J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 15 (3): 51 - 65, 2024

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Assessment of Irrigation Water Quality in the Reclaimed Lands in the North of Dakahlia Governorate

Asmaa N. Alshrabasy[1*]; A. M. Kenawy[2,3] and Eman F. Mohamed[4]

[1] Department of Geography and Geographic Information Systems Faculty of Arts, Mansoura University
[2] Instituto Pirenaico de Ecología, CSIC, Campus de Aula Dei, 1005, 50059, Zaragoza, Spain
[3] Department of Geography, Faculty of Education, Mansoura University
[4] Department of Geography and Geographic Information Systems Faculty of Arts, Mansoura University

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ABSTRACT

This study assesses the quality and suitability of irrigation water in Qalabasho-Zaian area (northern Dakahlia Governorate). Water samples from 23 sites were collected from irrigation and drainage networks across the study domain. Different chemical parameters of the sampled water were analyzed, including pH, electrical conductivity, major ions (Ca, Mg, K, and Na), and sodium adsorption ratio (SAR). Results indicate that, for the majority of the analyzed parameters, the irrigation and drainage networks were mostly beyond the safe limits of irrigation use. Specifically, we noted high salinity levels for irrigation water, as well as for potentially toxic elements such as Cd, Cr, Cu, Fe, Mn, Al, Se, V, Ni, Zn, As, Hg, Mg, Ca, Sr, In, Ba, and Ag. This high level of pollution is linked mainly to the location of the study domain at the end of a network of irrigation and drainage channels, combined with the proximity of the study area to a local industrial zone (Gamasa) and effluents discharge from industrial plants. Recalling the national policies that aim to maximize the use of the recycled of irrigation water, the results of this study can inform policy decisions at the local and regional levels regarding water quality standards, agricultural practices, and land use planning. This can help policymakers develop regulations and guidelines to protect water resources, promote sustainable agriculture, and mitigate potential risks to human health and the environment.

Keywords: Irrigation Water Quality Index, GIS, Qalabasho, Zaian area, Delta, Egypt.

INTRODUCTION

Water quality influences its suitability for a particular use (Malakar et al., 2019). The significance of irrigation water quality cannot be overstated in agricultural ecosystems. It exerts a direct impact on the health, yield, and overall productivity of crops. Poor-quality water may be a good alternative for fresh water in water scarce areas (Dotaniya, 2023). Numerous variables influence water quality, including the presence of contaminants, chemical composition, and origin. Superior irrigation water provides a multitude of advantages, such as heightened nutrient absorption (Evans, et al., 2019). , increased crop productivity, and decreased susceptibility to disease. Inversely, degraded and salinized soil can result from poor water quality, posing economic and environmental challenges (Ribaudo & Johansson, 2006). Pesticides, pathogens, heavy metals, and other contaminants have the potential to cause detrimental impacts on both plant life and the environment. As such, the recognition and preservation of water quality are critical for the sustainability of the agricultural sector and the food supply and for addressing the needs of an expanding human population and preserving finite natural resources.

Due to massive land reclamation and agricultural projects, the northern part of the Egyptian Delta has changed drastically in the last few decades. Improving food security, increasing agricultural output, and boosting economic growth have all motivated these initiatives. The transformation of large areas of degraded land into arable land is one of the main goals of land reclamation efforts in this region. Many agricultural benefits can be obtained from the reclaimed lands in this area. Soils rich with organic matter and generally conducive to growing a broad range of crops are few examples of these benefits. To cultivate crops all year round, there must be ready access to large quantities of irrigation water from the adjacent Nile River. Nonetheless, as a result of the expansion of reclaimed lands, the region has witnessed a diversification of agricultural practices. Several persistent challenges remain, including the need for sustainable practices in water resource management, prevention of soil degradation, and adaptation to climate change. These challenges underline the importance of continued efforts to ensure the long-term success of these agricultural initiatives.

A series of studies have assessed the irrigation water quality in the reclaimed lands of the Delta, Egypt. Khafagy (2018) and Allam (2013) both found that drainage water from the Northern Delta and Kafr El-Sheikh Governorate, respectively, could be reused for irrigation with special management. However, El-Agha (2011) highlighted the need for improved water management in the Meet Yazid command to address issues of water distribution and mismatch between demand and supply. El-Hassan (2009) and Salem (2017) both emphasized the positive impact of irrigation improvement on water quality and human health. El-Aassar (2016) discussed the potential impact of wastewater irrigation on groundwater quality, highlighting the need for treatment systems in the new reclamation areas. Also, Ashour (2021) found that current drainage and blended water in El-Behira Governorate did not meet the necessary quality standards for irrigation. In

* **Corresponding author.**
E-mail address: asmaa.alshrabasy@mans.edu.eg
DOI: 10.21608/jssae.2024.270005.1217

Dakahlia, El-Agrodi et al. (2018) evaluated the quality of drainage water from specific agricultural drains in the governorate and assessed the suitability of this water for irrigation, considering its potential contamination from sewage and industrial wastewaters. They found that the pH, COD, BOD, heavy metals, NO3–N, EC, and SAR values of the water samples generally fell within permissible or acceptable limits for irrigation. More recently, Elhdad (2019) assessed water quality for drinking, agriculture, and aquatic life purposes in Dakahlia Governorate, demonstrating that the water quality varied among different treatment plants, with some being unsuitable for drinking and aquatic life, while others were classified as excellent. Also, this study indicated different degrees of contamination by metals, except for Zn2+ and Ni2+, in the water used for drinking and aquatic life purposes.

Despite the existence of previous studies, there remains a notable gap in conducting a thorough evaluation of water quality in the reclaimed lands situated in the northern region of Dakahlia Governorate. To address this void, the primary objective of our study is to comprehensively assess the water quality of the irrigation system within this area. Our research endeavors to achieve this goal by conducting an in-depth analysis of various parameters including chemical composition, electrical conductivity, acidity, and presence of inorganic materials. We collected a total of 23 samples from the irrigation network spanning across the region, utilizing these samples as the basis for our assessment. Given the region's unique irrigation system intricacies and water deficit challenges, evaluating irrigation water quality assumes paramount importance, especially considering the interdependency of irrigation and drainage systems. Through meticulous examination and interpretation of the gathered data, we aim to provide valuable insights into the current state of water quality in the reclaimed lands, thereby contributing towards informed decision-making processes and the implementation of effective water management strategies in the region.

MATERIALS AND METHODS

1. Study area

This study focuses on the rehabilitation zone of Qalabasho, Zaian, situated within the geographical coordinates of 31° 13' 56.442", 31° 33' 26.103"E and 31° 21' 59.809", 31° 32' 45.778"N, covering an area of approximately 300 km^2 and hosting a population of 28,774 as of 2017, constituting 7.02% of the rural populace of the Belqas district and 0.62% of Dakahlia's rural population. The agricultural expansion within this zone has unfolded over multiple phases since the 1980s. Notably, agricultural land area has seen a consistent increase, juxtaposed with a rise in fish farms, which typically occupy about one-third of the agricultural land area in most years.

Qalabasho stands as one of the reclaimed lands in the northern Delta, located within the coastal zone of Dakahlia Governorate, and serves as one of the rehabilitated sectors in the governorate's northern region, a process initiated in the 1980s (Figures 1). However, the area contends with various pollutants originating from irrigation and drainage networks spanning agricultural and residential lands within the governorate, compounded by high-risk pollutants from the industrial zone in Gamasa, which falls within the study area. The study witnessed a conversion of wetlands into agricultural fields, followed by the proliferation of fish farms alongside agricultural land. Crops cultivated include watermelon, rice, tomatoes, various vegetables in summer, and wheat, sugar beets, and beans in winter. The study area encompasses 11 agricultural associations and state land, with each association averaging an area of 20.22 km^2. Supervised classification of remote sensing data reveals the area's agricultural use evolution (fig. 2), with plant-agriculture land increasing from 41.21% to 66.12% (table 1), and fish-agriculture land occupying 14.89% (fig 3,4).

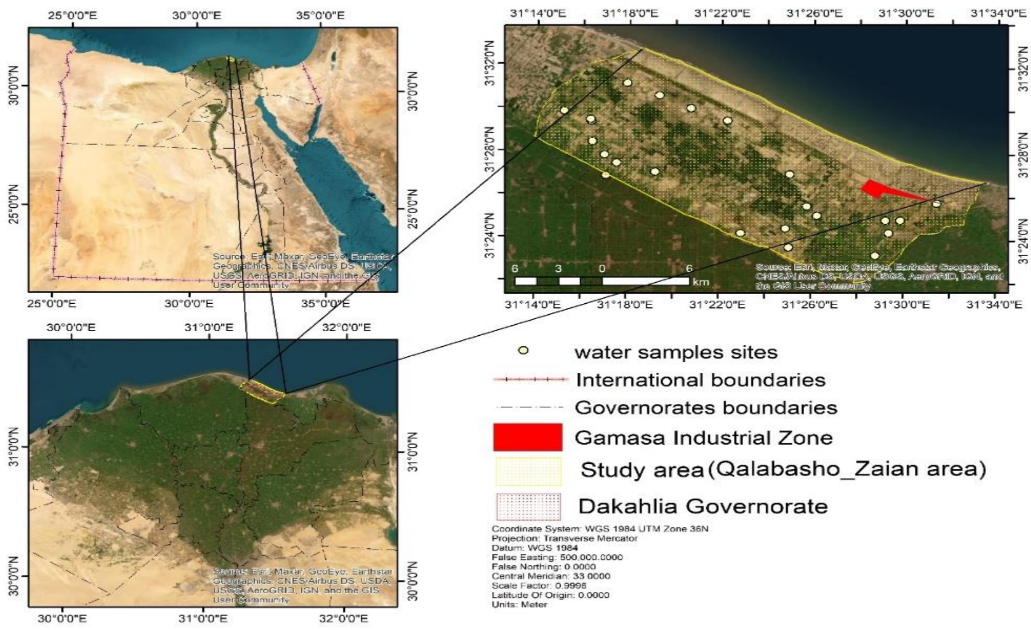

Figure 1. Location of the study area

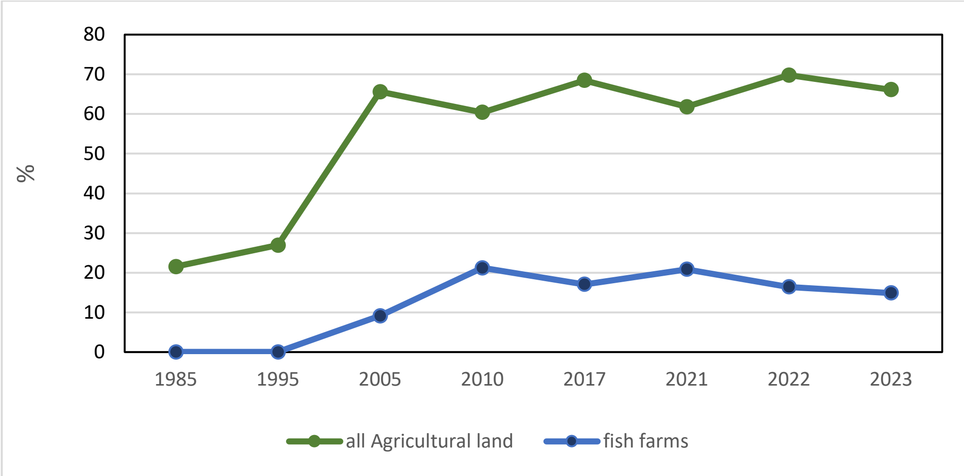

Figure 2. Change in the area of agricultural land and fish farms over the study area from 1973 to 2023.

