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Research Article

Assessment of environmental degradation on the Mostaganem Plateau Algeria: A critical analysis of soil and water resources

Habib Ouabel[1,3]*, Mohamed Lamine Taleb[1], Amina Hamadi[2,3]

[1]Department of science of nature and life, Faculty of science and technology, Tissemsilt University, Algeria
[2]Departments of Agronomic Sciences, Faculty of science of nature and life, Mostaganem University, Algeria
[1,3]Biodiversity and Conservation of Water and Soil Laboratory, Mostaganem University, Algeria

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***Corresponding author:**

E-mail:
ouabel.habib@univ-tissemsilt.dz

Abstract

This study underscores the importance of accounting for spatial dimensions and temperatures in evaluating payments and environmental interactions. Exploiting natural spaces can foster sustainable development, especially in vulnerable areas, but urbanization poses significant challenges. The Mostaganem Plateau, spanning 78,100 hectares with diverse landscapes, is highly sensitive to environmental pressures like abrasion. Urbanization, agriculture, industry, deforestation, and heavy port activities threaten its biodiversity. Using the plateau as a diagnostic tool helps identify the main causes of its deterioration. Analyzing agricultural and industrial impacts on soil and water highlights the severity of the situation. These analyses, along with in-depth geographic studies, reveal the complex decomposition processes driven by natural and human factors. Implementing effective political policies and management practices is crucial to counter negative influences and promote sustainable development. Protecting the Mostaganem Plateau's fragile ecosystem requires vigilant efforts from the scientific community and social and economic stakeholders. Addressing environmental and ecological impacts is essential for long-term development. Practical responses are needed to mitigate severe degradation and preserve the plateau's environmental integrity for future generations. The study emphasizes the urgent need for monitoring and intervention to safeguard this vulnerable region, ensuring its sustainability and resilience against ongoing threats. Protecting the Mostaganem Plateau's fragile ecosystem requires vigilant efforts from the scientific community and social and economic stakeholders. Addressing environmental and ecological impacts is crucial for long-term development. Practical responses are needed to mitigate severe degradation and preserve the plateau's environmental integrity for future generations.

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1. Introduction

Soil, as a non-renewable natural resource is indispensable for supporting agricultural production, natural vegetation and providing crucial environmental functions essential for ecological balance and food security. It serves as a foundation for sustainable development, emphasizing the need to preserve its productive uses, environmental and ecological functions, and consider its role in land management and territorial use as a collective challenge. While soils evolve slowly under the influence of natural factors like climate, topography, parent material, and vegetation, human activities such as land development, agricultural practices, atmospheric depositions, and accidental pollution can accelerate this process, contributing to ecosystem imbalance and degradation All these degradation phenomena, occurring at relatively short time scales compared to the slow processes of soil formation, pose a challenge for sustainable resource management

It is crucial to recognize that the ability of soils to regenerate is limited and making the preservation of soil and water resources a major problem, especially in densely populated urban areas with intense agricultural and industrial activities as well as the urban construction The scientific field is increasingly Mindful of implications Communauté écologique degradation for socio-economic development, with urban and coastal areas being particularly vulnerable due to high demographic pressure and significant port and tourist activities

In the north-oust of Algeria, the Mostaganem region in Algeria stands out for its semi-arid Mediterranean climate, characterized by moderately hilly terrain and farmlands that are both impoverished and fragile, making them vulnerable to inappropriate agricultural practices. (Larid et al., 2014) exemplifies an ecosystem severely affected by the degradation of its soil and water resources (Tebani & Mederbal, 2018) Spanning over 78,100 hectares, tray of Mostaganem faces significant erosive effects. Their susceptibility to erosion poses a significant threat to the environment. (Bousmaha A., et al. 2020), especially with the area experiences lofty density in urban tailoring and hosts diverse financial operations, including farming, manufacturing, and harbor activities currently according to. Despite its ecological importance, the plateau remains understudied, with few scientific investigations (Larid et al., 2014; Gorine, 2019).

The soil quality defined by its properties and functions is a critical consideration for sustainable land use (Karlen et al., 1997). The management of agricultural systems globally tends toward ecosystem degradation leading to a reduction in soil quality (Yang et al., 2020). The soil diagnosis degradation is essential for evaluating the reliability of lands management choices in agroecosystems. Feedback mechanisms can help users examine the sustainability of their management choices, identifying vulnerable production zones, estimating realistic food production, and monitoring changes in environmental sustainability and quality (Granastein et al., 2010; Rodrigues de Lima & Brussaard, 2010). Soil quality indicators are crucial for reliable diagnostics, employing multivariate statistical methods such as Principal Component Analysis (PCA) proving effective in identifying key indicators for soil quality assessment (Larid et al., 2014). While much research has focused on soil quality assessment in temperate zones, there is a paucity of studies in arid and semi-arid zones characterized by small-scale agricultural systems (Imaz et al., 2010).

This study contributes to the comprehensive analysis of degradation agents affecting soil and water resources in the highland of Mostaganem, situated in the northwest of Algeria. Aiming to shed light on an underexplored theme with significant ecological impacts on the region's rapid development. The study, organized into four chapters, addresses the degradation of soil and water resources, introduction to the plateau of Mostaganem, situated in the north-western region of Algeria, the discussion of the different agents of degradation and at the end proposals for primary measures (preventive and/or curative) to protect the soil and water resources of the tray of Mostaganem.

