

## Current state of soil microstructure in the Kur-Araz lowland of the Azerbaijan by remote sensing and photometry

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### Abstract

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Based on the data obtained using remote sensing and GIS technologies, the areas of soil salinity distribution were determined. Conducting soil monitoring in the Kur-Araz lowland, which is the region that best meets the needs of agriculture in the Azerbaijan Republic, is a very pressing issue. The best regressions were obtained for the period of active vegetation of crops. Analysis of field-selected crust samples (the surface layer of the transformed soil surface) and mixed samples of arable soil horizons showed that the humus content in the crust sample increases with respect to the mixed sample of the arable horizon when the surface is transformed under the influence of atmospheric conditions. The bulk of the population's demand for vegetable crops in the Republic of Azerbaijan is met by agrocenoses located in the areas of the Kura-Araz lowland. From this point of view, it is very necessary to study the soil and climatic conditions of these territories using modern methods.

*Keywords:* soil salinity; soil degradation; soil crust; GIS; spatial images; photometry

### Introduction

The soil surface is the place of maximum impact on the soil of atmospheric and meteorological conditions (temperature, precipitation, snowmelt, wind, solar energy), as well as human impact during agricultural use of soils. This is especially pronounced on arable soils, the surface of which remains open for a long time (Bunyatova et al., 2025; Hasanova et al., 2021). The maximum change in the soil surface under the influence of these factors occurs in irrigated soils of arid and subarid regions, which is manifested in the formation of crusts. Soil salinity significantly limits crop production. In

arid areas, yield losses can range from 21% to 43% due to unfavorable conditions caused by high salt content (Hasanova et al., 2021; Ismayilova et al., 2025). Secondary salinization is one of the main processes of land degradation, which negatively affects ecosystems and biodiversity. Increasing the amount and intensity of irrigation can lead to a significant deterioration in soil properties and to increased degradation. This phenomenon is associated with the accumulation of water-soluble salts, which inhibit plant growth and change the chemical composition of the soil (Jalilova and Hasanova, 2024; Kaplan et al., 2023). Proper distribution of water resources can reduce the level of salt accumulation in soils.

Soil salinization is a serious threat to agriculture and ecosystems, especially in regions with semi-arid and arid climates. At present, the most promising are the use of satellite data and automated methods for deciphering soil salinity. These studies are actively being developed in many countries (Kulmatov et al., 2021; Macnunlu et al., 2025). In Azerbaijan, especially in areas such as Ujar district, this problem creates unfavorable conditions for agriculture and vegetation, causing high salt accumulation in the soil as a result of drought and failure to apply proper irrigation methods. Salinization reduces soil productivity and poses problems for long-term agricultural activities and water management (Mammadova et al., 2024; Moussa et al., 2020).

The studies were conducted using soil samples collected from key sites, field observations, and the results of a model experiment. The soil surface condition, color, micromorphological and microtomographic structure, and chemical composition were analyzed. It has been established that the impact of atmospheric precipitation leads to changes in the properties of the surface layer of the arable soil horizon (Mirzezadeh et al., 2025). Changes in the mineralogical composition are expressed in the redistribution of minerals between granulometric fractions. The longer the soil remains exposed to alternating precipitation and drying, the more pronounced is the formation of surface microlayers of leaching (eluvial) and microlayers of leaching (illuvial), differing in the content of finely dispersed organomineral substances and their structural organization (Shukurov et al., 2025; Mammadova et al., 2025). The initial state of humus and the granulometric composition of the soil predetermine the specifics of the microhorizons formed on the surface. In this case, a layer of dusty or sandy material with a minimum amount of microaggregates and finely dispersed matter is formed in the upper part, and below, the size and number of aggregates clearly increases. The identified patterns should be taken into account in remote monitoring and mapping of soil properties. To determine the humus content in the arable horizon, it is necessary to conduct a survey of freshly plowed and harrowed fields. The mineralogical composition, in turn, will be better detected by images of the transformed arable land surface (Nazim and Oqtay, 2024; Nasirova et al., 2026).

