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Quality of water resources used for agricultural irrigation in the north-eastern coastal area of Azerbaijan

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ABSTRACT

The quality of water resources used for agricultural irrigation is a key factor influencing soil health, crop productivity, and long-term sustainability of agroecosystems. In arid and semi-arid regions, where surface water is limited and atmospheric precipitation is insufficient, groundwater becomes the primary source of irrigation. However, intensive exploitation of groundwater under such climatic conditions often accelerates secondary soil salinization, adversely affecting soil structure, plant growth, and overall agricultural output. Consequently, systematic assessment of irrigation water quality is essential for effective land and water resource management. This study aimed to evaluate the suitability of groundwater for irrigation purposes in the northeastern coastal region of Azerbaijan, an area characterized by hot climatic conditions and limited rainfall. The assessment is based on a comprehensive set of hydro-chemical indicators that reflect both salinity and solidity hazards. These include the degree of mineralization (M), Stebler coefficient (K), sodium percentage (Na%), sodium adsorption ratio (SAR), magnesium hazard ratio (MAR), potential salinity (PS), permeability index (PI), and Kelly's ratio (KR). Together, these parameters provide an integrated understanding of the potential impacts of irrigation water on soil permeability, salinity buildup, and ion toxicity. The hydro-chemical data were analyzed to determine the concentration and composition of dissolved salts, which are critical in evaluating irrigation suitability. Elevated salinity levels and unfavorable ionic balances, particularly high sodium and magnesium concentrations relative to calcium, can lead to soil dispersion, reduced infiltration capacity, and deterioration of the physical properties of soil. The calculated indices were compared against internationally accepted standards for irrigation water quality to classify the water into different suitability categories. The results highlight spatial variations in groundwater quality across the study area and indicate that, in certain locations, water irrigation poses moderate to high salinity and solidity risks. These findings underscore the need for appropriate irrigation management strategies, such as controlled groundwater use, periodic soil monitoring, and the adoption of salt-tolerant crops where necessary. Overall, this study provides valuable scientific insight into irrigation water quality in the northeastern coastal area of Azerbaijan and contributes to informed decision-making aimed at mitigating soil salinization as well as ensuring sustainable agricultural development in arid environments.

Keywords: water irrigation, groundwater, degree of mineralization, sodium adsorption ratio, salinity hazard, soil salinization, agricultural sustainability.

INTRODUCTION

Water plays a fundamental role in most geological and geochemical processes occurring within the Earth's crust. It is also a crucial resource for agriculture, used for irrigation, watering, storage, and other purposes. However, agricultural activities can lead to water pollution, depletion, and other problems. The works of many foreign scholars are devoted to sustainable management of water resources in the agricultural sector. Begam et al. (2025) reported that salinity, boron, chloride, and carbonate/bicarbonate concentrations are the indicators that allow standardization of irrigation water quality. Anthropogenic managements like cropping (tolerant varieties sowing), fertilizer, irrigation management, and mulching help to minimize the effect and impurities present in poor-quality irrigation water. It is advisable to use sustainable methods to conserve natural resources and go for conjunctive use of water (mixing of good plus bad water) for irrigation purposes.

Liu et al. (2025) collected 36 groundwater samples for their study to conduct a comprehensive assessment of groundwater suitability for irrigation in the Yanggong River basin in southwest China. Irrigation water quality index (IWQI) results showed that 86.49% of groundwater samples were classified as good, and 13.51% were classified as average. The Froseth random distribution (RF) model demonstrated the best prediction performance with a high correlation of 0.9581 and is an alternative model for predicting water quality.

A study by Singh et al. (2026) investigated the groundwater quality in the Mahanadi Upper Basin, a crucial tropical agricultural region in India. Using geographic information systems (GIS) and geostatistical methods, the study mapped and modeled spatial variations in water quality parameters. Excellent, good, and poor water quality were assessed over areas of 10,850.90 km², 18,845.1 km², and 1,003.8 km², respectively. Key findings include that 20% of samples exhibited high nitrate levels, 68% were at risk due to fluoride, and 25% of the area was considered unsuitable for irrigation based on Kelly's ratio. Rahu et al. (2024) proposed a comprehensive framework integrating the IoT technology and machine learning (ML) techniques for monitoring and assessing water quality in agricultural settings. To collect the necessary water quality data, they deployed a sensor array along the Rohri Canal and Gajrawah Canal in Nawabshah City, measuring parameters such as temperature, pH, turbidity, and total dissolved solids (TDS), then utilized the ML algorithms to assess the water quality index (WQI) and water quality class (WQC). Their findings indicate that the water quality in the Rohri Canal is generally better than in the Gajrawah Canal, which has higher pollution levels.