2. Materials and methods

2.1 Study of the Area

The tray of Mostaganem belongs to the Oran department. It occupies the western part of the coastal city of Mostaganem located on the west coast of Algeria, and covers an area of 1400 km^2 It is bordered by the plain of Relizane to the south, the Chéliff river lies To the east, to the north is the Mediterranean Sea, and to the west is the Habra Plain (Figure 1).

The plateau of Mostaganem is defined by its geographic coordinates., as identified by:
-Map Info 8.5 software and Geographic coordinates (latitude and longitude).

Latitude 1 = 35.877046°N,	Longitude 1 = 0.131484°E
Latitude 2 = 35.919308°N,	Longitude 2 = 0.275594°E

The east-west transect of the tray of Mostaganem (Figure 2) reveals a 35.4 km-long plain extending from the western slope of Djebel Dis to the eastern slope of Ain Nouissy (Sidi Chekka). On the surface, there are parallel and overlapping depressions, rising from west to east at elevations of 150 to 200 meters above sea level. Generally, these shallow thalwegs are unaccompanied by any surface streams of tectonic origin. The tray of Mostaganem exhibits undulating terrain (Figure 3), flowing in a north-south direction, it traverses A mountainous area Starting from north to south, notably including **DJEBEL DIS** in Mostaganem. Indeed, in the tray of Mostaganem (Figure 4), where the soils are predominantly sandy in texture, the yields of vegetable production, the main activity, and arboriculture suffer from deficits due to abiotic stresses such as drought and salinity.