Soil salinization in the Kur-Araz lowland regions occurs mainly due to high concentrations of salts ( $\text{NaCl}$ ,  $\text{MgCl}_2$ ,  $\text{NaHCO}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{CaSO}_4$ ,  $\text{MgSO}_4$ ,  $\text{Na}_2\text{SO}_4$ ), which negatively affects plant growth and can lead to a decrease in yields. Water-soluble organo-mineral complexes can precipitate during evaporation in the soil and be fixed at different depths. The evaporation barrier can be associated with the concentration of Ca, Na, K, Mg, F, S, Sr, Cl, Rb, Zn, Li, Ni, V, Mo. The middle quaternary alluvial and undifferenti-

ated eolian deposits that come to the surface are represented by sands and sandy loams with lenses and layers of loams and clays (Shukurov et al., 2025a; Shukurov et al., 2025b). Salinity is somewhat absent to a depth of 30–50 cm, below which the salt content increases sharply. Solonchak soils are formed on flat depressions. The main innovation of the study is to conduct a detailed analysis of salinity by different indices, both by area and by salinity intensity, and to show in a comparative form how each index reflects the risk of salinity. The soils are depleted of nutrients, low in humus (<1%), and are characterized by complete lack of structure and the ability to become waterlogged after irrigation and form a dense crust (Taghadosi et al., 2019; Williams et al., 2018). Under the influence of irrigation, salt migration processes in the soil profile are activated. Meadow soils are characterized by high alkalinity. The content of carbonates reaches high values and increases with depth. *Triticum aestivum* L., *Medicago* L., *Oryza sativa* L., *Avena sativa* L. are grown on the irrigated area. Natural vegetation is practically absent.

Unlike other studies, the aim of this work is not only to determine the risk of salinity, but also to show in practice how this risk can be assessed for agriculture and the environment. At the same time, potential applications for the use of the results and proposals for the development of methods to combat salinity will be made.