The study of Lyra et al. (2025) aimed to analyze the impacts of climate change, irrigation and nitrogen fertilization practices in the Almyros aquifer system. The analysis employed an Integrated Modelling System (IMS) to simulate coastal water resources, incorporating models for surface hydrology (UTHBAL), reservoir operations (UTHRL), groundwater hydrology (MODFLOW), nitrate leaching/crop growth (REPIC), nitrate pollution (MT3DMS), and seawater intrusion (SEAWAT). The study results highlight a significant decline in water availability across climate models, with reduced runoff and groundwater recharge projected for the Almyros Basin. Increased nitrate and chloride concentrations indicate deteriorating water quality, posing risks of seawater intrusion and nutrient pollution.

The study by Acar and co-authors (2025) included a thorough assessment of the current water and crop resources in the Konya River Basin, as well as proposals for the rational use of existing water resources in agriculture. Overuse of water resources in the region is driven by two key factors: the uncontrolled extension of irrigated land and the increased cultivation of water-intensive crops, such as sugar beets and maize. The first step toward sustainable water management is to coordinate crop rotation with existing water supplies and promote the use of water-efficient irrigation technologies such as sprinkler and drip systems. Furthermore, deficit irrigation is recommended for certain crops, such as sugar beets maize, sunflowers, beans, and potatoes, under field conditions.

In the Tarim Basin, Ma et al. (2024) used a combination of traditional hydrogeochemical methods with ordinary least squares (OLS) and geographically weighted regression modeling (GWR) to investigate the suitability of surface water irrigation during summer. The results showed that all water samples belonged to three types: SO4 Cl–Ca•Mg, SO4 Cl–Na, and HCO3–Ca Mg. The findings suggest that water quality is currently adequate for irrigation needs, but to ensure sustainable water use in arid regions in the future, increasing nitrogen concentrations caused by human activities and deteriorating water quality caused by reservoir construction must be taken into account.

In Azerbaijan, in addition to surface water resources, substantial reserves of groundwater are present and widely utilized. These groundwater resources serve multiple purposes, including drinking water supply, industrial and domestic use, as well as, most importantly, agricultural irrigation. Owing to the heterogeneous geological structure of the country, groundwater composition, depth of occurrence, and flow dynamics vary considerably from mountainous regions toward lowland areas (Ismayilov and Pashayev, 2019; Amanova et al., 2024; Mammadov et al., 2026). In many regions worldwide experiencing water scarcity, groundwater has become the primary source of irrigation. Azerbaijan is no exception, as limited surface water availability and uneven precipitation patterns necessitate extensive groundwater exploitation for agricultural production. However, agricultural activities themselves, particularly the improper application of chemical fertilizers, either excessive or insufficient-have contributed to groundwater contamination. Numerous studies indicate that the groundwater in the investigated area has been subjected to continuous anthropogenic pressure for centuries because of diverse human activities. At present, certain zones continue to experience groundwater recharged from both natural and artificial sources (Mehdiyeva, 2016). Statistical data indicate that groundwater accounts for approximately 20–23% of the total water abstraction used for drinking and domestic purposes in Azerbaijan, while the remaining 80–90% is primarily utilized for irrigation and technical needs. The vulnerability of groundwater to contamination is strongly influenced by geological conditions. In the areas where low-permeability rock layers are thick and exhibit low filtration capacity, groundwater tables are generally deeper and better protected from surface-derived pollutants (Sadigov and Mustafayev, 2024).

Despite the importance of groundwater resources, the ameliorative condition of irrigated lands in Azerbaijan remains a serious concern. Currently, 37.4% of irrigated lands are classified as unsatisfactory. These areas are characterized by shallow groundwater levels (less than 2 m below the surface), groundwater mineralization exceeding 3.0 g/L, and soil salinity levels greater than 1.0%. Such conditions negatively affect the physical properties of soil, crop productivity, and long-term land sustainability (State Standard of the Republic of Azerbaijan 2013; Sadigov et al., 2025).