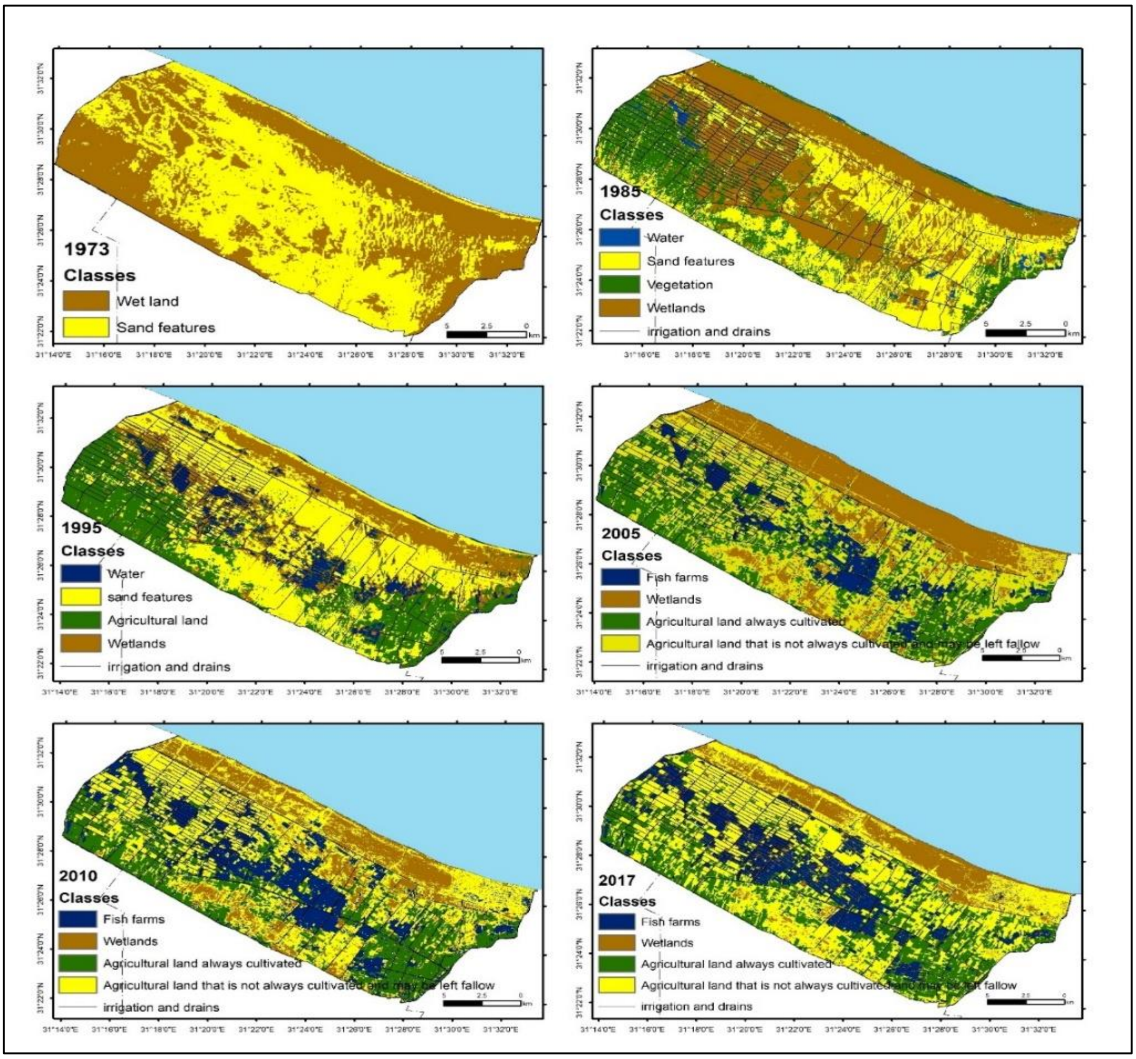

Figure 3. Changes in the Land use and land cover types across the study area (1973-2017).

Table 1. Land cover and land use change in study area over the period 1973-2023.

1973		1985		1995		classes	2005	2010	2017	2021	2022	2023
Classes	ratio	classes	ratio	classes	ratio		ratio	ratio	ratio	ratio	ratio	ratio
Water	0.35	Water	1.60	Water	7.67	fish farms	9.12	21.20	17.07	20.84	16.40	14.89
sand features	47.73	sand features	32.61	sand features	41.23	Wetlands	25.28	18.38	14.48	17.33	13.80	14.74
Wetlands	51.92	Vegetation	21.52	Vegetation	26.94	Agricultural land always cultivated	26.93	21.11	24.21	25.65	21.47	32.48
		Wetlands	44.26	Wetlands	24.15	Agricultural land that is not always cultivated and may be left fallow	38.67	39.31	44.24	36.19	48.32	33.64

Source: Observed classification of Landsat and Sentinel images using SVM method.

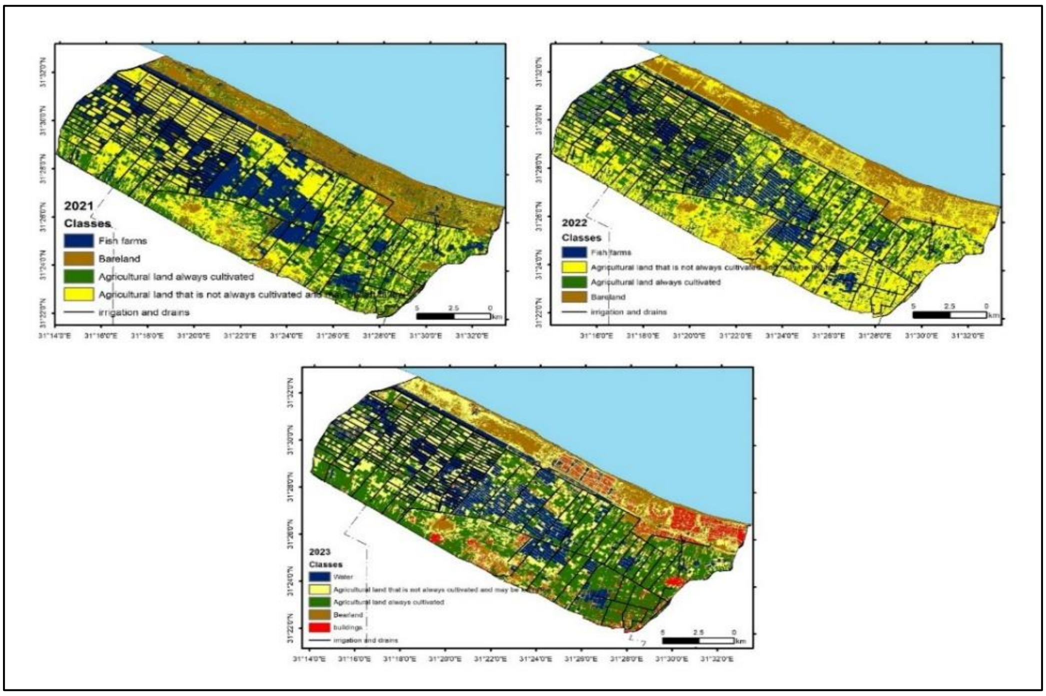

Figure 4. Changes in the Land use and land cover types across the study area (2021-2023)

2. Dataset description

Data for the laboratory analyses were collected from water samples obtained from canals and drainages within a closed network (fig. 5). The sampling locations were determined by dividing the area into 166 primary inspection units, with exclusion areas for state property and fish farms, resulting in 23 selected areas for water sampling (Fig. 6, 7, and 8). The assessment of water quality adheres to FAO standards (Ayers & Westcot, 1985). Samples were refrigerated and sent to the laboratory for chemical and inorganic analysis, including pH, electrical conductivity (EC), major cations (Ca2+, Mg2+, Na+, and K+), anions (CO32–, HCO–, and Cl–), and concentrations of potentially toxic elements (PTEs).

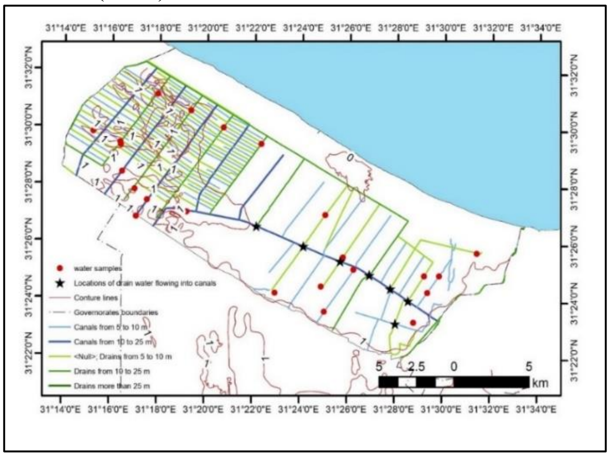

Figure 5. Locations of drain water flowing into canals.

Additionally, land cover and land use data were obtained using various sensors, including Landsat 4-5 TM C2 L1 and Sentinel 2, and classified using the Support Vector Machine (SVM) method. SVM is a non-parametric supervised machine learning technique designed for binary classification problems. It employs the concept of structural risk minimization (SRM) to maximize the margin between the hyper-plane and data points nearest to the spectral angle mapper (SAM). By maximizing this margin, SVM effectively separates data points into different classes using a hyper-spectral plane. This classification process ensures the maximization of margin width, enhancing the accuracy of land cover and land use classifications (Talukdar et al., 2020).

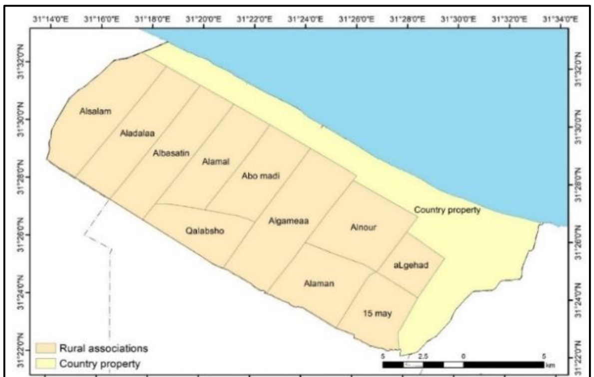

Figure 6. The Administrative division of study area in 2023.