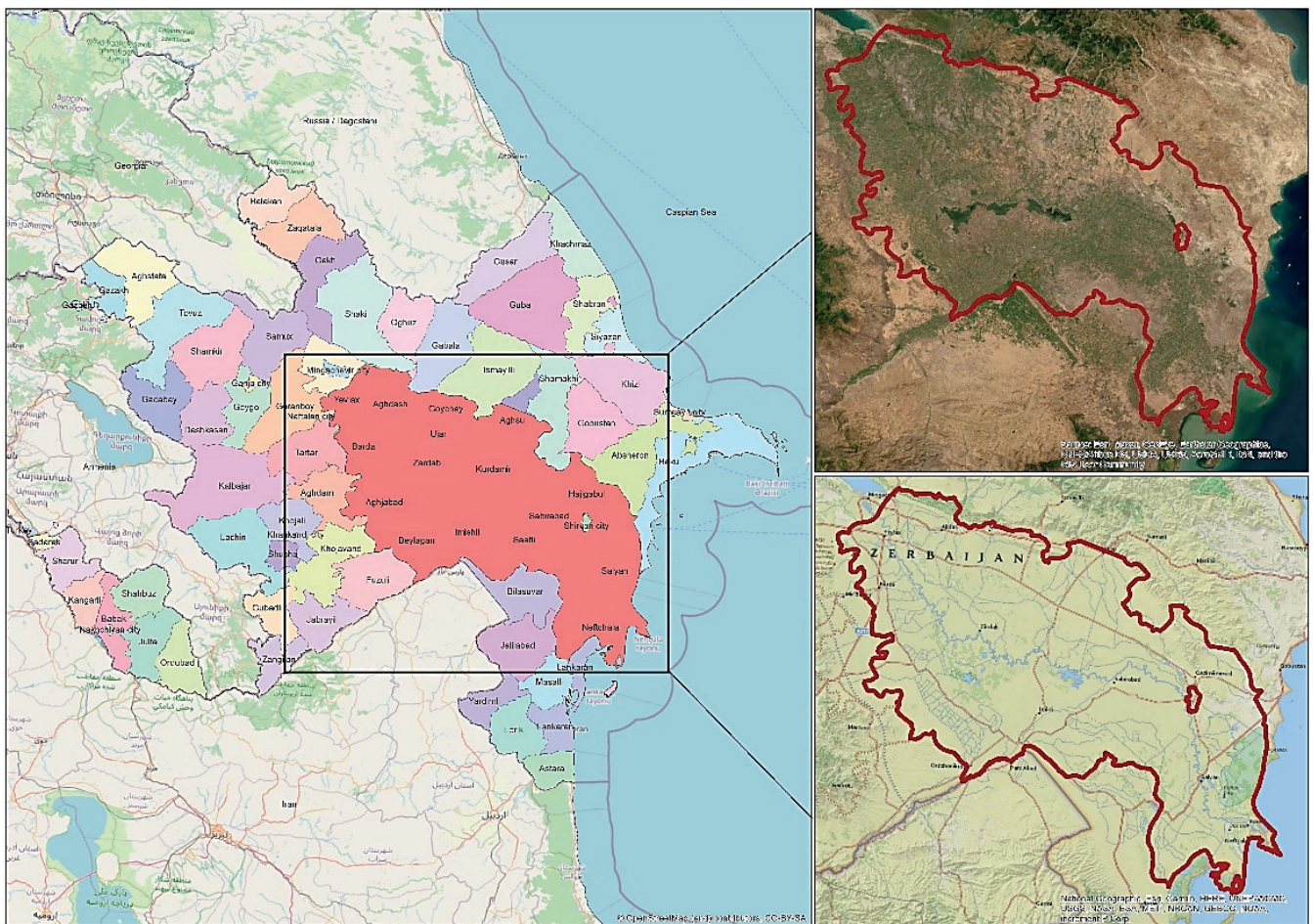
## Research methodology

Remote sensing technologies, such as Landsat-8 satellite imagery, offer promising opportunities for monitoring and mapping soil salinity at large spatial scales with high temporal resolution. The use of high spatial resolution satellite data in combination with a selective field survey allows for a rapid assessment of soil salinity in the study region based on regression analysis. The Kur-Araz lowland, located in Azerbaijan, has a diverse soil cover, which is largely determined by climatic conditions and anthropogenic activities (Figure 1).

The crust thickness ranges from 1 mm to 5 cm. Micromorphological analysis was performed using an Olympus BX51 polarizing microscope with an Olympus DP26 digital camera and Stream Basic software. Descriptions of microstructure elements are carried out according to the international classification of microfeatures (Figure 2). In the middle and lower parts of the soil micromonolith, a low content of finely dispersed material was noted, which is represented by small organomineral clots with loose packing between sand grains or forming thin fragmentary covers (cutans) on the surface of coarse sand particles. Differentiation of the material in the micromonolith during the exposure of the sample in the model experiment was manifested: 1 – in the residual accu-

mulation of the largest sand grains with clean (washed from films) surfaces on the soil surface; the mineralogical composition of large fractions is represented by quartz, feldspars and dark-colored weathered minerals and rock fragments; 2 – in the accumulation and compaction of finely dispersed material with scaly optical orientation of clay and smaller sand particles, probably partially displaced from the upper 2 mm, under the washed residual sand layer (Fig. 2, B). In the middle and lower parts of the micromonolith, loose, initially homogenized soil material with interaggregate porosity, with weakly decomposed plant residues and micro-clotted clay-organic micromass is noted. As a result, under the thin layering, material with larger aggregates is noted, between which there are crack fillings (infillings) with washed dust – they probably mark former cracks-cracking of the crust during the dry period with the inflow of fine dusty material during rains. The index values were calculated in ArcGIS software and the

salinity level of the territory was determined. If the surface of saline soils is covered by vegetation, then a high correlation is often observed between the degree of soil salinity and vegetation indices and indices calculated on the basis of the ratio of brightness in the red and near infrared channels; such indices reflect the state of vegetation: poor in the case of higher salinity, good in the case of low salinity. Using the Progress 1T field salinity meter, the electrical conductivity and temperature of the soils were determined, and the degree of salinity was calculated based on these data. The degree of salinity was determined in the following depth ranges: 0–20, 20–50, 50–100 cm. A total of 75 determinations were made. The coordinates of the points were recorded using the Garmin 62s GPS. Salinity maps were constructed based on regression analysis – creating regression equations between space imagery data and electrical conductivity measured in the field.