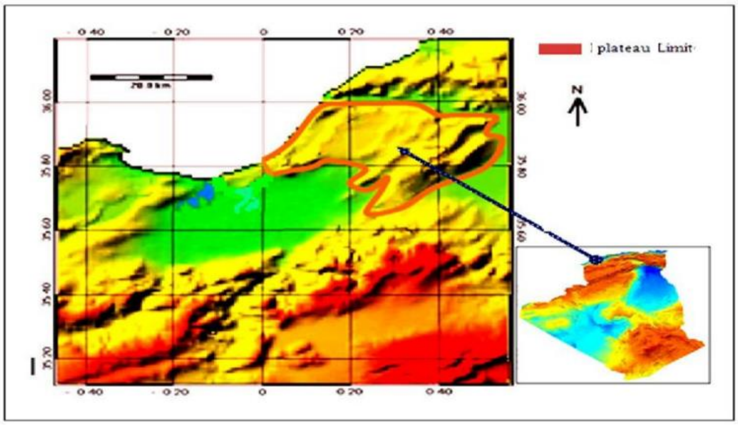

Figure 1. Map outlining the boundaries of the tray of Mostaganem area

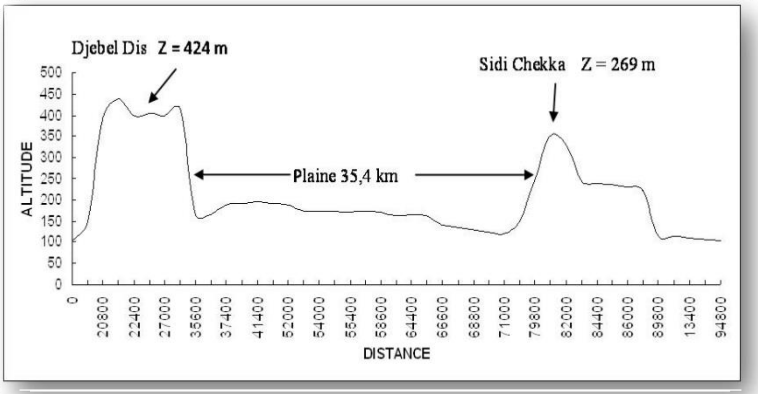

Figure 2. East-West Transect of the tray of Mostaganem

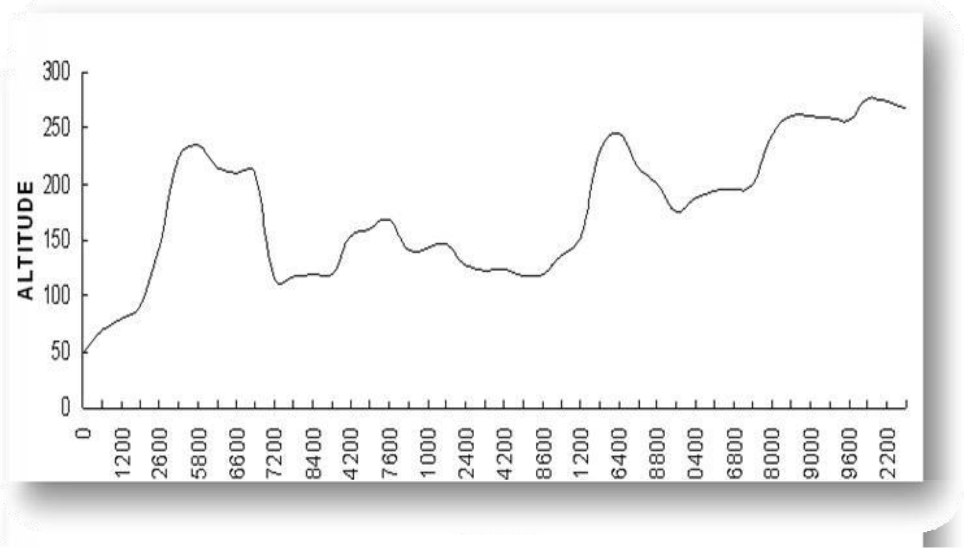

Figure 3. North-south transect of tray of Mostaganem area

Figure 4. Satellite image showing location of tray of Mostaganem

2.2 Methodological approach

Our approach was guided by the use of cartographic tools at de first, considered as spatio-temporal indicators (Kraak & Fabrikant, 2017). These tools allowed us to delineate spatial zones based on their degradation status and susceptibility to it, correlated with eco-pedological factors. It is important to note that degradation and susceptibility Representing two instances of environmental decline. aspects of the same ecological behavior in the face of agents impacting natural resources. In this approach, particular attention was given to the physical and soil-related attributes of the region of Mostaganem, situated in northwest Algeria. It followed five major steps: data acquisition, data processing, formatting of geographic and alphanumeric databases, and in-depth analysis of the results. This method was developed to gain a comprehensive understanding of the environmental state of The elevated terrain of Mostaganem is situated. despite the challenges related to the limited availability of physical data. The adopted methodology ensures a robust assessment. (Caïd N et al., 2019).

Topographic maps of the plateau, acquired by the INRH, were integrated into a Geospatial Information System (GIS) along with using remote sensing data for mapping purposes. the geographical features and vegetation. Concurrently, random samples of soil and water were collected at depth (Figure 5) and then were analysed at the INSID laboratory located in the wilaya of Relizane, Algeria. This integrated approach, combining geographical data, remote sensing, and laboratory analyses, provided a holistic view of the environmental state of the Mostaganem plateau in Algeria. It thus offers a solid basis for decision-making in the management and conservation of natural resources in the region. The methodology used in this study comprises several steps. Samples received at the laboratory are dried, weighed, then crushed and sieved. Physical analyses are performed on the fine soil, and pH and electrical conductivity are measured. Granulometric analysis is conducted using the Robinson pipette method. Finally, moisture measurement at different pF values is carried out by applying a determined pressure to soil samples.

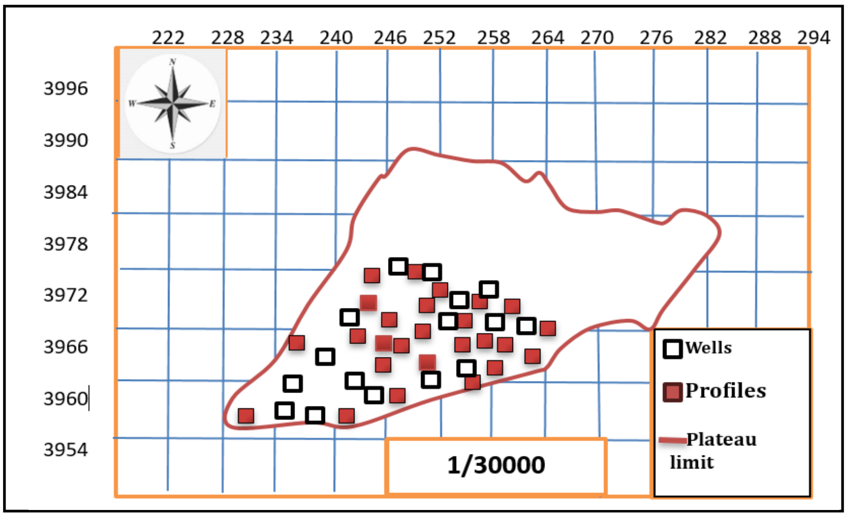

Figure 5. Sampling scheme for soil profiles and wells

3. Result and discussion

3.1 Soil analyses

Granulometric Analysis

For this study, we opted to use the USDA texture triangle to analyze our granulometric data, due to its relevance and widespread use in the scientific literature

The soil texture (Figure 6) It indicates that the features and expressions are distributed along the clay-sand axis, allowing us to identify three main groups within the study area.

-Sandy-clayey soil category -Clayey-silty soil category -Sandy soil category

The plateau of Mostaganem algeria consists of Sand proportion predominates, constituting between 66% and 94% of the samples taken from de soil of the tray of Mostaganem, with an average of 80.42%. Conversely, the clay fraction ranges from 0.15% to 10.21%, averaging 6.4%, while the silt content remains relatively low, varying between 3.90% and 20.96%, with an average of 12.77%. This prevalence of the sand fraction is illustrated in (Figure 7), where the highest frequencies for clay and silt are observed on the left side of the graph, indicating lower weight percentage presence, contrasting with the predominant presence of sand on the right side, where the weight percentage presence exceeds 60%.