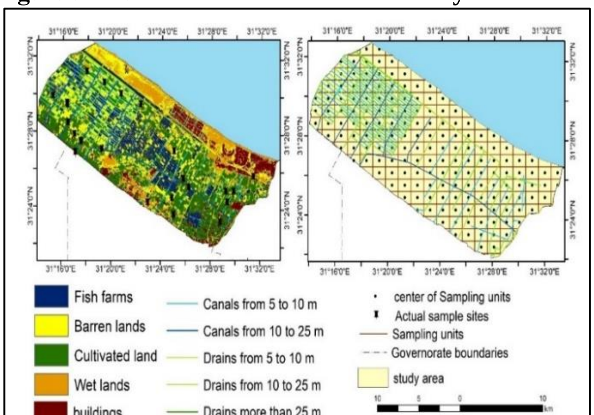

Figure 7. The different criteria applied for selecting sample sites in the study area.

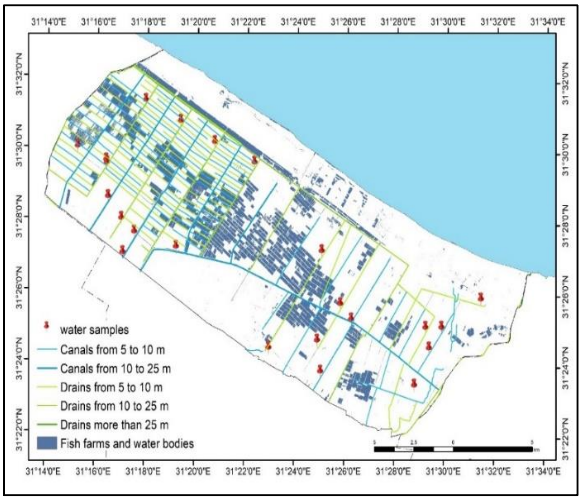

Figure 8. The spatial distribution of the sampling sites in the study area.

3. Methods

In the realm of assessing water quality, the concentration of soluble salts emerges as critical factors, dictating its fitness for a spectrum of applications, spanning from human and livestock consumption to crop irrigation (Zaman et al., 2018). The evaluation of water quality for irrigation mandates the scrutiny of four fundamental criteria: the total presence of soluble salts (indicating salinity hazard), the proportionate balance between sodium (Na+), calcium (Ca2+), and magnesium (Mg2+) ions – termed the sodium adsorption ratio (indicating sodium hazard), the residual sodium carbonates (RSC) – encompassing bicarbonate (HCO3−) and carbonate (CO32−) anion concentrations, and the potential accumulation of elements in excess, capable of inducing ionic imbalances or toxicity in plants. Water quality assessment was conducted at the central laboratories of the Faculty of Agriculture, Mansoura University, utilizing samples collected on January 20th, 21st, and 22nd, 2022. This analysis forms the basis for understanding the suitability of water for various agricultural purposes and underscores the significance of maintaining optimal water quality standards for sustainable farming practices.

The Inverse Distance Weighted (IDW) method was employed to map water quality parameters over the study area. The IDW stands as one of the most widely employed geostatistical and mathematical interpolation techniques, adept at mapping and predicting spatial distribution maps across various domains, including water quality parameters (Yang et al., 2020). Particularly, IDW interpolation is favored when the variable being mapped exhibits a decrease in influence with distance from its sampled location, making it suitable for capturing spatial and temporal trends. In the dame context, to visualize the interpolation maps effectively, this study employed the classification method of geometric intervals, known as "Smart quantiles," initially introduced in the Esri Geostatistical Analyst extension. Geometric intervals classification, or smart quantiles, is particularly advantageous for non-normally distributed data, aligning well with the characteristics of the data analyzed in this study. The spatial interpolation results were subsequently classified and displayed using this method.

Furthermore, this paper leveraged two spatial statistical techniques, namely "Measuring Geographic Distributions," focusing on the Directional Distribution (Standard Deviational Ellipse) and Median Center methods. The Directional Distribution, through the generation of standard deviational ellipses, offers insights into the spatial characteristics of geographic features, including central tendency, dispersion, and directional trends (Scott & Janikas, 2009). On the other hand, the Median Center method identifies the location that minimizes the overall Euclidean distance to features in a dataset, providing valuable information on spatial clustering and distribution patterns. Through the integration of these spatial statistical methods with the IDW interpolation technique, this study offers a comprehensive understanding of the spatial dynamics and trends in water quality parameters, facilitating informed decision-making for sustainable water management practices in irrigated agricultural areas.

RESULTS AND DISCUSSION

Optimal levels of inorganic elements are crucial for soil and plant health, as they play a vital role in facilitating the growth and development of agricultural crops. In low concentrations, these elements are beneficial and essential for plants, contributing to their robust growth. However, elevated concentrations can prove detrimental to the agricultural environment, leading to toxicity and posing risks to both human health and the ecosystem (Alloway & Heavy, 2013). We conducted a laboratory analyses of water samples in Zaian region, Dakahlia Governorate, and trace the spatial distribution of these contaminants, including salinity, acidity, cations, and anions. Results indicate that the distribution of inorganic elements varies distinctively from one element to another.

SAR, PH, AND EC:

The salinity levels of irrigation water exhibit a notable variation across the study area, increasing along a southeast to northwest axis. Various degrees of usage restrictions have been observed throughout the region, with the unrestricted category occupying a minimal area of 1.07%. Conversely, areas experiencing slight to moderate usage restrictions cover approximately 42.75% of the study area, while severe usage restrictions encompass roughly 56.20% of the total area. Electrical conductivity levels predominantly range between 3.5 to 4, (table 2) (fig. 9) constituting the most prevalent category across the study area, covering 16.49% of the total area. The decline in salinity towards the east could be attributed to the continuous discharge of factory waste from the industrial zone situated south of Gamasa. Regarding water acidity, an overwhelming majority of 99.28% falls within the safe zone for irrigation use. The pH levels predominantly fall within the range of 7.5 to 8, accounting for 72.67% of the study area, followed by pH levels between 8 to 8.5, covering 16.60% (fig. 10) of the total area. Analysis of the relationship between sodium adsorption ratio (SAR) (fig. 11) and electrical conductivity of water (ECW), facilitated through GIS spatial analysis, indicates that most of the region falls within the category of light to moderate usage restrictions, except for the eastern parts, which exhibit no usage restrictions. Overall, the study area predominantly falls within the second category of usage restrictions, highlighting the spatial variability of water quality parameters across the region.

Table 2. Electrical conductivity, acidity and chemical properties of irrigation water for the different samples.

code	latitude	longitude	Na	K	Ca	Mg	CO3	HCO3	Cl	SO4	EC	PH	SAR	RSC
1	31.52359	31.42847	1.20	0.05	0.51	0.39	0.00	0.28	1.36	0.51	0.21	6.82	1.79	-0.62
2	31.48929	31.40517	9.38	0.29	3.53	3.26	0.00	5.13	9.78	1.54	1.64	7.50	5.10	-1.65
3	31.43729	31.41812	9.07	0.28	3.91	3.16	0.00	5.24	9.08	2.11	1.65	7.62	4.83	-1.83
4	31.47974	31.38763	15.53	0.36	7.32	6.44	0.00	6.07	17.47	6.11	2.96	7.91	5.92	-7.69
5	31.417	31.39343	14.75	0.52	5.48	5.39	0.00	5.55	15.47	5.13	2.63	7.98	6.32	-5.33
6	31.2918	31.4575	9.94	0.31	3.88	3.38	0.00	0.00	12.28	5.23	1.75	7.29	5.22	-7.26
7	31.27309	31.48962	10.62	0.34	4.87	3.48	0.00	5.76	11.08	2.46	1.92	7.51	5.20	-2.59
8	31.27269	31.49109	52.23	1.76	7.27	15.07	0.00	8.27	51.37	16.69	7.62	8.05	15.63	-14.07
9	31.41714	31.44986	19.34	2.26	15.95	7.58	0.00	7.49	22.09	15.55	4.52	8.15	1.99	-16.03
10	31.345	31.50018	32.35	2.40	22.16	16.73	0.00	6.40	35.00	32.24	7.36	8.11	2.59	-32.49
11	31.32217	31.50987	32.92	2.23	20.40	10.53	0.00	6.90	33.00	26.17	6.61	8.24	2.96	-24.02
12	31.29874	31.51926	16.32	2.03	14.18	6.93	0.00	6.90	18.80	13.76	3.95	7.68	1.78	-14.20
13	31.37162	31.49084	10.27	1.82	9.57	5.00	0.00	6.48	12.40	7.78	2.67	7.08	1.35	-8.09
14	31.41458	31.40799	23.23	1.24	11.12	8.51	0.00	6.18	34.51	29.82	3.61	7.90	7.41	-18.06
15	31.38224	31.4041	17.10	1.25	7.87	5.55	0.00	0.39	19.07	13.67	2.86	8.27	6.60	-14.37
16	31.31979	31.45077	14.81	1.14	7.79	5.19	0.00	8.12	16.40	5.09	2.17	7.41	5.81	-5.44
17	31.28307	31.46378	11.57	1.05	7.11	3.85	0.00	5.14	12.14	2.37	3.04	8.54	4.94	-26.14
18	31.25356	31.49726	8.68	1.08	9.19	3.51	0.00	0.03	11.87	5.10	1.11	7.42	3.44	-18.95
19	31.48683	31.41481	10.77	0.55	10.96	5.23	N.D.	4.24	15.06	8.22	2.27	7.82	4.67	-7.73
20	31.49747	31.415	9.85	0.31	13.21	5.11	N.D.	4.37	15.32	8.79	2.13	8.71	5.89	-8.19
21	31.42988	31.42527	16.07	0.50	14.30	7.28	N.D.	5.30	25.97	6.88	3.28	8.14	1.67	-14.59
22	31.27414	31.47391	17.41	1.30	8.81	6.49	N.D.	7.16	19.37	5.87	5.68	9.02	5.13	-1.81
23	31.28423	31.44772	10.19	0.19	11.60	4.92	N.D.	4.90	18.70	3.30	2.67	7.12	5.19	-2.37

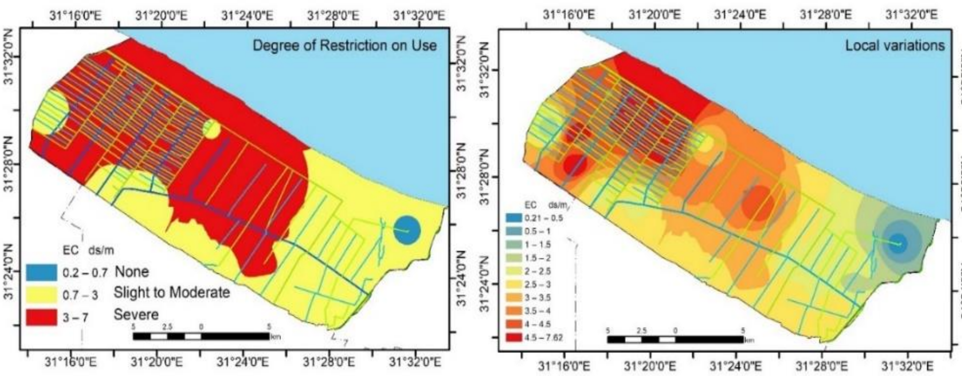

Figure 9. Degrees of electrical conductivity according to standard and EC.