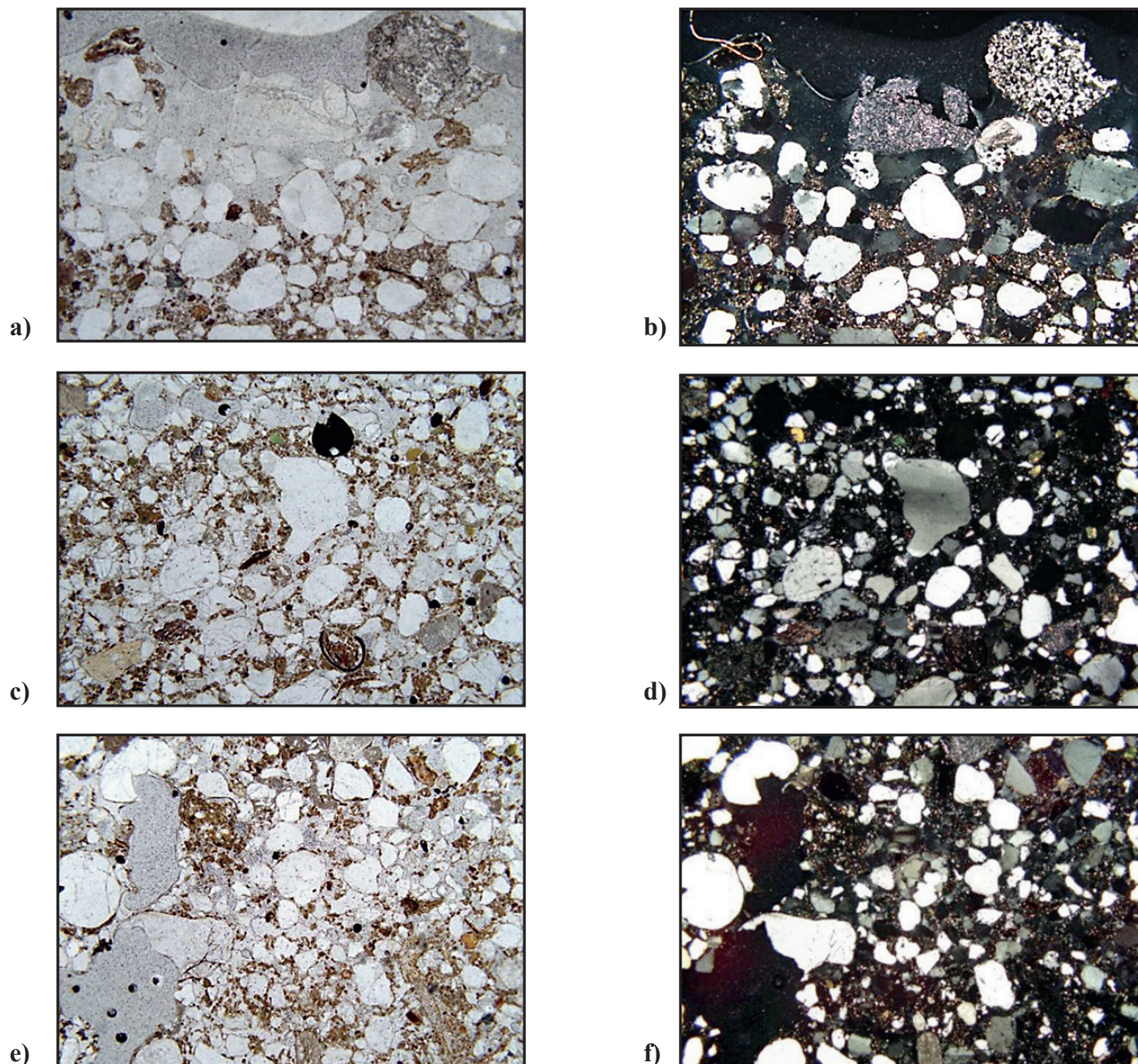
**Fig. 1. Research area**

Source: Made by authors in 2024 year

## Results

The degradation process in arid regions leads to the removal of humus horizons and exposure of the profile, as a result of which fine-grained deposits come to the surface in the form of soils similar to elements of the lithosphere. The