Effective management of the groundwater regime is therefore a critical component in the planning, construction, and operation of irrigation systems. Improvements in soil ameliorative conditions and agricultural productivity largely depend on groundwater depth, chemical composition, and long-term fluctuation trends. During the design and implementation of ameliorative measures, it is essential to establish an optimal groundwater regime, defined as a state in which a favorable soil water-salt as well as aeration balance is achieved with minimal irrigation, drainage, and ameliorative interventions (Huseynov et al., 2025).

MATERIALS AND METHODS

The study was conducted within the Siyazan–Sumgait massif, which is situated in the northeastern coastal zone of Azerbaijan. This region is characterized by arid to semi-arid climatic conditions and increasing reliance on groundwater resources for agricultural irrigation. The selected area includes both newly irrigated lands and virgin (undeveloped) territories, allowing for a comparative assessment of soil and water conditions under differing land-use regimes.

Field investigations were carried out over a six-year period from 2018 to 2023. Experimental plots were established at representative locations within the soils of Shurabad and Gilezi villages in the Khizi district, which are considered characteristic of the massif in terms of soil properties and hydrogeological conditions. Site selection was based on soil type, irrigation history, and groundwater influence to ensure the representativeness of the collected data. To evaluate the ameliorative condition of the soils as well as the quality of irrigation water, systematic soil and water sampling was performed. A total of 29 soil samples were collected from the experimental plots at depths corresponding to agriculturally relevant soil horizons. In addition, six water samples were obtained from the groundwater sources used for irrigation within the study area (International soil classification system for naming soil and creating legends for soil maps, 2014; Dinka, 2016; Jafarova and Hajiyeva, 2024; Mustafayev et al., 2025).

The geographical coordinates of all sampling locations were recorded using global positioning system (GPS) technology to ensure spatial accuracy and facilitate mapping as well as future monitoring. The collected samples were transported to the laboratory under appropriate conditions and subsequently analyzed using standard physicochemical methods to determine key parameters related to soil salinity, groundwater mineralization, and irrigation suitability (Figure 2) (Amanova et al., 2024; Gumbatov et al., 2024).

The studies were carried out in both irrigated and non-irrigated (raw) areas under field and laboratory conditions. Chemical analyses were conducted in accordance with the methodologies widely applied within the country. Soil samples were collected from the experimental sites to determine soil salinity and related physicochemical properties.

The primary objective of this study was to evaluate the initial hydrochemical characteristics of the soil–water system in the semi-arid and anthropogenically impacted areas of the Siyazan–Sumgayit zone, with particular emphasis on the soils characterized by heavy granulometric composition. The Siyazan–Sumgait massif is situated within the coastal transition zone of the Caspian Lowland and is defined by a semi-arid climate as well as distinctive geoclimatic conditions. These conditions are shaped by the combined effects of long-term land reclamation practices and the influence of transgressive phases of the Caspian Sea, which collectively differentiate the area from classical semi-arid regions such as those of India, Iran, and the Mediterranean basin.

Given that the salinity-related parameters are recognized as key indicators in FAO and other international irrigation water quality guidelines, and considering the unique hydrochemical regime of the region, associated with semi-arid conditions and the Caspian Lowland environment, the assessment of salinity and sodicity risks as well as their potential impacts on soil productivity was identified as a priority. Accordingly, analyses were conducted to determine dry residue, total dissolved solids (TDS), sodium adsorption ratio (SAR), and the composition of major anions and cations.

Comprehensive water-salt (gravimetric) analyses were performed following the method of Arinushkina (1961). The water-physical properties of soils were determined using the methodology proposed by Kachinskiy (1970), while the granulometric composition was analyzed according to the classification system developed by Mammadov (Mammadov et al., 2025). The composition of exchangeable (absorbed) bases was determined following the method of Gedriots (1955) and soil pH was measured using a pH meter (Dospekhov, 1984).

The reliability and accuracy of the obtained results were verified using mathematical and statistical analysis methods (Kovda, 1973).