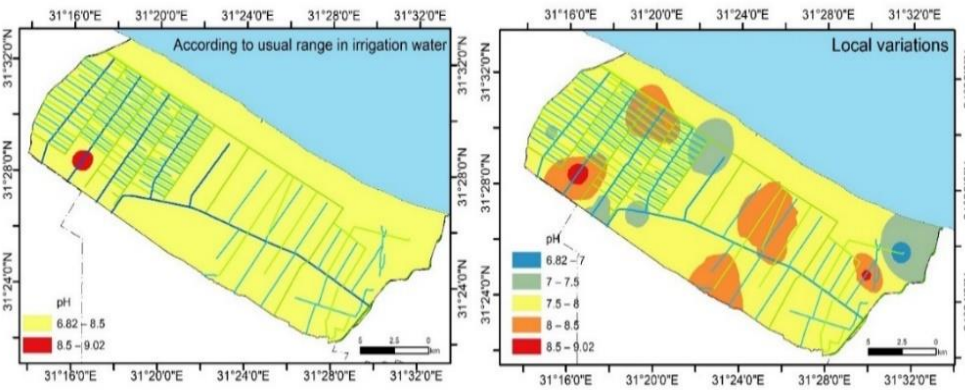

Figure 10. Degrees of pH according to standard and geometric intervals.

Cations and anions:

The spatial interpolation maps of the region reveal a consistent trend wherein the concentration of both cations and anions increases towards the northwest while decreasing towards the southeast and east. Notably, the concentrations of Sodium (Na) and HCO_3 fall within the safe category for use, as indicated in Figures 12 and 13. Similarly, the majority of the region falls within the safe category for irrigation concerning the components of K and Ca, as illustrated in the same figures. However, the distributional pattern of elements such as SO_4 and Mg varies with respect to the safe categories. Specifically, a significant portion of the area, amounting to 80.16%, falls into the unsafe category for Mg concentration, with a notable increase in concentration observed within the ranges of 3.69-6.22 and 6.22-10.09, encompassing 41.36% and 45.16% of the area respectively, as depicted in Figures 12 and 13. Similarly, for the element SO_4, approximately 49.69% of the region is classified in the unsafe zone for sulfate concentration in water, with concentrations primarily falling within the ranges of 11.20-19.39 and 19.39-32.24, covering 36.40% and 7.71% of the region respectively (Figures 12 and 13).

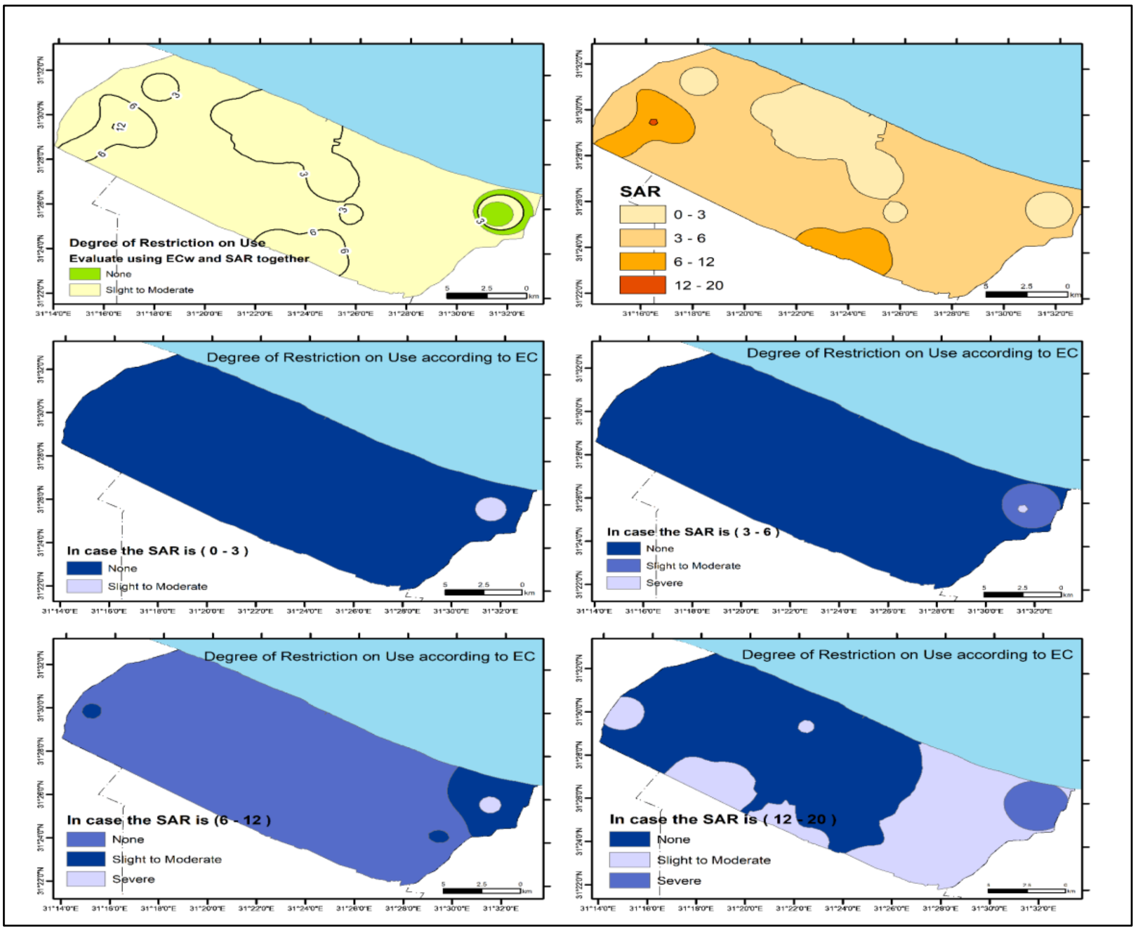

Figure 11. The infiltration rate of water into the soil. Evaluate using ECW and SAR together for samples.

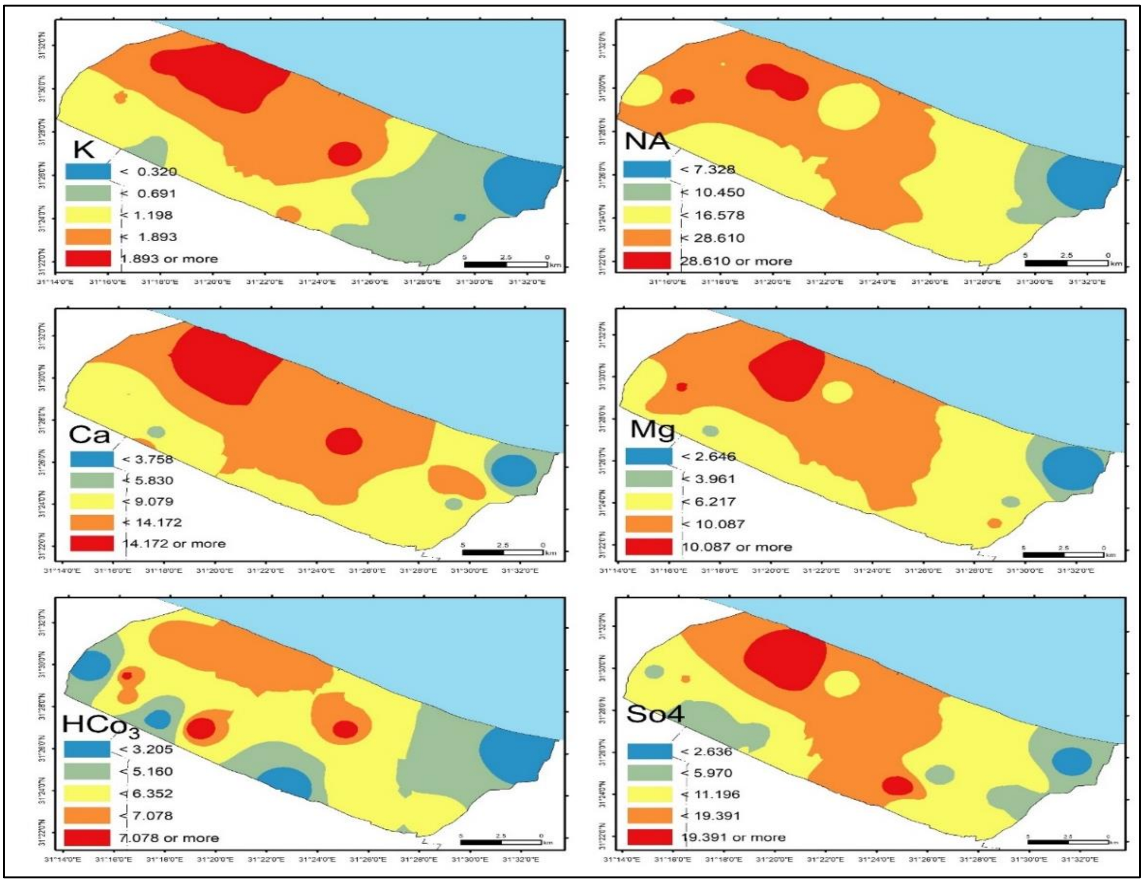

Figure 12. Concentrations of some cations and anions in the study area according to geometric intervals.

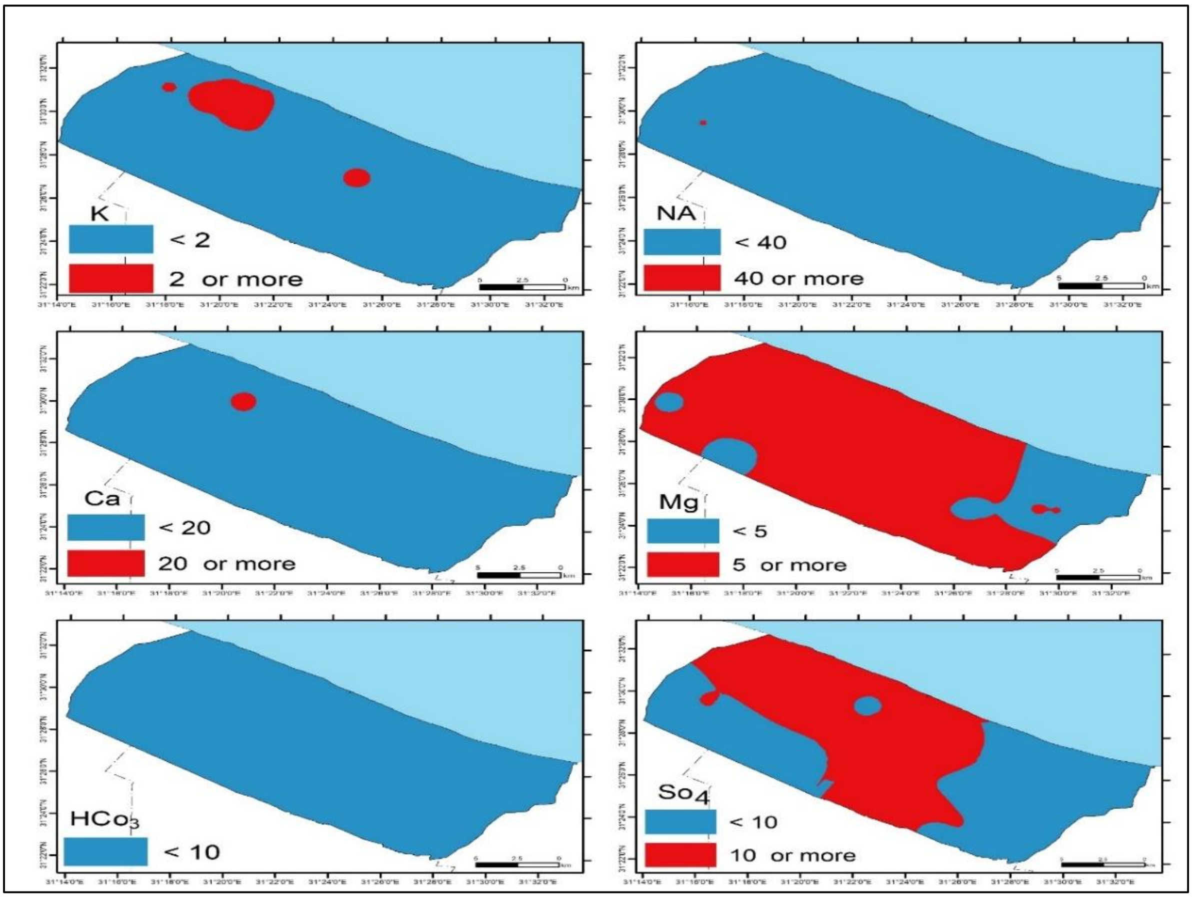

Figure 13. Concentrations of some cations and anions in the study area according to standards.