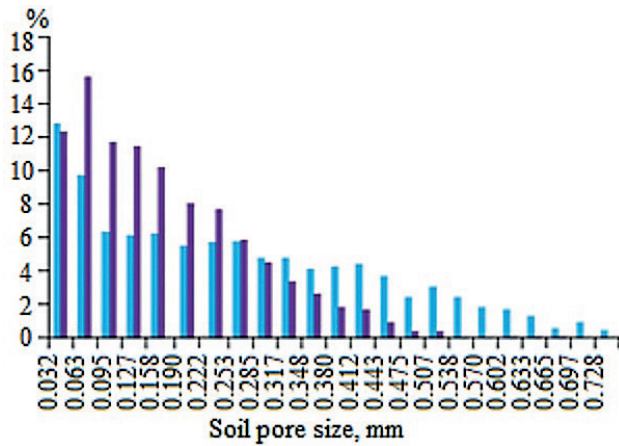
quality assessment of the best regression models for each crop-depth combination using the Jackknife method showed that the standard deviations for different crops and depths ranged from 0.9 to 2.5 dS/m. Taking into account the following FAO soil salinity gradations by electrical conductivity (dS/m): 0–2 – non-saline, 2–4 – slightly saline, 4–8 – mod-



**Fig. 2. Elements of the microstructure of crust microhorizons of bulk arable material from soil**

*Note:* a and b – two-layer structure of the crust surface – the upper microlayer of purely sand grains of different mineralogical composition, the lower one – sand grains are located in compacted finely dispersed material (0–5 mm), c and d – clumped clay-humus substance between sand grains, isolated plant residues (20–25 mm), e and f – unequal distribution of micro-clotted clay-humus substance between sand grains (35–40 mm).