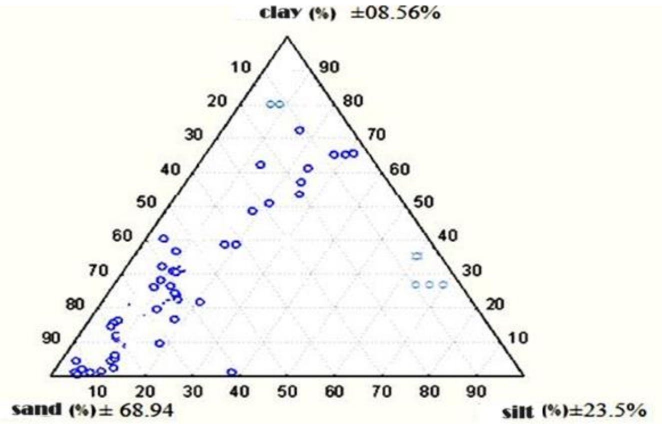

Figure 6. Soil texture results in Mostaganem

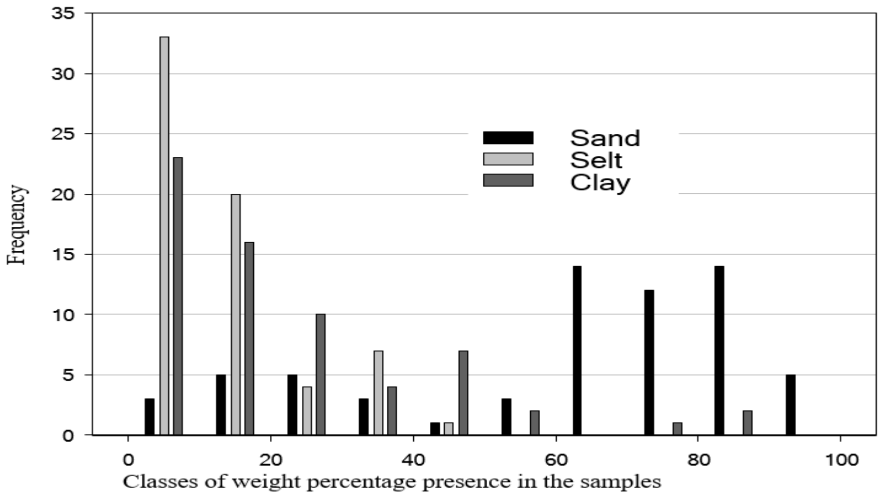

Figure 7. Granulometric fraction Plateau distribution in Mostaganem

Physicochemical analyses

Overall, constituting about 89% of all samples, the soil in the study area predominantly exhibited pH levels ranging between 7 and 8, with a cumulative occurrence of 58. Concerning total limestone content, the results indicate a prevalence of moderately limestone soils, with approximately 59% of the samples falling within the CaCO3 class between 10 and 20%. However, it is noteworthy that there is significant dispersion in CaCO3 values, with a gap between extreme values of 21.66 and a standard deviation of 6.60.

The soils demonstrate notable salinity, with an average electrical conductivity amounting to 4.21 dS.m^{-1} and that of diluted extract equal to 1.02 mS.cm^{-1}.

Regarding organic matter, the majority of the tray soils have a high organic matter content, with 40% and 54% of the analyzed samples, containing respectively ranging from 2 to 4% and surpassing 4% of OM.

Statistical analyses

After the results emerged from the application of Principal Component Analysis (PCA) as an exploratory method, identifying the linked associations that preserve all variables, it delineates how they are organized and how their members are combined. (Larid et al., 2014) in a graphical description of the information contained in large data sets. While descriptive statistics tools allow for the examination of variables one by one or pairwise through graphical or the calculations for numerical summaries (mean, variance, covariance, correlation, standard deviation) are regarded as basic preliminary studies in research. while essential in any statistical analysis, are unsatisfactory here as they overlook potential relationships between variables, which are often the most critical aspect (Rencher & Christensen, 2012).

Eigenvalues and eigenvectors

The eigenvalue, as shown in Table 1, is 3.70 with a percentage indicating 17.63%. This percentage is derived from the ratio of the eigenvalue of (axis F1) to the grand sum of all eigenvalues, amplified by one hundred, indicating the proportion of information explained by (axis 1).

Table 1. Eigenvalues of the variables

	F_{01}	f_{02}	f_{03}	f_{04}	f_{05}	f_{06}	f_{07}	f_{08}	f_{09}
EV :	03,700	03,210	02,580	01,970	01,880	01,510	01,210	01,190	01,050
Var %	17.630	15.300	12.300	09.380	08.970	07.190	05.780	05.670	04,990
Cum%	17,630	32,920	45,220	54,600	63,570	70,770	76,550	82,210	87,200

Two axes represent the cumulative percentage of information obtained, accompanied by an explanation, obtained by adding together the proportions explained by each individual axis:

According to Kaiser's rule and Cattell's test (Table 1), the plot of eigenvalues shows nine axes that best represent and synthesize the data in our study. Indeed, the proportion of information explained from the cumulative proportion of information from the initial to the ninth axis is 87.20%.