Moving on to specific elements, the element Cd (table 3) demonstrates a concentration peak in the central region of the study area, with the majority of its parts falling within the unsafe range for concentration. Notably, concentrations decrease towards the southeast and west, with ranges between 0.05 and 0.04 covering 17.79% of the region (Figure 14). Cd's presence, when overexposed, can adversely affect the agricultural environment, potentially accumulating in plant parts consumed by humans, thus entering the food chain. Industrial activities, including mining and plastic waste incineration, contribute significantly to Cd pollution in the environment. Similarly, the element Cr exhibits a concentration peak to the east of the study area, with the entire region falling outside the safe range for its concentration. The majority of concentrations exceed 0.5, with ranges between 0.26-0.58 and 0.58-0.89 covering 29.88% and 21.37% of the region respectively (Figure 14). The accumulation of chromium in plants can detrimentally affect the quality and nutritional value of agricultural crops, with sources of pollution primarily stemming from waste mining and chemical processing industries.

Table 3. Non-organic elements concentrations for water samples.

code	Al	Se	V	Hg	Ag	B	Ba	Ca	Cd	Co	Cr
1	0.16	0.00	0.07	0.01	0.03	0.00	0.00	115.12	0.00	0.00	0.00
2	0.11	0.00	0.03	0.01	0.00	0.12	0.04	134.28	0.00	0.00	0.02
3	0.14	0.00	0.02	0.02	0.01	0.12	0.04	197.56	0.00	0.00	0.02
4	0.00	0.00	0.11	0.12	0.00	0.22	0.00	109.71	0.01	0.00	0.00
5	0.00	0.00	0.59	0.18	0.33	0.19	0.09	111.54	0.00	0.00	0.25
6	0.02	0.00	0.06	0.00	0.03	0.16	0.04	109.51	0.00	0.00	0.00
7	0.05	0.00	0.07	0.02	0.00	0.14	0.03	99.87	0.00	0.00	0.00
8	1.05	0.00	0.77	0.00	0.00	1.42	0.00	124.96	0.00	0.00	0.00
9	263.17	ND	ND	0.05	ND	ND	1.77	717.99	0.10	0.00	ND
10	13.99	5.17	0.37	0.16	2.18	ND	1.82	886.32	0.10	ND	0.97
11	11.82	ND	0.60	0.01	ND	ND	1.28	683.99	0.07	ND	0.03
12	43.58	ND	0.90	ND	ND	ND	1.46	754.96	0.10	ND	0.09
13	9.38	ND	0.40	ND	0.47	ND	1.12	542.92	0.02	ND	0.27
14	58.07	ND	ND	0.85	ND	ND	0.33	222.44	0.07	ND	1.01
15	762.63	1.61	0.91	1.19	ND	ND	0.36	157.41	ND	ND	1.00
16	122.27	0.47	ND	0.83	ND	ND	0.22	155.82	ND	ND	2.07
17	995.35	0.00	ND	0.84	ND	ND	0.20	142.26	ND	ND	0.78
18	2125.56	ND	ND	0.37	0.40	ND	0.26	183.89	ND	ND	0.85
19	38.49	11.81	1.20	5.30	0.69	4.47	0.05	219.25	ND	ND	2.00
20	5.21	19.59	1.20	1.70	0.47	2.07	ND	264.20	ND	ND	0.92
21	115.79	36.30	0.15	0.50	0.73	0.19	0.17	285.97	0.05	ND	4.24
22	193.53	10.46	1.53	0.52	0.13	ND	ND	227.37	0.02	ND	1.17
23	0.20	16.89	0.53	0.30	ND*	ND	ND	232.04	ND	ND	0.38

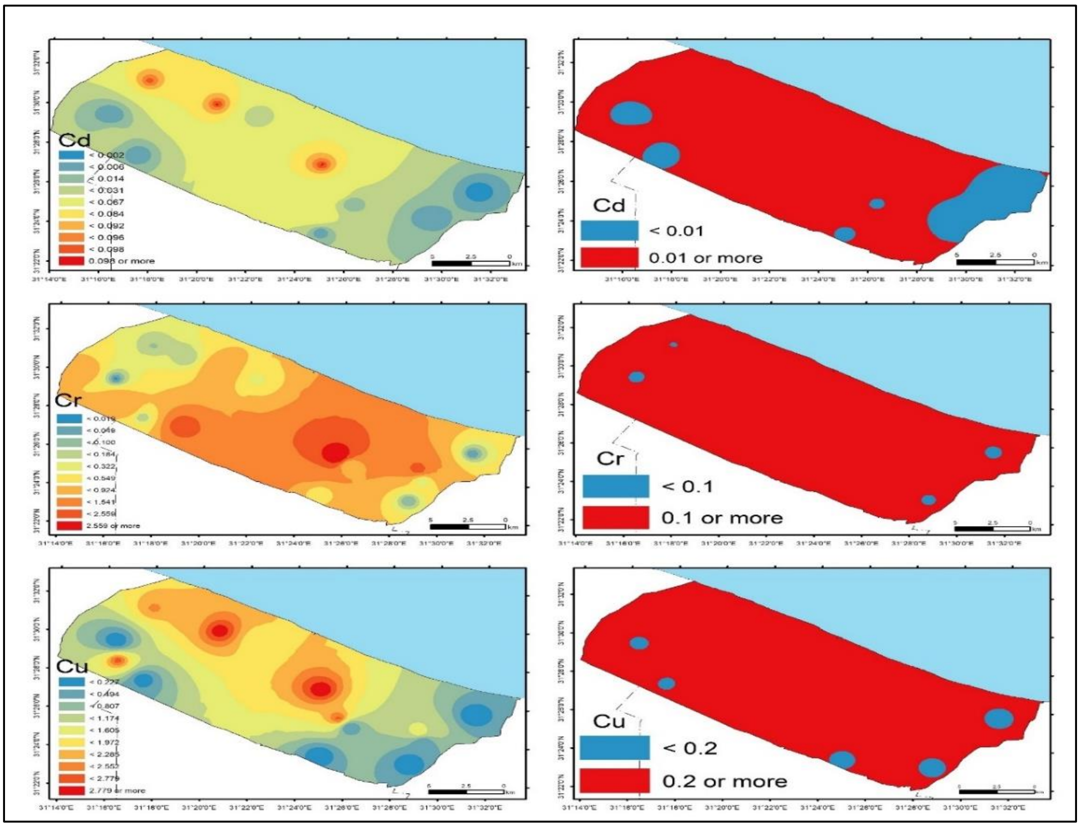

Figure 14. Concentrations of Cd, Cr, and Cu according to standards and geometric intervals.

Cu demonstrates concentration in the central region of the study area (table 4), albeit relatively less towards the east and west. The majority of its area falls outside the safe concentration range of 0.2, with concentrations reaching up to 2.97 in certain areas (Figure 14). Industrial activities such as electronic waste disposal and manufacturing contribute to Cu pollution in the environment. The element Li showcases a sharp decrease in concentrations across the study area, with the entire region falling within the safe zone for its concentration (Figure 15). Contrastingly, the element Fe exhibits concentration in the central region, with 72.64% of the area exceeding the maximum safe concentration of 5 (Figure 15). Safe areas are primarily concentrated in the east and west regions, with industrial waste serving as a significant source of Fe pollution. The element Mn demonstrates concentrations falling within the unsafe range for over 90% of the region, with concentrations exceeding 0.2 (Figure 15). Safe areas are concentrated in the east and certain points in the west region. Regarding Se and Al, their concentrations rise within safe limits for use, primarily concentrated in the center-east of the region. These elements originate from industrial waste and waste decomposition, with potential pollution sources including waste recycling plants (Figure 16). Similarly, V concentrations increase towards the east and west, reaching safe limits for use. Mining and manufacturing operations contribute significantly to V pollution, alongside its usage in chemical industries (Figure 16).

Table 4. Non-organic elements concentrations for water samples.

