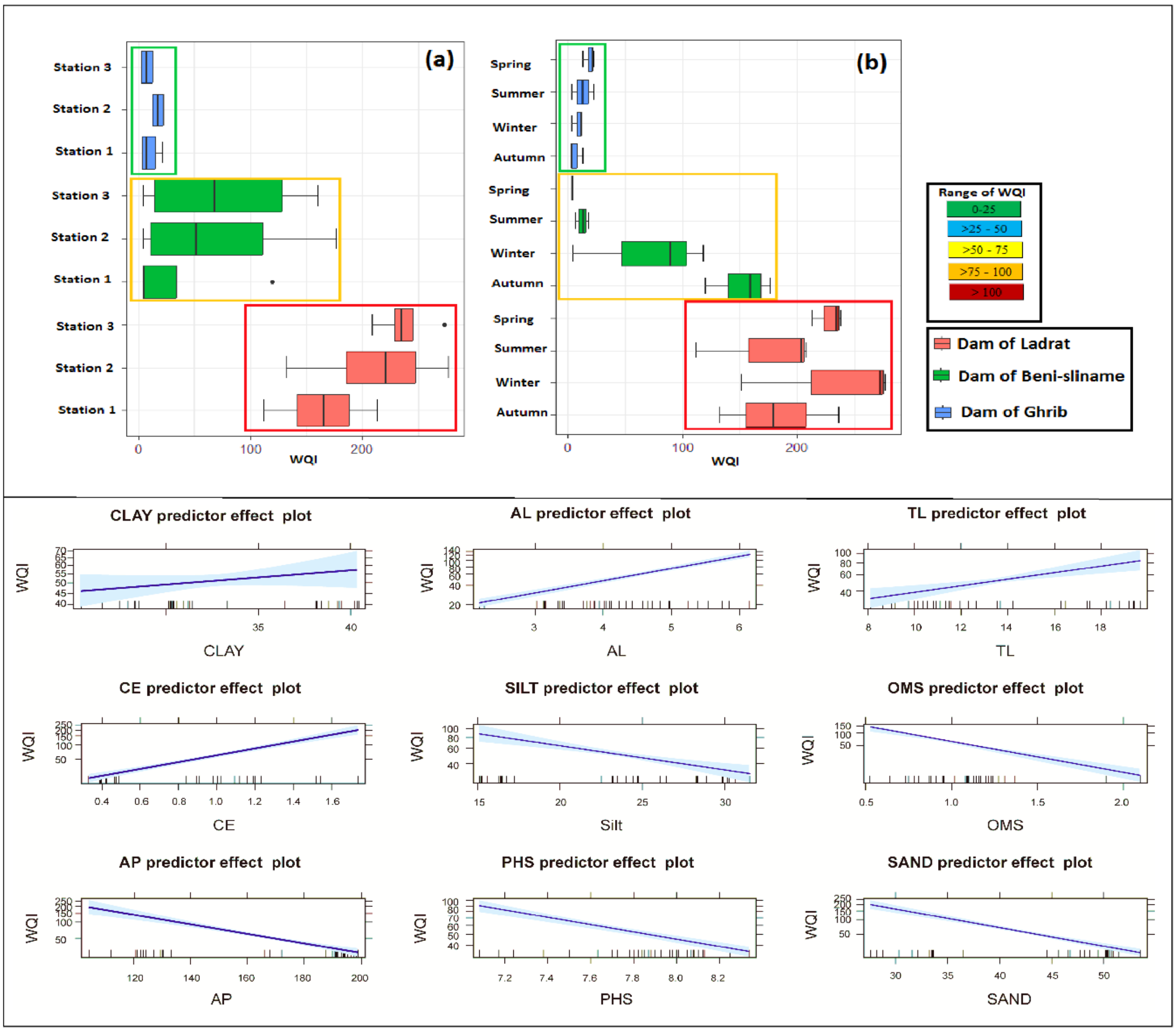

Fig.3. (a) : WQI as a function of the stations. (b) WQI based on season (c). Effect of physico-chemical parameters of soil on the Water Quality Index (WQI) in the three studied dams.