Table 2. The eigenvalues of the variables

AXIS1-AXIS2: 17 ,63%	+	15,30%	=	32,93%	RELATIVE TO PLAN 1-2
AXIS1-AXIS3: 17 ,63%	+	12,30%	=	29,93%	RELATIVE TO PLAN 1-3
AXIS1-AXIS4: 17 ,63%	+	09,38%	=	27 ,01%	RELATIVE TO PLAN 1-4
AXIS2-AXIS3 :15,30%	+	12,30%	=	27,60%	RELATIVE TO PLAN 2-3
AXIS2-AXIS4: 15,30%	+	09,38%	=	24,68%	RELATIVE TO PLAN 2-4
AXIS3-AXIS4: 12,30%	+	09,38%	=	21,68%	RELATIVE TO PLAN 3-4

Study of Variables

Examining the table of variable contributions allows us to Identify the variables that exert significant influence on the shaft forming factor axis:

Axis 1: The dominant axis is active limestone

Variables	SC	VC%
Revenue %	00,79	21,31
X Total	00,78	21,02
Total limestone: TL	00,78	21,02
Chlorine: Cl	00,31	8,35

Axis 2 : Axis of predominance of Magnesium

Variables	SC	VC %
Mg (g/l)	0,00074	22,90
Na (g/l)	0,00044	13,70
CS	44 ,00	13,70
Sulfates	0,28	08,60

Axis 3 : Axis for the dominance of large sands

Variables	SC	VC%
CS%	00,49	19,11
FS%	00,46	17,89
CO %	00,40	15,36
OM%	00,34	13,15
pH d	00,28	11,02