RESULTS AND DISCUSSION

The Siyazan-Sumgait massif is characterized by a piedmont plain, where aeolian, lacustrine, and deluvial-alluvial deposits predominate. Within the riverbeds, both modern and ancient alluvial-proluvial sediments are widely distributed. The climate of the massif is classified as subtropical, influencing soil formation and vegetation patterns (Rawat et al., 2018).

Tectonic activity, coupled with Quaternary transgressions of the Caspian Sea, has significantly influenced the relief of the region. In the northwestern sector, a dissected mountainous relief is observed, genetically linked to the surrounding mountain systems of the northwestern plain. The hydrographic network of the massif is primarily formed by the Samur-Absheron Canal, Takhtakorpu-Jeyranbatan Canal, Atachay River, and Gilgilchay River. The construction of irrigation canals, collector-drainage systems, and the expansion of agricultural land have resulted in substantial changes in vegetation cover, with desert and semi-desert vegetation largely replaced by ruderal communities dominated by weeds (Ramil et al., 2024; Khudaverdi et al., 2025).

The soil cover within the Siyazan-Sumgait massif exhibits high spatial heterogeneity and is predominantly represented by grey-brown soils (*Calcic Gypsisols*), grey soils (*Haplic Calcisols*), takyr soils, and solonchaks (Figure 1). Field surveys indicate that in the northeastern coastal zone of Azerbaijan soils range from non-saline to strongly saline (Shyamala et al., 2020, Sadigov, 2023).

The analysis revealed that the physical clay content (<0.01 mm) in the particle size distribution of the soils common in the Siyazan-Sumgait massif ranges from 36.00 to 82.79%, while the silt fraction content (<0.001 mm) ranges from 11.60 to 42.20%. These soils are classified as light, medium, and heavy clays based on their particle size distribution. Studies show that the pH of the soil solution in the study area ranges from 7.4 to 8.8, indicating an alkaline environment. The $CaCO_3$ content in the soils ranges from 8.328 to 24.342%. The humus content in the soils of the study area is 1.79–1.82% in the upper layers, indicating an insufficient supply of humus to these soils (Figure 2).

Hydrogeological studies reveal that the groundwater in the region is generally found at depths of 1.6–2.0 meters below the surface. Seasonal variations in groundwater mineralization range from 35 to 45 g/L, with total mineralization values spanning 0.6–95.2 g/L. Chemically, the groundwater is predominantly of the sulfate-chloride-sodium and chloride-sulfate-sodium types. This study highlighted the intricate interplay between tectonics, climate, and anthropogenic activity in shaping the geomorphology, soil properties, and hydrogeological conditions of the Siyazan-Sumgait massif, providing a basis for

Figure 1. Soil map of the Siyazan-Sumgayit massif

Figure 2. Soil and water sampling activities in the Shurabad village study area

sustainable land use and water resource management in northeastern Azerbaijan.

Several researchers have emphasized the importance of assessing the qualitative indicators of irrigation water to enhance the productivity of irrigated agriculture. Evaluating the impact of irrigation water quality on crop performance is therefore of critical significance. Various methods exist to determine the suitability of water for irrigation; in this study, widely accepted and reliable indicators were employed.

The primary indicator considered was the degree of water mineralization (M). The suitability of irrigation water is influenced by factors such as soil type, the composition of dissolved salts, and the crops being cultivated. Highly mineralized water can be applied on permeable, well-drained soils, whereas less mineralized water is preferable for poorly drained, heavy-textured soils. Given that the study area predominantly consists of heavy granulometric soils, the assessment of irrigation water quality was conducted primarily based on this criterion (Tables 1 and 2). As it can be seen from Table 2, the mineralization level of the water samples taken from other sites, with the exception of the sample from the irrigation canal, is very high and unsuitable for irrigation.

The Stebler, or irrigation coefficient (K), is used to evaluate the potential of low-quality irrigation water to cause secondary soil salinization. On the basis of this coefficient, irrigation water is classified as follows: water with K > 18 is considered fully suitable for irrigation; water with K values between 6 and 18 is suitable; water with K values ranging from 1.2 to 6 is marginally suitable; water with K < 1.2 is regarded as unsuitable for irrigation.