Redundancy Analysis (RDA) of the effect of soil parameters on the physicochemical parameters of the water from the three dams and results of the Monte Carlo test:

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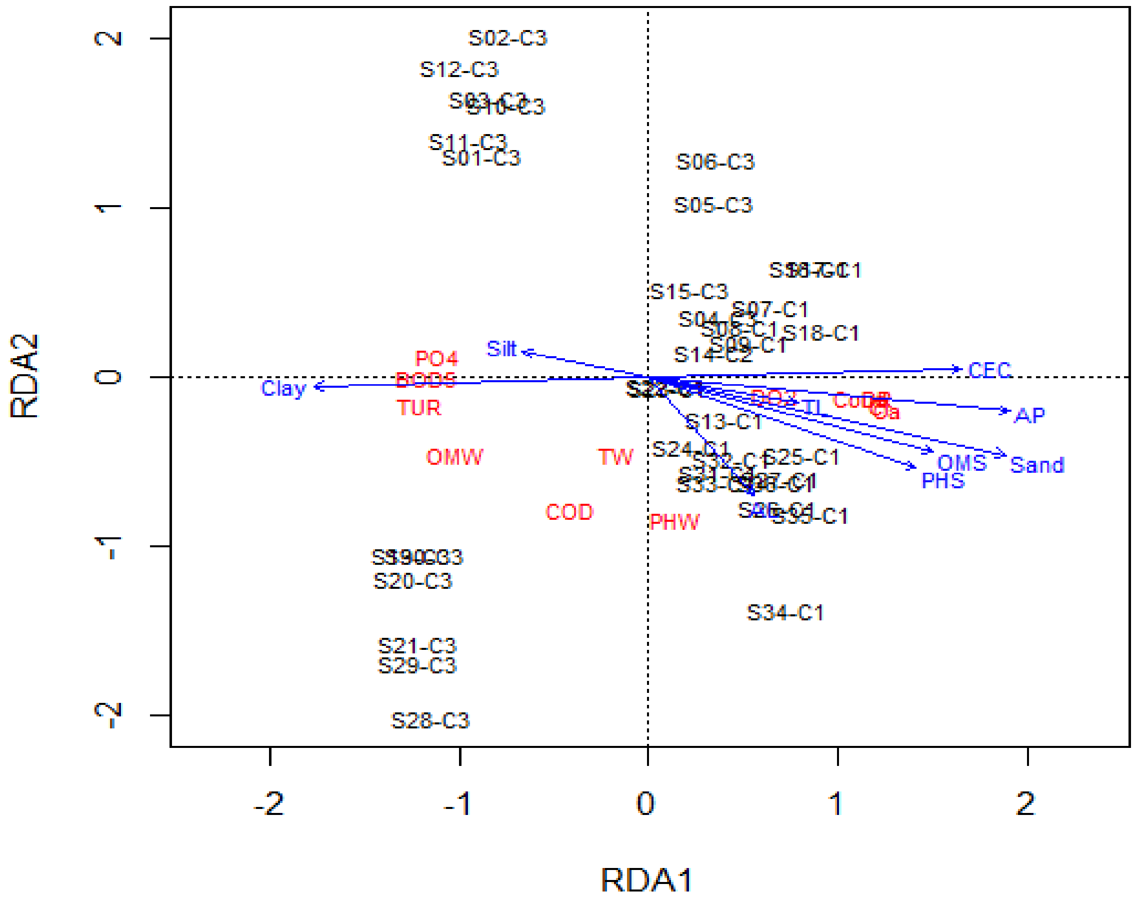

Fig. 4. Redundancy analysis illustrating the effect of soil parameters on water quality.

The redundancy analysis (RDA) concerning the relationships between the physico-chemical soil variables and water parameters revealed that the total variability of the redundancy analysis is 65.38%. (Fig 4). According to the first axis (RDA1 = 56.12%), the physico-chemical component of the waters (Cond, DO2, Cl-, Ca+2, and DR) appears to be positively related to the edaphic component. (Sand, PHS, CE, OMS, TL et AP). And negatively correlated with silt and clay.
For axis (RDA2=9.26), PO-4 is positively correlated with silt and BOD5, while OMW and TUR are negatively correlated with clay. (Fig 4).
According to the results of the Monte Carlo tests, it is observed that active limestone (AL) does not have a significant effect (p-value > 5%), whereas clay and total limestone (TL) and soil electrical conductivity (EC) have a significant effect (p << 2.00E-16), which leads to an increase in water mineralization. Silt has a significant negative effect (p=1.62e-06), while assimilable phosphorus (AP), organic matter (OMS), sand (SAND), and soil pH (PHS) also have a negative effect on water quality (p-value < 5%), (Table 6).

Table 6. Results of the GLM model and the Monte Carlo test.