Axis 4 : Monitoring axle for the electrical conductivity of the diluted extract

Variables	SC	VC%
Ced	00,42	21,08
FS%	00,25	15,73

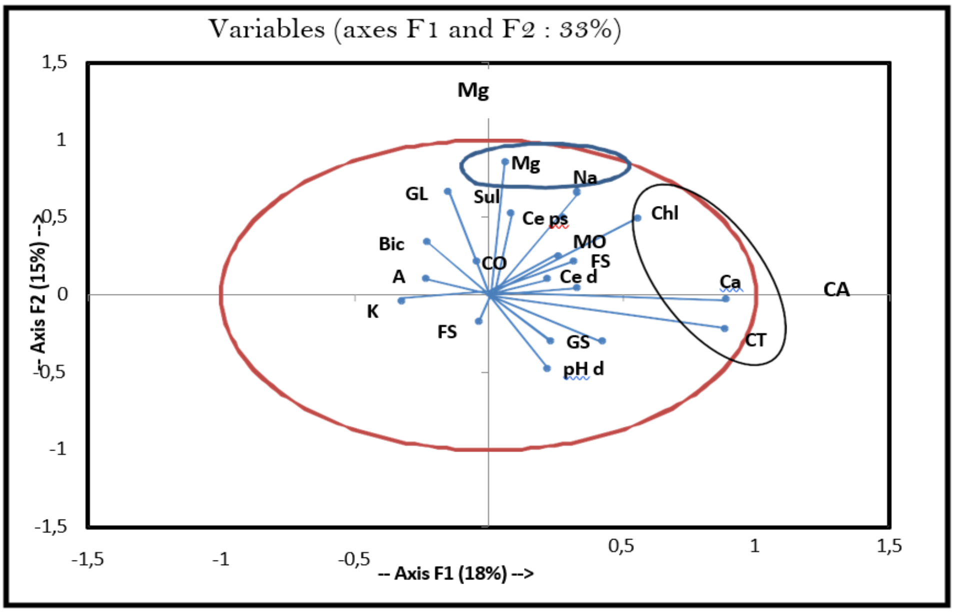

Figure 8. Project variables onto the axis 1-2 plane

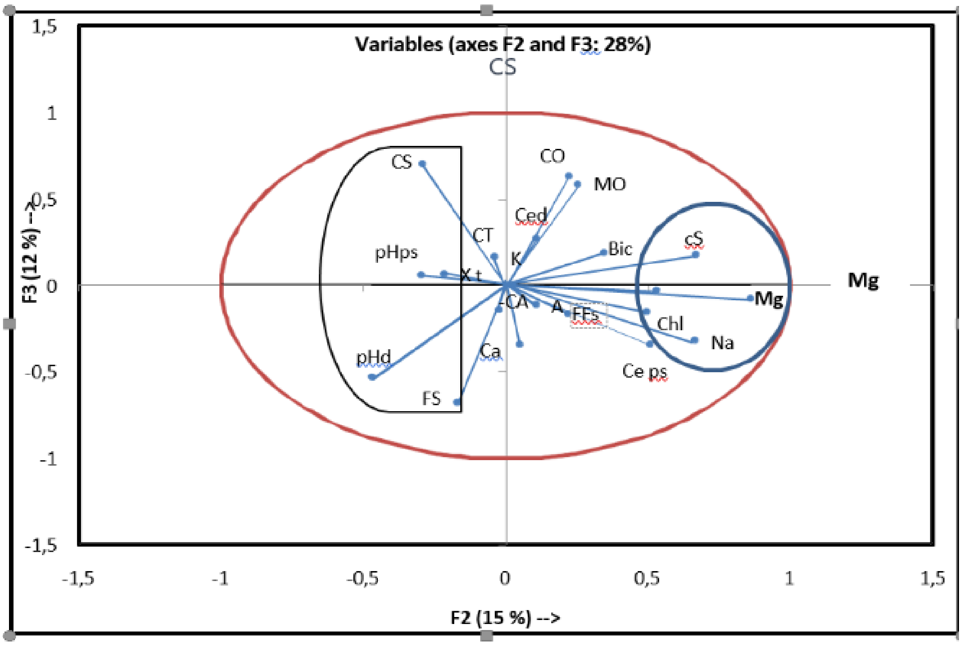

Figure 9. Project variables onto the axis 2-3 plane

The plane formed by axes 2-3, explaining 28% of the data, indicates that's axis 3differentiates between several variable (CO, OM, LG, Mg, Na, GS, FS, pH, and EC) The coordinates of individuals (Table 3 in the appendix) unveil relationships between the studied parameters for various sets of profiles. The representation of only the F1 and F2 axes explains 33% of the data. showing a strong correlation between the variables within each group. It clusters the variables divided into two sets: (Tl, calcium %, and chlorine ions) and (magnesium, sodium, fluoride%, and sulfate). The correlation between the vectors of organic carbon and low-length organic matter is weak, suggesting limited contribution to soil coverage by both axes. However, the statement in the chart shows that magnesium has the longest arrow length in determining axis 2. This is attributed to its significant impact.

Table 3. Summary of PCA Results

Profiles	Associated with	Remarks
2, 3 and 9	Mg, Na, pH	Basic soil
4, 13 and14	Clay	Erosion
1,2,2,3,7,9,12, 23 and 24	(Coarse sand), (Fine sand)	Intense wind erosion (deposition)
3, 6, 17 and 20	CT, CA - Intense water erosion	CT, CA - Intense water erosion
5, 8, 10, 11 and 18	Conductivity - Saline soils	Conductivity - Saline soils
2, 3,15 and 24,	Magnesium - Contaminated	Magnesium - Contaminated

3.2 Water analysis

Physico-chemical analyses

The analysis of physico-chemical parameters of water samples collected from 13 wells distributed in the same area provides valuable insight into the water quality in this specific region.

Interpreting the results regarding sodium concentration in water samples reveals significant quantities in certain wells, with notable variability. This fluctuation prompted us to calculate the Sodium Adsorption Ratio (SAR) of the water samples, providing a more precise measure of sodium's effect on water quality (Figure 9). The findings indicate that the vast majority of studied water samples (85%) have a SAR below 3, indicating that water quality remains suitable for agricultural use. However, two samples have a SAR above 3, suggesting that these waters should be used cautiously to prevent any detrimental impact on crops. This interpretation is further supported by more recent studies that have also underscored the importance of SAR in assessing water quality for agriculture (Zheng et al., 2018; Mukate & Shende, 2020; Al-Ruwaih, 2021).

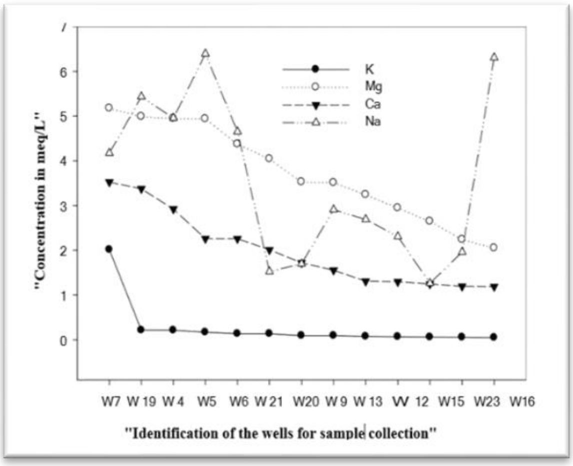

Figure 10. Concentration of cations in the waters of the different wells studied

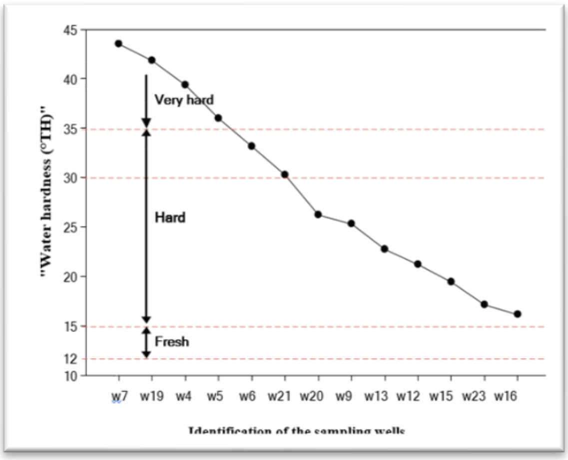

Figure 11. Hydrotimetric degree of water from the different wells studied

The pH, an importante indicator of water acidity or alkalinity, reveals that most samples fall within a range between 6.6 and 7.0, with extreme values ranging from 6.52 to 7.89. This range, relatively close to neutrality, suggests water quality generally suitable for various uses, including agricultural irrigation. The electrical conductivity (EC) of the samples gives an overview of their salinity. Approximately 77% of samples have an EC between 3 and 5 dS.m^{-1}, categorizing them as C4 according to the USDA classification, indicating high salinity. These waters, while often unsuitable for irrigation due to their high soluble salt content, may require specific treatment for safe use. The remaining 33% of samples have an EC between 5 and 6.5 dS.m^{-1}, categorizing them as C5, rendering them generally unusable except under particular circumstances.