code	Cu	Fe	Ga	In	Li	Mg	Mn	Ni	Pb	K	Sr	Zn	As	Na	Bi
1	0.00	0.00	0.02	0.00	0.00	79.31	0.00	0.03	0.00	55.61	0.00	0.00	0.01	325.12	0.05
2	0.00	0.10	0.59	0.00	0.00	88.21	0.00	0.00	0.00	50.94	0.41	0.04	0.00	314.96	0.09
3	0.00	0.03	0.59	0.00	0.00	59.37	0.00	0.00	0.03	40.67	0.40	0.04	0.01	307.88	0.00
4	0.00	0.02	2.08	0.00	0.00	99.81	0.00	0.04	0.00	33.12	0.60	0.14	0.00	268.91	0.00
5	0.00	0.00	1.45	0.00	0.00	94.73	0.00	0.00	0.00	19.87	0.58	0.17	0.07	214.62	0.00
6	0.00	0.19	0.61	0.00	0.00	101.21	0.00	0.00	0.02	22.68	0.43	0.04	0.00	287.25	0.03
7	0.00	0.00	0.77	0.00	0.00	99.11	0.00	0.00	0.00	17.35	0.43	0.02	0.05	267.67	0.00
8	0.00	0.00	14.65	0.69	0.00	109.31	0.00	0.04	0.00	11.59	1.78	0.20	0.56	301.68	0.00
9	2.97	20.45	ND	ND	ND	181.83	0.55	1.37	2.16	176.53	1.86	4.29	ND	889.80	ND
10	2.95	15.58	ND	ND	ND	257.38	0.48	1.44	1.83	187.24	2.68	5.76	ND	1474.46	1.28
11	2.15	9.68	0.55	ND	0.12	204.63	0.35	1.03	1.92	173.73	2.21	3.71	ND	1192.42	0.29
12	2.35	14.41	1.55	ND	ND	166.31	0.67	1.55	1.53	158.74	1.78	4.25	ND	750.72	ND
13	1.67	10.75	2.44	ND	ND	117.47	0.63	1.02	1.41	142.07	1.45	3.29	ND	472.43	ND
14	ND	7.99	3.26	ND	ND	102.10	0.44	0.12	0.51	48.38	1.08	5.14	1.21	534.25	ND
15	ND	7.87	10.38	6.64	ND	66.62	0.33	0.05	0.27	48.92	0.63	6.34	0.09	393.19	ND
16	ND	4.71	1.51	7.65	ND	62.32	0.28	0.18	0.16	44.38	0.74	3.54	0.58	340.68	ND
17	ND	5.17	15.85	0.22	ND	46.18	0.28	ND	1.11	40.83	0.60	5.11	0.47	266.00	0.07
18	ND	6.22	10.13	0.84	ND	42.06	0.32	ND	0.50	42.05	0.69	6.15	0.99	199.56	ND
19	1.59	5.69	ND	ND	0.15	62.77	0.47	0.43	1.17	21.54	0.98	4.15	ND*	247.81	ND
20	0.97	5.29	2.40	6.61	ND	61.33	0.33	ND	0.42	12.23	0.99	3.52	0.17	226.63	ND
21	2.69	52.11	10.33	ND	1.30	87.34	0.87	1.83	0.32	19.53	1.20	7.19	ND	369.54	ND
22	2.74	4.80	5.69	1.19	ND	115.65	0.48	0.78	0.26	22.01	1.59	4.38	ND	727.26	ND
23	0.23	6.45	1.85	1.24	0.47	59.02	0.42	ND	1.18	7.42	0.98	3.13	0.08	234.43	ND

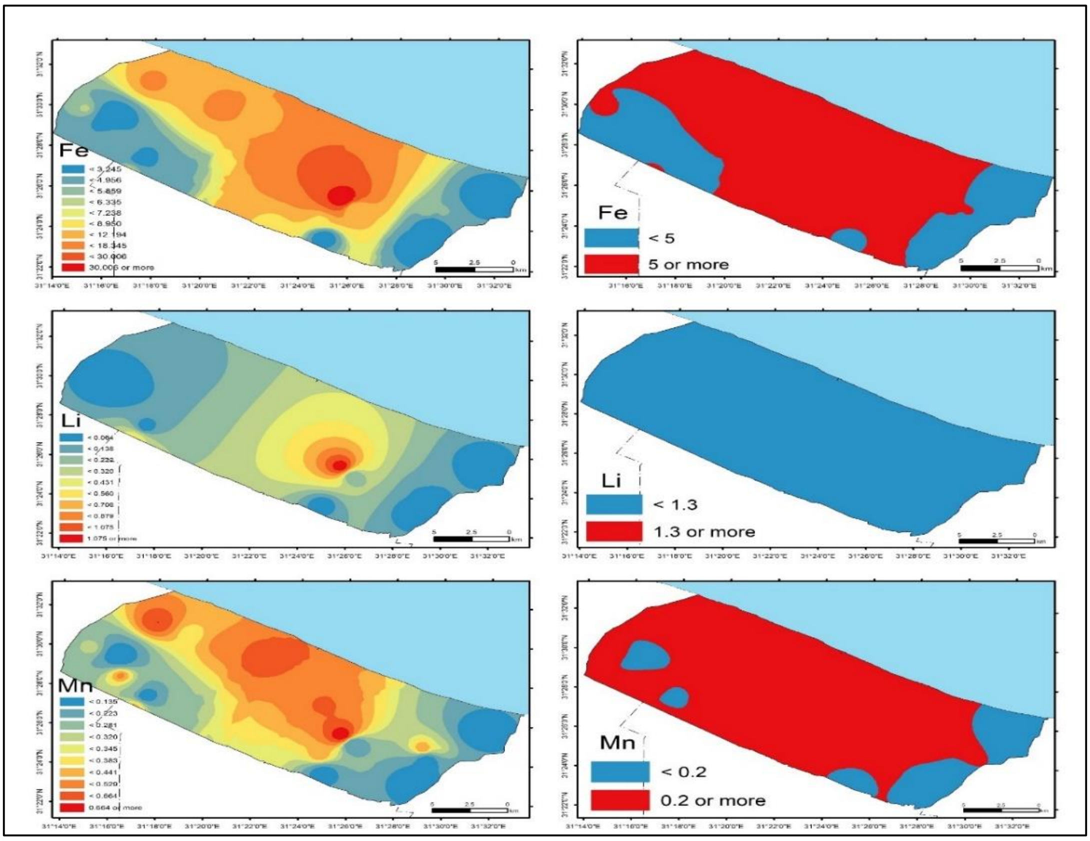

Figure 15. Concentrations of Fe, Li, and Mn according to standards and geometric intervals.

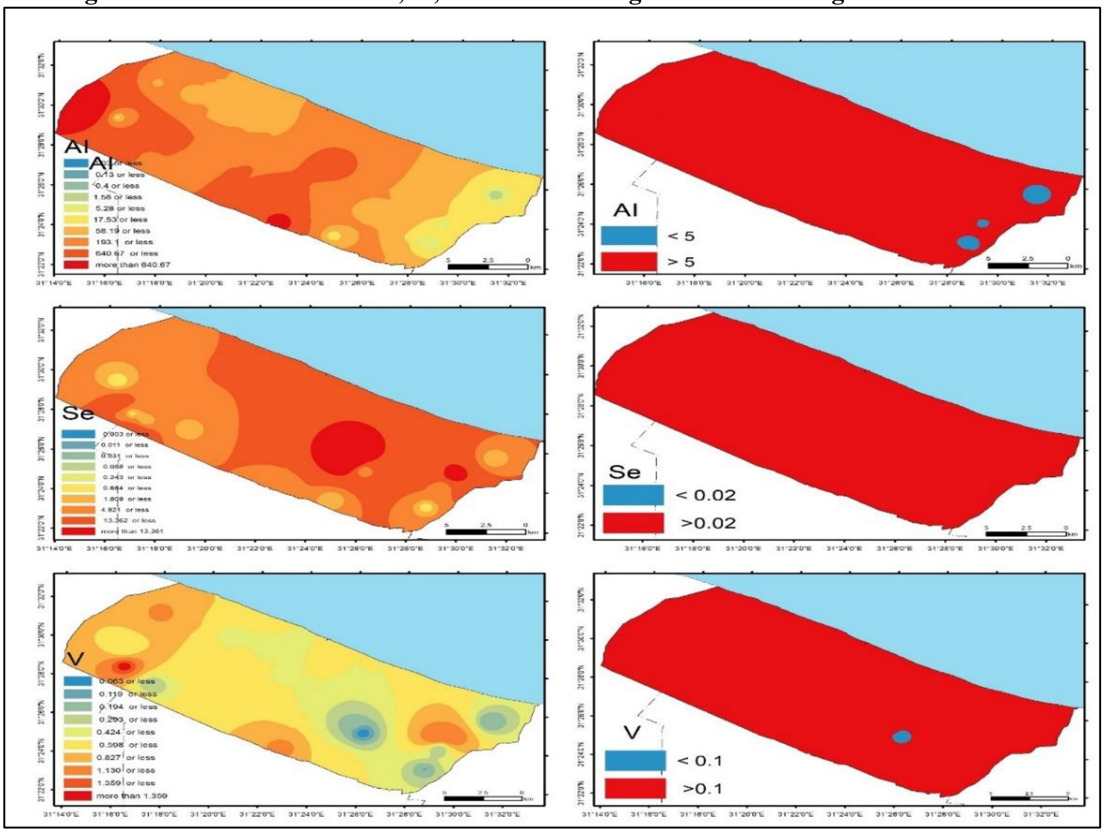

Figure 16. Concentrations of Al, Se, and V according to standards and geometric intervals.

On the other hand, Pb concentrations fall within safe limits for use, with increasing concentrations towards the north and decreasing towards the south and east (Figure 17). Conversely, Ni concentrations predominantly fall within the unsafe range, with sources of pollution originating from mineral and chemical industries (Figure 17). Zn concentrations increase around waste incineration sites, primarily in the central and southern regions of the study area. Industrial activities such as waste incineration contribute significantly to Zn pollution (Figure 17). Regarding elements such as As, B, and Hg, concentrations primarily originate from fertilizer and chemical industries, with concentrations falling within the unsafe range for a significant portion of the region (Figure 18). Elements essential for crops, such as K, Ca, and Mg, demonstrate varying concentrations across the study area, with K exhibiting deficiency in approximately 62.45% of the region, while Ca concentrations primarily fall within the normal range for use (Figure 19). Sr and Bi concentrations primarily concentrate in the north and west regions of the study area (Figure 20). However, In concentrations exceed permissible limits for use, primarily concentrated in the south and central regions, originating from electronic waste (Figure 20). Lastly, elements such as Ag and Ba exhibit high concentrations, particularly in the northwestern parts of the region (Figure 21).

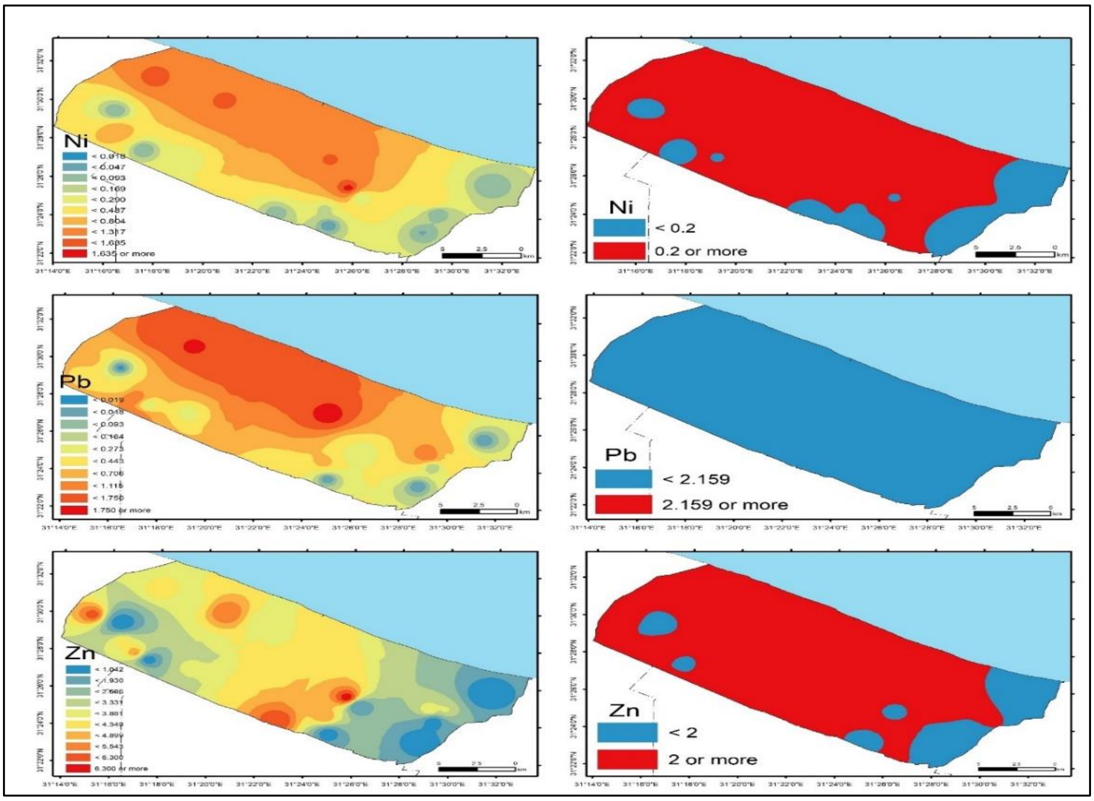

Figure 17. Concentrations of Ni, Pb, and Zn according to standards and geometric intervals.