High sodium concentrations in irrigation water adversely affect soil permeability and promote alkalinity, which degrades soil structure and reduces crop productivity. The sodium percentage (Na%) is calculated using the following equation:

$$Na\% = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad (1)$$

Table 1. Permissible limits of irrigation water mineralization degree

Water quality category	Permissible mineralization degree for irrigation water (g/l)
	Heavy-textured soils
I – Fully suitable	0.2–0.5
II – Suitable	0.5–0.8
III – Marginally suitable	0.8–1.2
IV – Unsuitable	>1.2

On the basis of the Na% values, irrigation water is classified into four categories: water with Na% ≤ 20 is fully suitable; Na% between 20 and 40 is suitable; Na% between 40 and 80 is marginally suitable; and Na% exceeding 80 is considered unsuitable for irrigation (Table 3, Figure 3). As it can be seen from Table 3, the samples taken from the non-functioning drainage and irrigation canals were considered suitable because the Na concentration was within the acceptable range, site 2 was considered less suitable, and the water samples taken at points 1, 4 and 5 were considered unsuitable for irrigation.

The sodium adsorption ratio (SAR), also referred to as sodium hazard, is an important indicator used to evaluate the potential impact of sodium ions (Na^+) in irrigation water on soil chemical and physical properties. SAR expresses the tendency of sodium to replace calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions within soil exchange complexes. Such ion exchange leads to the deflocculation of soil aggregates, resulting in reduced soil permeability and structural degradation.

Irrigation with sodium-rich water promotes adverse interactions between sodium ions and the soil matrix, which diminish soil infiltration capacity and restrict water movement through the soil profile. Consequently, these processes negatively affect plant growth and agricultural productivity. Compared to calcium and magnesium, an elevated proportion of sodium exerts a disproportionately strong influence on soil stability and, therefore, on the suitability of water for irrigation purposes. It was established that the irrigation water with SAR < 10 is fully suitable

Table 2. Assessment of Stebler or irrigation coefficient (K) of water samples taken from the study area (2023)

I. $Na^+ - Cl \leq 0$			
No.	Sample name	K	Water quality assessment
1	N-3 drain (not in operation)	0,63	Unsuitable
2	N-6 TSA incoming irrigation canal	36	Fully suitable
II. $Na^+ - Cl > 0$			
1	N-2 H = 1.80 m	0.31	Unsuitable
2	N-1 H = 1.78 m	0.11	Unsuitable
3	N-4 H = 1.90 m	0.09	Unsuitable
4	N-5 H = 2.10 m	0.15	Unsuitable
III. $Na^+ - Cl^- + SO_4^{2-} > 0$			
1	N-2 H = 1.80 m	3.92	Unsuitable
2	N-1 H = 1.78 m	0.48	Unsuitable
3	N-4 H = 1.90 m	0.39	Unsuitable
4	N-5 H = 2.10 m	0.80	Unsuitable

for agricultural use; the water with SAR values between 10 and 18 is considered marginally suitable; and the water with SAR > 26 is classified as unsuitable for irrigation (Table 3).

Calcium and magnesium in natural waters are generally present in a state of equilibrium. An excessive concentration of either ion can adversely affect soil properties, as it may contribute to increased soil salinity and deterioration of soil structure. Consequently, the magnesium content of irrigation water is considered an important criterion for assessing its suitability for agricultural use. The Magnesium Percentage (MAR) is calculated using the following equation:

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (2)$$

On the basis of the MAR values, the water with MAR ≤ 50% is regarded as fully suitable for irrigation, whereas the water with MAR > 50% is considered marginally suitable (Table 3).

Potential salinity (PS) is an important parameter used to evaluate the salinity hazard of irrigation water. During repeated irrigation events, poorly soluble salts tend to precipitate and accumulate in the soil, while highly soluble salts remain in solution and progressively increase soil salinity, thereby adversely affecting soil properties and crop productivity. Potential salinity is calculated using the following equation:

$$PS = Cl^{-} + \frac{1}{2} SO_4^{2-} \quad (3)$$

On the basis of the PS values, irrigation water is classified as follows: the water with PS values between 3 and 15 meq/L is considered fully suitable for irrigation; the water with PS values between 15 and 20 meq/L is regarded as suitable; and the water with PS values exceeding 20 meq/L is classified as unsuitable for irrigation use.