Coefficients:	GLM Model				Monte Carlo test results			
	Estimate	Std. Error	zvalue	Pr(>|z|)	Df	AIC	F	Pr(>F)
(Intercept)	15.455223	0.951865	16.237	<2,00E-16				
CLAY	0.014783	0.011818	1.251	0.210956	1	73.721	28.0132	0.005
AL	0.452135	0.034317	13.175	<2,00E-16	1	92.619	2.6862	0.060
TL	0.078117	0.020213	3.865	0.000111	1	91.103	4.2639	0.020
CE	1.639234	0.147264	11.131	<2,00E-16	1	77.253	22.2174	0.005
SILT	-0.064695	0.013490	-4.796	1.62e-06	1	91.941	3.3837	0.025
OMS	-1.695557	0.182601	-9.286	<2,00E-16	1	81.014	16.6402	0.005
AP	-0.020675	0.002572	-8.040	8.99e-16	1	68.976	36.7499	0.005
PHS	-0.744718	0.077553	-9.603	<2,00E-16	1	82.261	14.9160	0.005
SAND	-0.086282	0.007373	-11.702	<2,00E-16	1	69.218	36.2761	0.005

Note : St. Error: the standard error of the estimate; Z-value: the z-value calculated to the test the null hypothesis; Pr(>|z|): the p-value associated with the test of the variable in the model; Df: degrees of freedom for the F-test; AIC: Akaike information criterion; F-value: the F-value to test the overall significance of the variable; Pr(>F): the P value associated with the F-statistic.

Discussion

The soils of the three dams differ considerably in their composition, for example.

The soils of the Ghrib and Beni Slimane dams are primarily sandy, which promotes water infiltration. According to the results, the electrical conductivity (EC) in this area is quite high. The soil pH is also high, which gives these soils alkalinity that promotes nutrient retention. However, these soils have a low amount of organic matter (OM), which can limit the availability of nutrients in the long term. However, due to the presence of limestone soils, the levels of calcium and chloride in the soil and water are quite high, which increases the hardness of the water.

On the other hand, the soils of the Ledrat dam are primarily silty and clayey. The risk of eutrophication is higher in these soils, as it promotes the accumulation of organic matter and nutrients, such as phosphate (PO-4), which can leach into the water. The ability of the soils to retain nutrients is limited in this area due to the lower electrical conductivity (EC). Furthermore, even the soil PH is quite high, which promotes the release of nutrients, thereby increasing water pollution, especially during periods of heavy rainfall.

soils with a high content of limestone (both total and active) promote high alkalinity and contribute to water hardness, which is confirmed by the observed relationship between the parameters Ca+2 and Cl- in the case of the Beni Slimene and Ghrib dams.

Temperature is a key ecological factor that has a significant influence on the physico-chemical properties of aquatic ecosystems (Leynaud, 1968 ; Ramade, 1993 ; Angelier, 2003). The water temperature at the study stations near the three dams shows a certain spatial stability and does not exceed 29°C. At the same time and in all the studied stations, the water temperature follows similar seasonal variations. The minimums were observed in winter (13C°) and the maximums in summer (29C°). Referring to these results, we can say that the profile of annual variations in water temperatures follows that of atmospheric temperatures in relation to the region's climate. Similar results have been reported in subsequent studies (Bouaroudj et al.,2018 ; Allalgua et al., 2017).

Furthermore, the present study indicated that the PH of the waters in the three dams is neutral to slightly alkaline. and remain within the recommended range (6.5-8.5) of Algerian standards. This can be explained, on one hand, by the nature of the soils, primarily composed of deep non-acidic brown limestone soils with a PH greater than 6.8 (Hallouche,2017).

This result is consistent with that shown in the study by Touhari et al.,2018 for water samples collected from the reservoirs of the upper Chéliff watershed, as well as the study by Hamaidi on the waters of the Keddara reservoir (Hamaidi et al.,2013). And (Bouguerne ;2016) on the waters of the Ain Zada dam. And Bouhezila on the waters of Lake Reghaia (Bouhezila, et al.,2020).

The measurement of conductivity allows for a quick but very approximate assessment of the overall mineralization of water and to monitor its evolution (Rodier et al., 2009). The electrical conductivity of the water in the Ghrib dam remains high, with an average of 2326 µS/cm, which indicates increased mineralization due to the presence of dissolved salts, calcium (Ca+2), and chlorides. (CL-) These values are similar to those reported by Drouiche et al., (2022), Roy et al., (2015); Etteieb et al., (2017) Bouaroudjet al., (2018), and they exceed the levels recommended by the WHO.

The phosphate values measured in the three studied dams range from a minimum value of 0 mg/l recorded at the Ghrib dam to a maximum value of 0.286 mg/l recorded at the Ledrat dam. These values are below the Algerian standard of 0.5 mg/l. According to the framework used to report the phosphate situation, it is noted that the water in the Ledrat dam reached a significant level of pollution during the month of January. This is due to the use of chemical fertilizers that contain phosphate, as well as the cultivated lands near the dam. Our results remain lower than those of Bouakkaz (2015), who found that the water from the Oum Lakraa and Boussoufa stations reached a significant pollution level of 0.46 mg/l during the sampling periods of August and November.