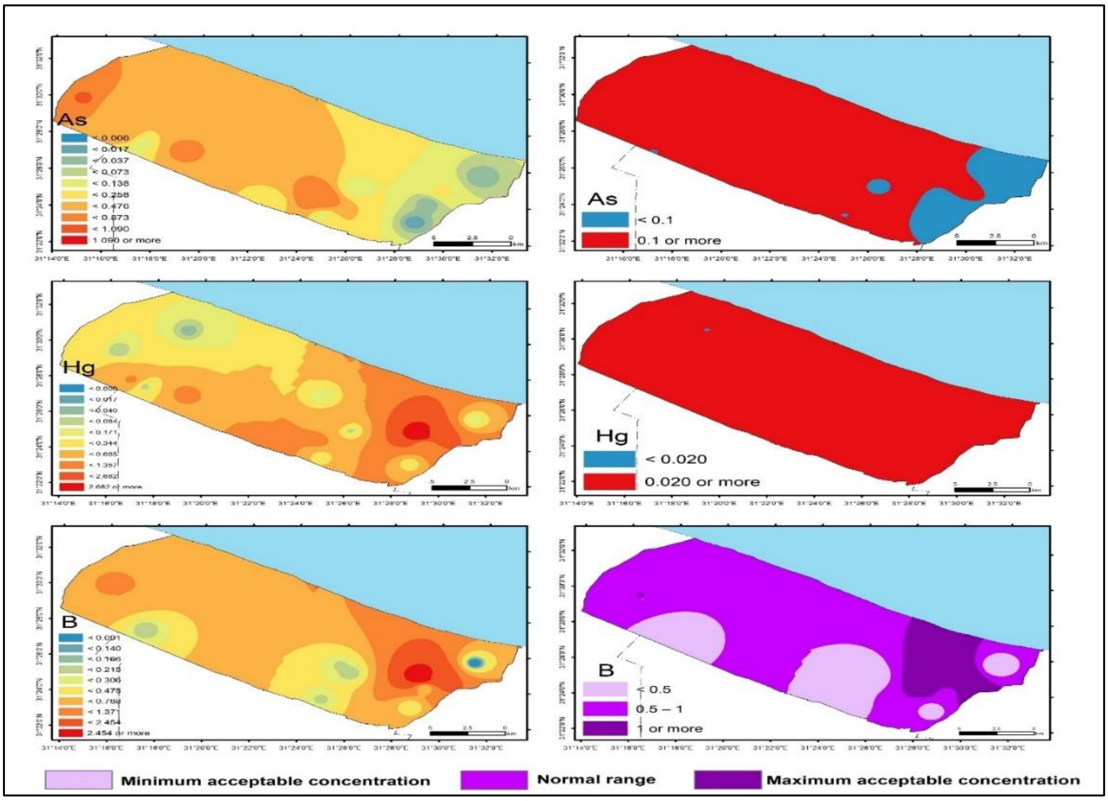

Figure 18. Concentrations of As, Hg, and B according to standards and geometric intervals.

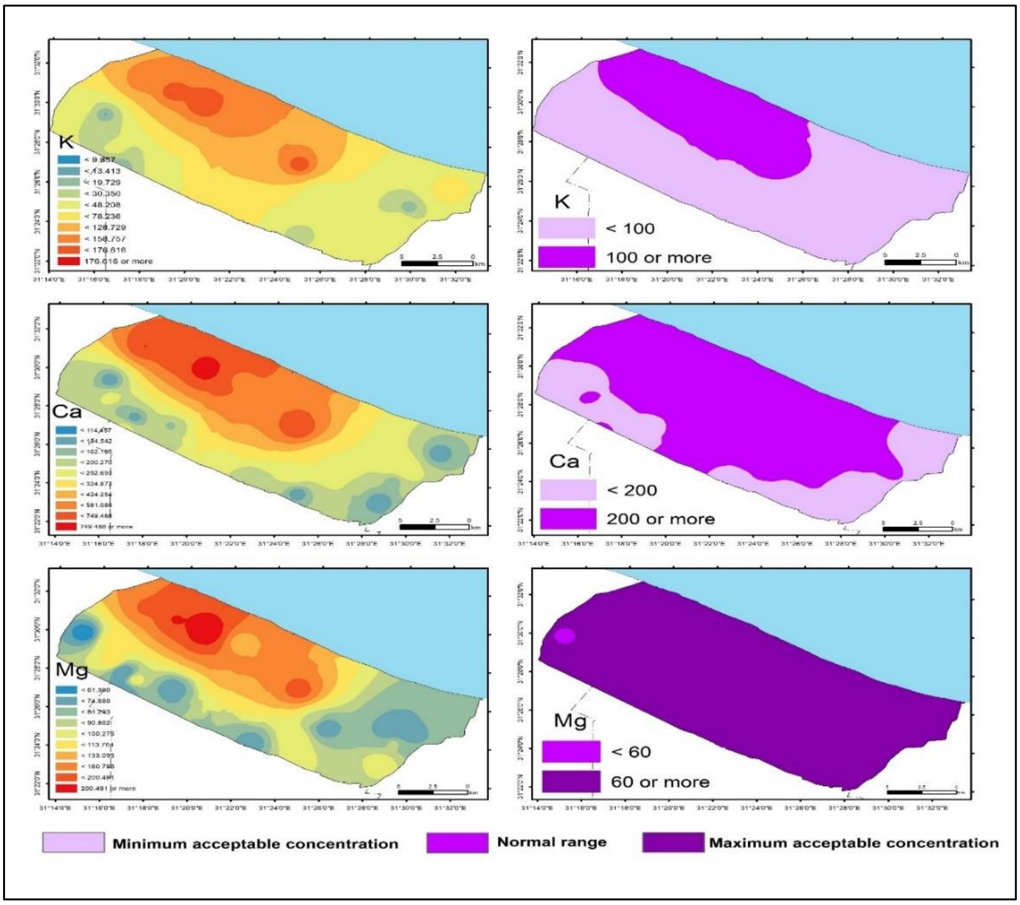

Figure 19. Concentrations of K, Ca, and Mg according to standards and geometric intervals.

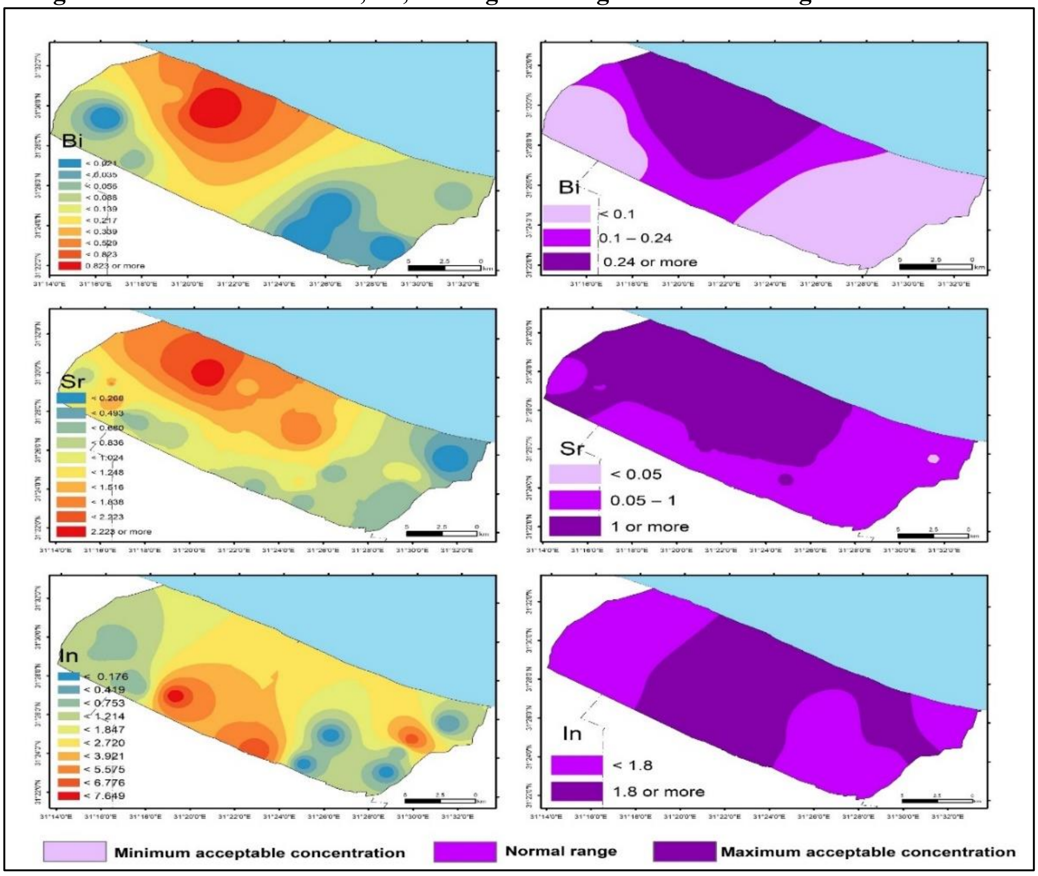

Figure 20. Concentrations of (Bi, Sr, In) according to standards and geometric intervals