Water hardness, primarily attributable to the presence of calcium and magnesium, is an essential aspect to consider. Results show that 54% of samples are classified as hard and 46% as very hard in terms of hydro-timetric degree (°TH). This increased hardness may be related to the presence of a shallow limestone layer in the region, influencing the chemical composition of groundwater.

This analysis highlights the diversity of water quality in the studied region, emphasizing the importance of monitoring and understanding physico-chemical parameters to ensure sustainable and safe use of local water resources.

3.3 Principal Component Analysis (PCA)

Correlation Matrix (Eigenvalues and Eigenvectors)

As with soil analyses, we will apply Principal Component Analysis (PCA) to the results obtained from water analyses. To do this, the eigenvalues of the variables are presented in Table 3.

Table 4. Eigenvalues of variables

	F1	F2	F3	F4	F5	F6
EV	03,09	01,36	01,20	01,02	00,92	00,63
Var %	34,28	15,15	13,40	11,38	10,22	07,03
Cum %	34,28	49,44	62,85	74,23	84,46	91,49

The cumulative proportion of information explained by two axes is obtained by adding together the proportions and clear from before by each individual axis.

Axis1-Axis2 : 34,28%	+ 15,15%	= 45,43%	Regarding the plane 1-2
Axis1-Axis3 : 34,28%	+ 13,40%	= 47,68%	Regarding the plane 1-3
Axis1-Axis4 : 34,28%	+ 11,38%	= 45,66%	Regarding the plane 1-4
Axis2-Axis3 : 15,15%	+ 13,40%	= 28,55%	Regarding the plane 2-3
Axis2-Axis4 : 15,15%	+ 11,38%	= 26,53%	Regarding the plane 2-4
Axis3-Axis4 : 13,40%	+ 11,38%	= 24,78%	Regarding the plane 3-4

Study of variables

Axis 1: Axis of predominance of electrical conductivity

Variable	Squared cosine	Variable contribution %
Ce: Cerium	0,82	26,68
Cl: Chlorine	0,80	25,78
Mg: Magnesium	0,48	15,49
PH: pH	0,28	9,00
Na: Sodium	0,26	8,52

Axis 2: Axis of predominance of calcium (Ca)

Variable	Squared cosine	Variable contribution %
Ca: Calcium	0,45	32,88
SO4: Sulfate	0,30	22,33

Axis 3: Axis of predominance of sulfate (SO4)

Variable	Squared cosine	Variable contribution %
SO4: Sulfate	0,45	22,33
K: Potassium	0,28	15,33

Axis 4: Axis of predominance of magnesium (Mg)