Turbidity results from the presence of suspended materials in water (organic debris, clays, microscopic organisms…). The assessment of the abundance of these substances measures its degree of turbidity (Jemali and Kefati, 2002). The turbidity of water is caused by suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. The average turbidity of the waters of the Ledrat dam is higher, with an average value of 16.43 NTU, which explains the presence of a large amount of suspended matter, due to the surrounding clayey soils and the contributions of dissolved organic matter in the waters of this dam is more exposed to organic pollution, as evidenced by the positive relationship between the OMS and the PO-4 present in the water.

The Beni Slimane dam shows significant seasonal fluctuations, with an increase in the values of dry residues and chlorides during the summer season. One can observe this seasonal variation in the levels of dissolved oxygen (DO2), which fluctuate significantly depending on temperatures and nutrient inputs at different stations.

The biochemical oxygen demand (BOD5) is a measure of the oxygen in water that is required by aerobic organisms. The biodegradation of organic matter exerts an oxygen tension in the water and increases the biochemical oxygen demand (Abida and Harikrishna ;2008). The average BOD5 values ranged from 3.907 to 20.3 mg/l, with an average value of 2.3

mg/l. The average value exceeds the allowable limit of WHO standards. These values are similar to those found by Khelfaoui at the level of the Oued Saf-Saf in Algeria (khelfaoui ,2010).
The stations located in the Beni Slimene and Ghrib and Ledrat dams have high-lighted significant disparities in water quality. The Ledrat dam, in particular, has shown high levels of WQI, especially in summer and autumn, which suggests a deterioration in water quality, likely due to increased inputs of nutrients and organic matter during these periods. On the other hand, the Ghrib dam has shown increased stability of the parameters, even though the values of conductivity and chloride are particularly high, which suggests significant mineralization. The strong mineralization is mainly due to the geological nature of the surrounding soil.
The redundancy analysis (RDA) applied in this study highlighted the interactions be-tween soil parameters and the physicochemical parameters of water in the three studied dams. (Ledrat, Beni Slimene, Ghrib) The results obtained indicate that water quality is influenced by the majority of the physicochemical parameters of the surrounding soil.
The soils of the Ghrib and Beni Slimene dams have a sandy texture, rich in total and active limestone, which strongly influences water quality by increasing concentrations of calcium (Ca^{+2}) and chloride (Cl^-) and electrical conductivity.
The sandy texture is characterized by a low capacity for nutrient and water retention compared to silt and clay (Dexter,2004). Areas where the soil is sandier, such as around the Ghrib and Beni Slimene dams, promote greater soil permeability.
allowing for the rapid movement of water and nutrients. And leads to a rapid leaching of minerals, which increases the mineralization of the water. The active lime-stone and total limestone present in these soils release calcium into the water, leading to an increase in electrical conductivity and dry residues. This interaction explains why the two dams have highly mineralized waters with high levels of conductivity and dry residues due to the particular composition of their soils.
On the other hand, the clayey and loamy soils, particularly around the Ledrat dam, are negatively correlated with these parameters, which explains their ability to retain nutrients, limit the leaching of minerals such as calcium and chlorides into the water, and reduce mineralization and concentrations of dry residues in the water. As a result, the waters of the Ledrat dam exhibit low concentrations of calcium and chloride, as well as low electrical conductivity and dry residues.
The water parameters such as turbidity (TUR), organic matter (OMW), and BOD5 are negatively correlated with clay, indicating that clayey soils, particularly present in the Ledrat dam, retain suspended matter, which reduces turbidity and organic matter in the water.

Conclusion
The results of our study have shown that land ownership has a significant impact on water quality in the three studied dams: Ghrib, Ledrat, and Beni Slimene. In the Ghrib and Beni Slimene dams, multivariate analyses have shown that parameters such as soil electrical conductivity (EC) and active limestone (AL) and total limestone (TL) are closely related to indicators of water mineralization, such as the electrical conductivity of water, calcium, and chlorides.
On the other hand, the clayey and loamy soils, mainly present at the Ledrat dam, seem to be responsible for a deterioration in water quality by promoting high concentrations of dissolved organic matter (OMW), phosphates (PO^-4), and turbidity (TUR), particularly in the summer.
The statistical models (GAM and GLM) applied in our results confirmed that seasonal and spatial factors play a crucial role in the degradation of water quality. In particular, the summer periods.
The importance of the physicochemical composition of soil in the process of mineralization and the overall quality of surface waters is highlighted by the interactions between soil and water parameters, suggesting that management efforts should take into account the nature of the soils in order to improve water quality in these reservoirs.
Finally, even though this study has provided essential data on the interactions between soil and water in the studied dams, it would be crucial to conduct further studies taking into account other environmental parameters in order to better manage water resources sustainably in our study area.

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