*Source:* Authors' own elaboration



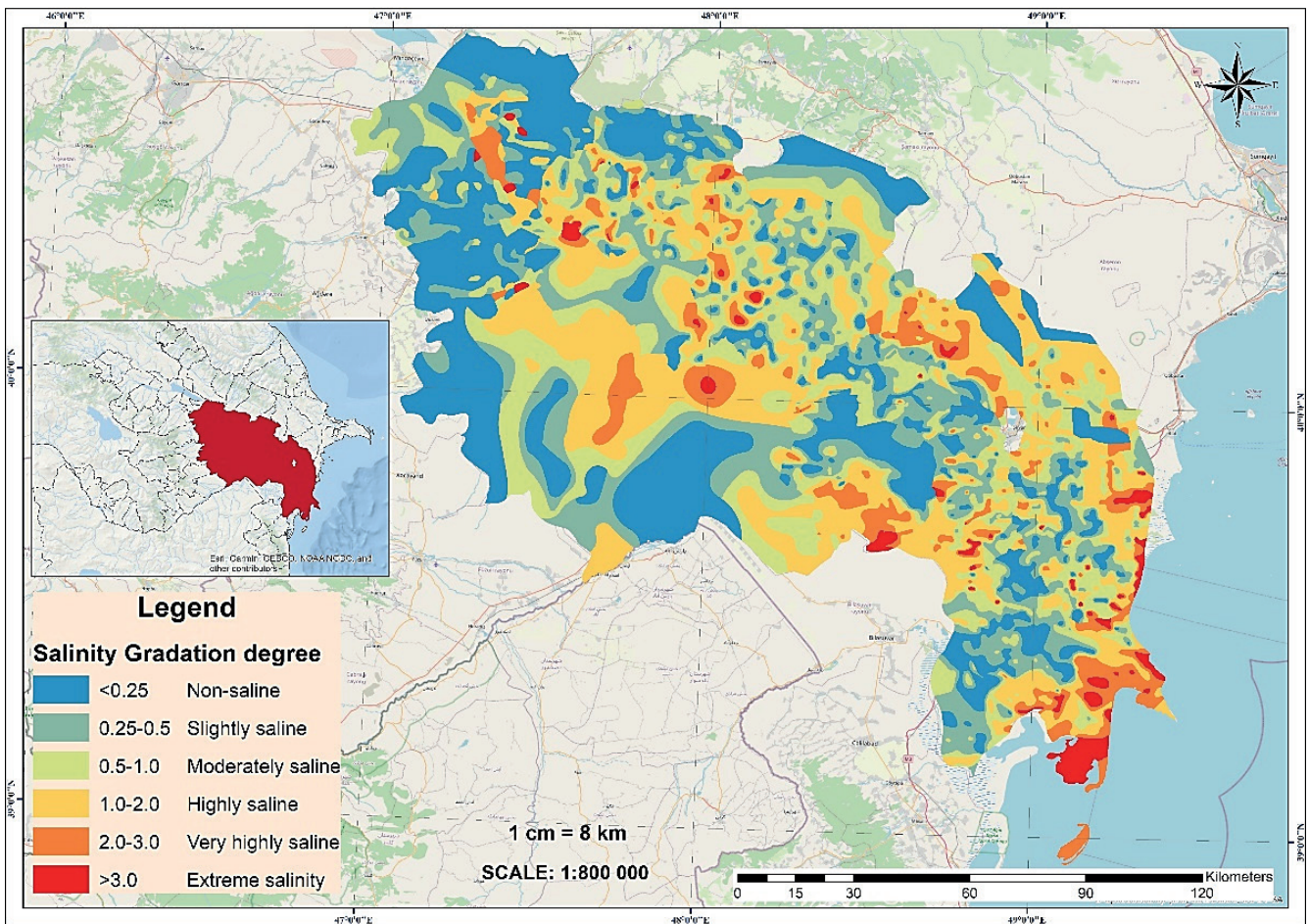
**Fig. 3. Soil pore size in Kur-Araz lowland soils**  
 Source: Authors' own elaboration

erately saline, 8–16 – highly saline, >16 – very highly saline. It can be concluded that the salinity prediction error does not exceed one gradation on average.