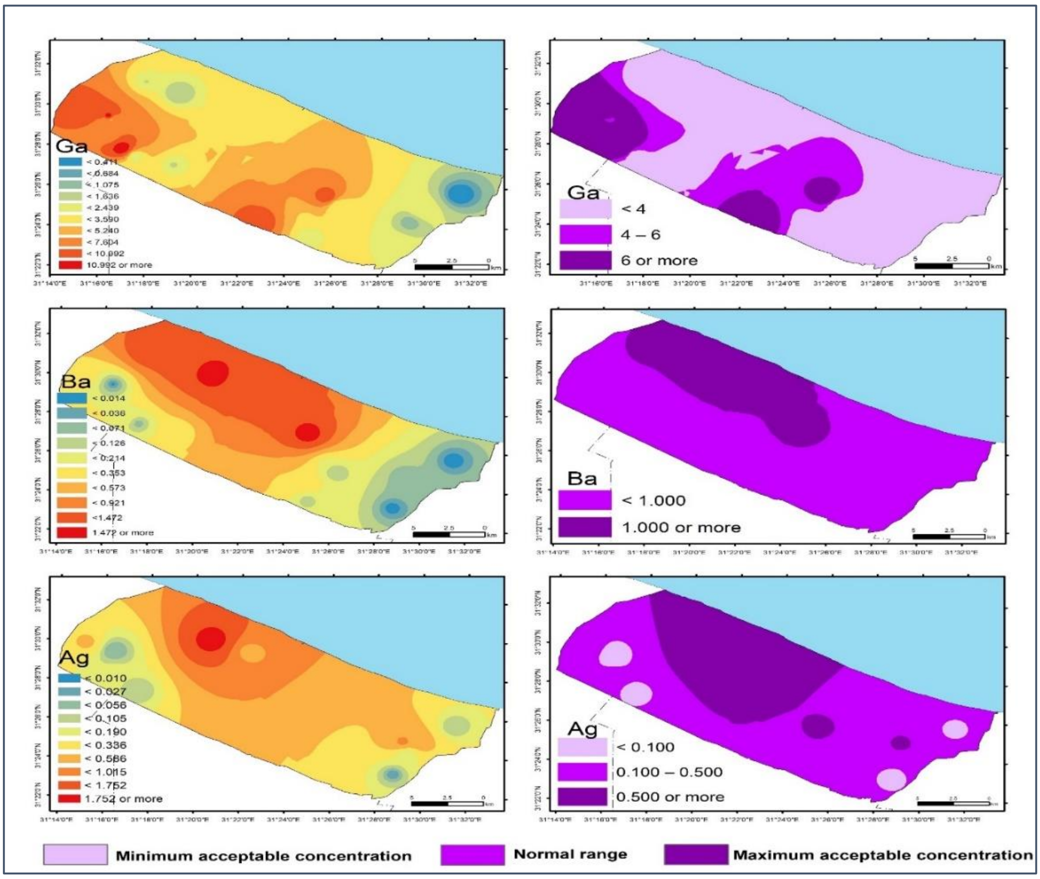

Figure 21. Concentrations of (Ga, Ba, Ag) according to standards and geometric intervals

Directional Distribution and Median

The analysis of the directional distribution of inorganic elements in irrigation water reveals a consistent pattern, predominantly concentrating in the eastern region while diminishing towards the west. Moreover, the Median Center tends to be situated in the eastern part for most elements, with a few exceptions where it concentrates in the south of the industrial zone, while for the remaining elements; it is concentrated in the center and east of the region. In terms of directional distribution, a narrow oval shape is observed for all elements affected by pollution, indicating high concentrations in the water of the area. Conversely, elements related to K, Ca, and Mg exhibit a regular circular shape in the middle of the area, signifying their relatively uniform distribution. For elements with weak concentration or below the minimum threshold in the area, a very small oval shape is observed in the middle of the region (Figures 22 and 23).

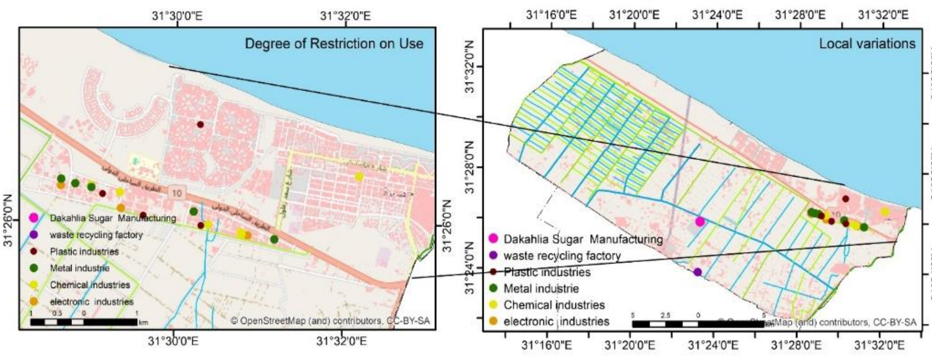

Figure 22. The dominant human activities in the study domain in 2023.

Overall, it is evident that the distribution of cations and anions is intricately linked to soil processes and is influenced by drainage activities. Moreover, the distribution indicators for inorganic elements are primarily shaped by two key factors: the presence of the industrial zone in Gamasa and the operations of the waste recycling plant in Qalabshow. These entities serve as central points in the region, significantly impacting the distribution of various components, largely due to the discharge of industrial waste or the incineration of waste materials. The analysis reveals that most elements exceed permissible concentration levels in all liquid areas, posing significant concerns for the suitability of water for irrigation purposes. However, rare elements such as Li and Pb remain within acceptable limits. Consequently, it becomes imperative to implement an integrated system for treating factory wastewater effectively. Additionally, there is a pressing need to reevaluate the waste recycling processes at the Qalabsho facility, emphasizing the isolation of waste from the soil and implementing measures to cover and insulate it from rainwater. These measures are essential to mitigate environmental contamination and safeguard the region from various pollutants, ultimately enhancing the quality of water used for irrigation.

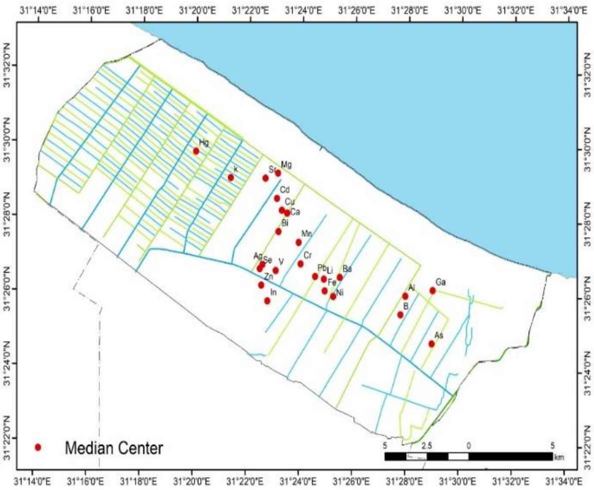

Figure 23. Median center of non-organic elements in study area according to the different collected samples.

CONCLUSION

Based on a comprehensive analysis of various water quality parameters and inorganic elements in the Qalabasho-Zaian area (northern Dakahlia Governorate), several key conclusions can be drawn, as follows:

- The study highlights the significant impact of industrial zones and waste recycling plants on the distribution of inorganic elements in the region. These industrial activities serve as focal points for pollution, leading to elevated concentrations of contaminants in irrigation water.
- The spatial distribution of water quality parameters and inorganic elements exhibits distinct patterns across the study area. While some elements show a concentration gradient from southeast to northwest, others exhibit localized peaks and valleys influenced by specific sources of pollution.
- The analysis reveals a gradient of salinity and acidity levels across the study area, with salinity increasing along a southeast to northwest axis. Despite variations in salinity, the majority of the region falls within acceptable limits for irrigation use, except for areas affected by industrial waste discharge.
- The concentration patterns of cations and anions demonstrate a consistent trend, with concentrations increasing towards the northwest and decreasing towards the southeast and east. While certain elements fall within safe limits for irrigation, others exceed permissible concentrations, posing risks to soil and plant health.
- Industrial activities such as mining, chemical processing and waste incineration contribute significantly to the pollution of irrigation water with heavy metals and other contaminants. The concentration peaks of elements such as Cd, Cr, and Cu coincide with areas affected by industrial discharge, highlighting the need for stricter pollution control measures.
- Elevated concentrations of heavy metals such as Cd, Cr, and Ni pose risks to human health through the contamination of food crops and water sources. Exposure to these contaminants can lead to adverse health effects, emphasizing the importance of mitigating pollution sources and ensuring water quality.
- To address the challenges posed by water pollution, integrated strategies for wastewater treatment and waste management are essential. Implementing effective treatment systems for industrial wastewater and adopting best practices for waste disposal can help minimize environmental contamination and safeguard water resources.

In conclusion, the findings of this study underscore the urgent need for proactive measures to mitigate water pollution and protect soil and water resources in the Zaian region. By addressing the sources of contamination and implementing sustainable management practices, we can ensure the long-term viability of agricultural ecosystems and safeguard the health and well-being of communities dependent on these resources.

Acknowledgments:

We express our gratitude to the Mansoura University Research Unit Account for providing funding for project number (MU-ART-20-1), which focuses on "Agricultural Environment Assessment for Sustainability and Development Objectives in the Northern Reclaimed Area of Dakahlia Governorate Utilizing Geomatics Techniques." Additionally, we extend our appreciation to Ahmed Naji Al-Awadi and Shadi Omar Al-Shabrawi for their diligent efforts during the field study.

Conflicts of Interest: The authors declare no conflict of interest.

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تقييم جودة مياه الري في الأراضي المستصلحة شمالي محافظة الدقهلية

أسماء الشرباصي[1]، أحمد القناوي[2،3] و إيمان فؤاد محمد[4]

[1] قسم الجغرافيا ونظم المعلومات الجغرافية بكلية الآداب – جامعة المنصورة
[2] معهد جبال البرينيه للايكولوجيا - المركز الوطني للبحوث - مدينة سرقسطة- اسبانيا
[3] قسم الجغرافيا بكلية التربية – جامعة المنصورة
[4] قسم الجغرافيا ونظم المعلومات الجغرافية بكلية الآداب – جامعة المنصورة

الملخص

تعتمد الزراعة المروية على الإمدادات الكافية من المياه ذات الجودة الملائمة للاستخدام. تهدف هذه الدراسة إلى تقييم جودة وملائمة مياه الري بمنطقة (قلبشو – زيان بمحافظة الدقهلية). ومع اهتمام الدولة باستخدام المياه ذات الجودة المحدودة في الزراعة تظهر أهمية هذه الدراسة، حيث تم جمع عينات مياه من 23 موقعاً للري والصرف. وتم تحليل الخصائص الفيزيائية والكيميائية لعينات المياه، بما في ذلك الرقم الهيدروجيني، والتوصيل الكهربائي، والأيونات الرئيسية(Ca ، Mg، K، وNa) ، ونسبة امتصاص الصوديوم (SAR). ومن خلال العوامل التي تم تحليلها، ظهر أن شبكات الري والصرف في الغالب تقع خارج الحدود الآمنة لاستخدام الري، وعلى وجه التحديد، لوحظ ارتفاع مستويات ملوحة مياه الري وكذلك تركيزات عالية للعديد من العناصر مثل Cd ، Cr، Cu، Fe، Mn، Al، Se، V، Ni، Zn، As، Hg، Mg، Ca، Sr، In، Ba، Ag ويرتبط هذا المستوى العالي من التلوث بشكل أساسي بموقع منطقة الدراسة في نهاية شبكة قنوات الري والصرف مجتمعة مع قرب منطقة الدراسة من المنطقة الصناعية المحلية (جمصة) ومصنع إعادة تدوير النفايات. وتسلط هذه النتائج الضوء على الحاجة إلى معالجة مياه الصرف قبل وصولها إلى نظام الري. ومن المهم أيضًا عزل محطة إعادة تدوير النفايات وأكوام النفايات المحيطة بها، والتي يمكن أن يكون لها آثار إيجابية على جودة مياه الري وصحة النظام البيئي بشكل عام.