Variable	Squared cosine	Variable contribution %
Mg: Magnesium	0,25	23,92

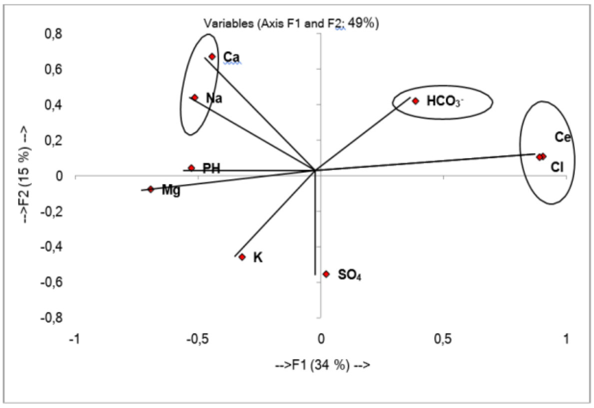

Figure 12. axis 1-2 Dropping the variables

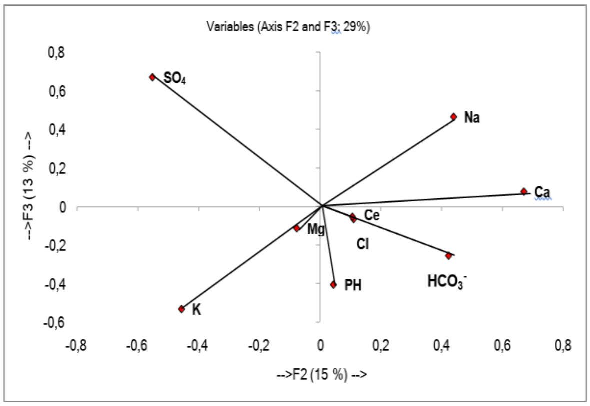

Figure 12. axis 2-3 Dropping the variables

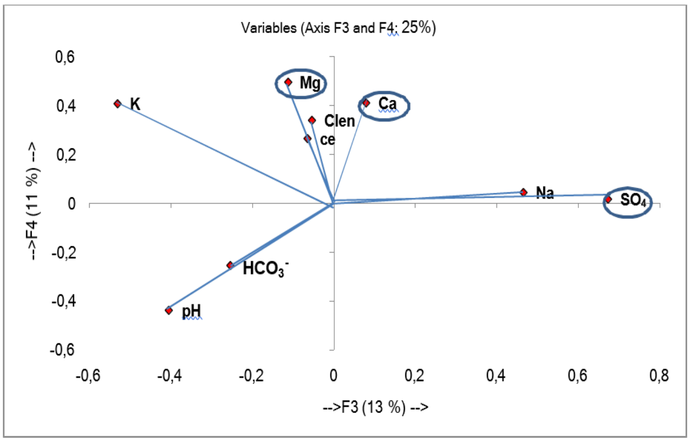

Figure 13. Axis 2-4 Dropping the variables

Table 5. Summary of PCA Results

Class	Well N°.	pH	EC	Cl	HCO_3	So_4	K+	Mg^{2+}	Ca^{2+}	Na^+
Class 1	2, 3, 8, 9, 11, 12, 15	7.09	1.70	9.10	4.10	1.96	3.55	35.38	23.75	241.0
(L2)	16, 19, 22 & 24									
Class 2	1, 2, 3, 10, 13, 17,	7.15	1.25	8.50	4.80	1.12	2.12	21.14	45.15	169.0
(L18)	18, 20, 21, 25 & 26									
Class 3	4, 5 & 7	6.64	5.13	41.10	5.40	2.39	1.80	22.31	23.87	114.0
(L4)	6 &14	6.66	2.15	14.70	4.50	4.12	1.26	20.15	6.15	48.0

We performed a comprehensive diagnosis in this study, of the water samples collected from various wells. Characterization tests of the wastewater revealed significant and irregular pollution, which could be detrimental to the receiving aquatic environment (river, lake).

We have highlighted pollution due to the presence of biogenic ions or nutrients, exceeding acceptable standards for industrial water discharge in most cases. This is particularly evident in the phosphate and sulfate concentrations. These two elements promote algae growth, which can disrupt the surrounding environment. Furthermore, we observed elevated electrical conductivity values, which may indicate pollution from mineral elements. Significant amounts of salts were detected in the water samples, particularly at wells 4 and 5. To improve the quality of these waters and ensure the preservation of the receiving environment, interventions are necessary to address this environmental issue. This could involve establishing national standards and implementing a water recycling and treatment station for the plateau of Mostaganem Algeria.

4. Conclusion

Groundwater pollution due to various human pressures such as consumption, urbanization, agriculture and industrial activities leads to the degradation of the ecosystem. Environmental monitoring can be greatly enhanced by tracking groundwater, which helps mitigate the effects of many agricultural and industrial activities. These activities consume more water intensively, which contributes to pollution through waste and leakage. Therefore, diagnosing groundwater degradation and pollution is a crucial indicator of resource degradation, especially in volatile environments such as the Mostaganem Plateau. The study begins by analyzing the results of several research points in the southwestern part of the Mostaganem Plateau. The initial focus is on pre-water zones that receive wastewater through seepage down the sandy slopes of the plateau. A gentle hydrogeological cover is essential to determine the sensitivity of water transport to land and to identify preferred flow zones. The collected data reflect a systematic approach that contributes significantly to a diagnostic study of the degradation of soil and water resources within an ecosystem. Water test results showed that two-thirds of the samples had a pH between 6.6 and 7, indicating neutrality. However, this is not enough to comprehensively estimate water quality mainly due to the presence of magnesium sulphate. High water hardness can cause problems in irrigation and industries by inhibiting saponification and clogging channels with carbonates and magnesium hydroxides. The high sulfate content makes the water unfit for human consumption and unacceptable for industrial use, requiring careful management in agricultural production. Electrical conductivity (EC) and sodium absorption ratio (SAR) are critical indicators. Increased electrical conductivity raises the osmotic pressure of water, which hinders plant water absorption and causes physiological stress and insufficient humidity under standard conditions. Especially soil erosion in the Mostaganem Plateau, caused by wind erosion. Strong wind activity is observed in the northwestern and southwestern parts. In contrast, significant valley and channel formation occurs in the southeastern part. Sheet erosion is less frequent in bare areas than in cultivated areas, indicating that human activities increase soil degradation through erosion. Soil pollution is linked to the rate of vegetation cover, which is often disrupted by urban and industrial pressures. Forests, mainly in the form of paths, cover about 2% of the plateau. In the southwestern part, forest areas are shrinking due to the boundaries between agricultural fields. In the northwest. Scattered grass formations, sometimes leaving large areas of bare soil, are evident around towns such as Hassi Mamish, Mazagrane and Stedia. Runoff effects are visible in the sparse plain in the northwest, while they are minimal under the Bokkerdal Forest in the southwest. The scientific community underestimates this form of soil degradation, despite causing a significant loss of fertile lands on the Mostaganem Plateau. Concrete construction encroachment on agricultural lands exacerbates the problem. An integrated approach is crucial to studying the factors of soil and water resource degradation. This ongoing study produces indicators of soil and water health, enabling various stakeholders to assess their environmental impacts and maintain the environmental balance of the region within the framework of social and economic development.

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Author's Declaration

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