Soil permeability, defined as the ability of soil to transmit water, is strongly influenced by the long-term application of irrigation water, particularly when the water contains elevated salt concentrations. This effect is closely associated with the relative proportions of the Na^{+}, Ca^{2+}, Mg^{2+}, and HCO_3^{-} ions present in the irrigation water. In this context, M. O. Dinka examined the interrelationships and

Table 3. Assessment of some chemical samples taken from the study area (2023)

№	Sample name	Mineralization degree (g/l)	Na%	SAR	MAR	PS	PI, %	KR
1	N-3 drain (not in operation)	5.56	9.62	1.49	89.84	97.55	11.71	0.11
2	N-6 TSA incoming irrigation canal	0.58	14.74	0.67	60.00	3.60	35.09	0.17
3	N-2 H = 1.80 m	3.75	78.49	13.39	62.96	16.40	87.51	3.65
4	N-1 H = 1.78 m	3.278	89.84	36.87	60.55	15.65	92.88	8.85
5	N-4 H = 1.90 m	3.684	89.88	40.32	60.00	15.83	92.51	8.88
6	N-5 H = 2.10 m	2.974	82.43	22.55	63.47	16.60	86.28	4.69

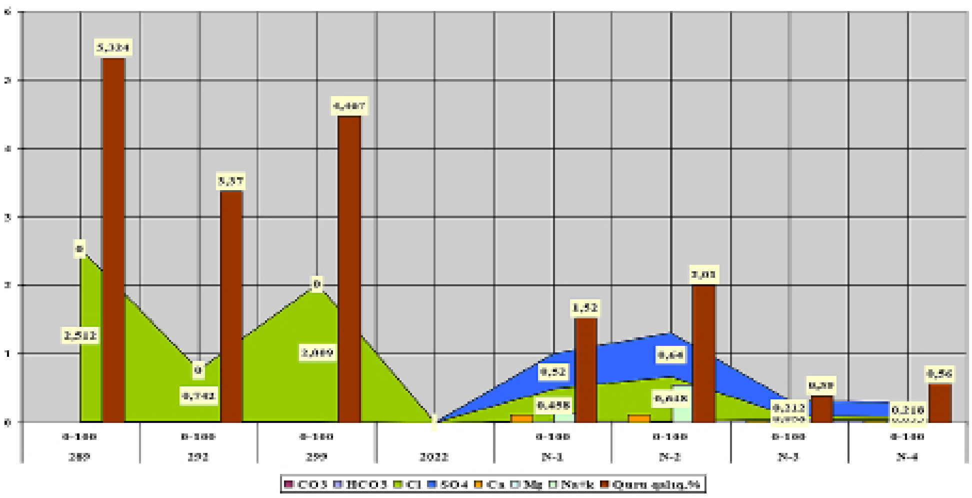

Figure 3. Changes in the salinity of the soils of the Siyazan-Sumgayit massif

combined evaluation of SAR, PI, Na%, as well as MAR indices in assessing irrigation water quality. The permeability index (PI) is calculated using the following equation:

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad (4)$$

On the basis of the *PI* values, irrigation water is classified into three categories: Class I (PI > 75%), which is fully suitable for irrigation; Class II (PI = 25-75%), which is marginally suitable; and Class III (PI < 25%), which is unsuitable for irrigation. Accordingly, irrigation is recommended only for water belonging to Class I and Class II (Table 3).

Kelly's ratio (KR) is an index used to evaluate the relative dominance of sodium ions in irrigation water in comparison to calcium and magnesium ions. A high KR value indicates an excess of sodium, which may adversely affect soil structure and permeability when such water is applied for irrigation. Kelly's ratio is calculated using the following equation:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \quad (5)$$

On the basis of the KR values, irrigation water is classified as follows: the water with KR < 1 is considered suitable for irrigation; the water with KR values between 1 and 2 is regarded as marginally suitable; and the water with KR > 2 is classified as unsuitable for irrigation use (Table 3, Figure 3).