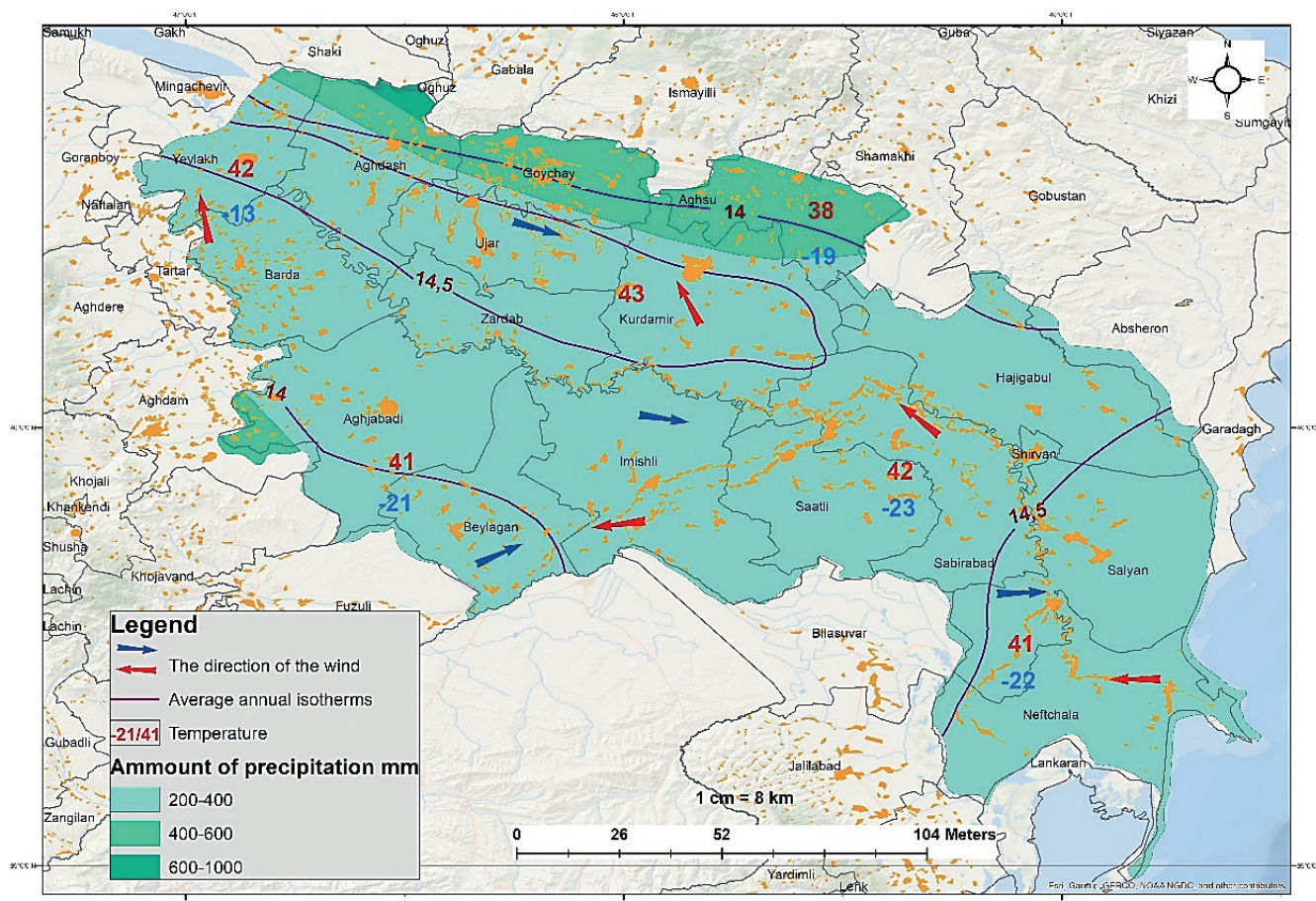
As a result of continuous farming and irrigation with the waters of the Kura River, salinization has increased due to the rise in groundwater levels. As can be seen, soil salinity is at a higher level in the Ujar, Sabirabad, Imishli, Saatli, and Kurdamir regions (Fig. 4).

Comparative study of climate indicators in different regions is one of the most pressing issues of our time. Amount of precipitation, average annual isotherms, wind direction were determined in 2024 year (Fig. 5).

The bulk of the population's demand for vegetable crops in the Republic of Azerbaijan is met by agrocenoses located in the areas of the Kura-Araz lowland. From this point of view, it is very necessary to study the soil and climatic conditions of these territories using modern methods. Reducing



**Fig. 4. Degree of salinity gradient**  
 Source: Made by autors in 2024 year



**Fig. 5. Climate indicators of the Kura-Araz lowland**

Source: Made by authors in 2024 year

the level of anthropogenic impact promotes humus mineralization.

## Conclusion

In the moderate climate zone, the impact of irrigation water on the open surface of arable soils leads to changes in the properties of both the surface and the surface layer of the arable horizon. The state of the organomineral substance and the granulometric composition of the original soil predetermine the formation of a crust, which morphologically represents a microprofile with leaching and washing-out microhorizons. Most of the changes are related to the microstructure, mineralogical composition of silt, humus content, as well as their ratio and structural organization of soils. Redistribution of granulometric fractions in each newly formed microhorizon is caused by the processes of destruction of the original microaggregates, eluvial-illuvial redistribution of fine aggre-

gates and/or fine dust-silt fractions. Changes in the material and chemical composition of the surface layer of soils cause changes in their spectral reflectivity, which must be taken into account when detecting soil properties using remote and non-contact sensing data.

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