Land reclamation measures such as the application of gypsum, the selection of salt-tolerant plant species, and the blending of irrigation waters of differing quality should no longer be considered generalized management practices, but rather interventions justified by site-specific hydrochemical conditions. In the Siyazan–Sumgait massif, gypsum ($CaSO_4 \cdot 2H_2O$) application is recommended to mitigate the risks associated with elevated soil pH and sodification, particularly in heavy clay soils. The addition of gypsum promotes the replacement of exchangeable Na^+ with Ca^{2+}, thereby improving soil aggregation, enhancing water permeability, and sustaining soil fertility.

Furthermore, the high sodium content detected in both soil and water samples necessitates the selection of salt-tolerant crop species adapted to such conditions. In addition, the controlled mixing of irrigation water with low mineralization and groundwater characterized by higher mineralization levels is proposed as a management strategy to regulate electrical conductivity (EC) and

Table 4. Annual changes in the amount of salts in soils of the study area

Sample No	Depth, cm	Dry residue, %	Chlorine, %
2017			
9, slightly saline	0–25 25–50 50–100	0.200 0.390 0.360	0.056 0.105 0.070
5, moderately saline	0–25 25–50 50–100	0.600 0.300 0.565	0.049 0.112 0.133
4, highly saline	0–25 25–50 50–100	1.795 1.985 2.235	0.644 0.700 0.896
2021			
15, slightly saline	0–30 30–60 60–100	0.200 0.395 0.520	0.021 0.077 0.056
13, moderately saline	0–30 30–60 60–900	0.545 0.650 0.955	0.126 0.063 0.105
16, highly saline	0–30 30–60 60–100	0.785 1.130 1.280	0.413 0.567 0.476
2022			
3, slightly saline	0–30 30–60 60–90	0.41 0.28 0.21	0.049 0.021 0.021
2, highly saline	0–35 35–68 68–91	1.13 2.84 2.75	0.035 0.819 1.092

sodium adsorption ratio (SAR). This approach can contribute to the stabilization of soil chemical properties and support improved agricultural productivity under the specific environmental conditions of the Siyazan–Sumgayit massif.

On the basis of the comprehensive evaluation of irrigation water quality using multiple indices-including the Stebler coefficient, sodium percentage, sodium adsorption ratio, magnesium adsorption ratio, potential salinity, permeability index, and Kelly's ratio, it was determined that the water quality in the studied area varies from suitable to unsuitable for irrigation purposes. Several samples exhibit elevated salinity and sodium-related hazards, which may adversely affect soil permeability, structure, and long-term agricultural productivity if used without proper management.

Therefore, the long-term application of these water resources for irrigation should be accompanied by appropriate irrigation and soil management practices. Such measures may include controlled irrigation scheduling, periodic soil leaching, blending poor-quality water with better-quality sources, the application of soil amendments (e.g., gypsum), and the selection of salt-tolerant crops. Implementing these strategies can help minimize the risks of secondary salinization and sodicity, ensuring sustainable agricultural production in the study area (Table 4)

CONCLUSIONS

Research results showed that the Siyazan-Sumgayit massif is dominated by heavy, gray-brown clay soils with low water absorption capacity. These soils are highly salinized. In the 0–100 cm layer, the soil density is 1.14–1.50 g/cm³, the specific gravity is 2.69–2.80 g/cm³, the porosity is 42.7–50.8%, and the hygroscopic moisture is 8.8–9.5%.

Groundwater was found to be widespread throughout the area and has a predominantly sulfate-chloride-sodium and chloride-sulfate-sodium chemical composition. The groundwater depth from the surface varies from 1 to 18 m in the Khizi district and from 0.5 to 16.5 m and 0.3 to 8.5 m in the Shabran and Siyazan districts, respectively, while the degree of mineralization ranges from 0.8 g/L to 95.2 g/L.

It was established that the drainage water is sulfate-chloride in terms of salt type, while the samples taken from irrigation canals and groundwater from the Takhtakorpu reservoir are chloride-sulfate. It was established that as a result of the reclamation measures carried out, the salt content in the soils of the study area decreased by 0.39–2.01% compared to 1968.

The research results show that in order to increase soil fertility and improve crop productivity, it is advisable to introduce comprehensive agro-melioration measures in the territories, along with the widespread use of advanced irrigation methods.

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