



CHEMICAL PROPERTIES OF SOIL IN UZBEKISTAN

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Abstract: *The chemical properties of soil are crucial for ensuring sustainable agriculture, plant growth and fertility. This study aims to investigate variations in chemical indicators in irrigated and saline soils in Uzbekistan, mainly sieroze and grey soils. The study aimed to determine the relationships between soil pH, cation exchange capacity (CEC), organic matter content, and the presence of macroelements (N, P, K) and micronutrients in their available forms, and to assess their impact on agricultural productivity.*

Samples were collected from 45 typical and saline soil profiles in the Tashkent and Fergana Valley regions between 2022 and 2025. Standard agrichemical methods (pH-metry, titrimetry, spectrophotometry and atomic absorption spectrometry) were employed. The results showed that most soils had a pH between 7.8 and 8.6, exhibiting carbonate and alkaline properties. The CEC was found to be between 12 and 28 meq/100 g and the organic matter content was found to be between 0.6 and 1.8%. The available forms of phosphorus were sharply reduced by carbonates (often <15 mg/kg P_2O_5), while potassium remained at medium-to-high levels.

High salinity ($EC > 4$ dS/m) and pH limit the uptake of micronutrients such as Fe, Mn, and Zn by plants. These results confirm the importance of applying organic fertilisers, gypsum and phosphatic fertilisers in a sustainable way to improve soil fertility in Uzbekistan. This information can be used to develop sustainable soil management strategies.

Keywords: *soil chemical properties, pH, CEC, organic matter, salinisation, Uzbekistan, fertility*



Introduction

The Central Asian region, particularly Uzbekistan, has an arid and semi-arid climate, and agriculture here is based primarily on irrigation systems [1]. The region is facing severe soil degradation as a result of one of the world's greatest ecological disasters: the drying up of the Aral Sea. According to FAO data, globally, saline soils cover 1.381 million hectares (10.7% of the Earth's land surface), and a further 1 billion hectares are at risk due to climate change and human activities. Uzbekistan accounts for 70% of the world's saline soils, particularly in its irrigated lands (FAO, 2024; Khasanov et al., 2023).

In Uzbekistan, approximately 50% of irrigated land is affected by salinisation to varying degrees: 30% are mildly salinised, 16% moderately, and 4% severely (Dustnazarova et al., 2021). In the Karakalpakstan Republic, saline soils account for 77% of land; in the Khorezm region, it is 100%; in the Bukhara region, 87%; in the Jizzakh region, 79%; and in the Navoi region, 87% (Jumaniyazov et al., 2024). The salinity level has increased sharply in some regions in recent years (2020–2025): by 33% in Jizzax, 82% in Namangan, and 34% in Fergana (Umarov et al., 2025). This process is known as secondary salinisation and is primarily caused by poor irrigation practices, excessive water usage, inadequate drainage systems, and the use of saline water for irrigation.

The chemical properties of soil, such as pH (acidity/alkalinity), cation exchange capacity (CEC), organic matter content, soluble salts (EC), and the presence of macroelements (e.g. nitrogen, phosphorus, and potassium), as well as the availability of micronutrients, are key factors in determining plant growth, nutrient uptake, and overall productivity. In Uzbek soils, particularly in sierozems (Calcisols according to the World Reference Base for Soil Resources (WRB)) and brown soils, the pH is typically between 7.8 and 8.6, exhibiting strongly alkaline and carbonate characteristics (Turdaliev et al., 2023). This leads to phosphorus binding with calcium and converting into insoluble Ca-P forms, resulting in available P_2O_5 levels often being below 15 mg/kg. The average organic matter content is 0.6–1.8%, with most areas having less than 1% (FAO and local studies, 2022–2025). Low organic



matter content reduces CEC (typically 12–28 meq/100 g), weakening nutrient retention capacity and breaking down soil aggregates.

Climate change is exacerbating these problems. In the Khorezm region, the proportion of weakly saline soils is projected to decrease slightly from 55.4% to 52.4% between 2050 and 2100, while the proportion of moderately and strongly saline soils is expected to rise (Khamidov et al., 2022). Rising summer temperatures, water scarcity and increased evaporation accelerate the accumulation of salinity in the soil. Consequently, the yield of major crops such as cotton and wheat could fall by 20–40%, sharply reducing export volumes (Khasanov et al., 2023). For instance, a 1% increase in salinity can lower wheat yields by 0.09% (Babadjanova et al., 2024).

The Aral Sea basin is the area most severely affected by this process. As a result of the sea drying up, salt dust storms, rising groundwater levels and the spread of salinity are being observed. In Karakalpakstan, salinity levels (EC_e) reach 35.7 dS/m 15 km from the dry lake bed, which is 4.8 times higher than agricultural land (2025 studies). This situation is affecting more than just

In Karakalpakstan, the salinity level (EC_e) is 35.7 dS/m, 15 km from the dry lake bed. This is 4.8 times higher than the salinity level of agricultural land, as shown in 2,025 studies. This situation affects not only agriculture, but also ecological stability, the socio-economic situation and public health.

Local and international studies (Uzoqov & Holiqulov, 2018; Jabbarov et al., 2022; FAO, 2020–2024) suggest that sufficient up-to-date information on the spatial and temporal variability of the chemical properties of irrigated soils in Uzbekistan is lacking. Most studies are based on outdated data or cover only a few regions. Therefore, comprehensive agrichemical monitoring is necessary in active agricultural areas such as the Tashkent and Fergana valleys.

This study aims to assess the spatial variability of chemical indicators (pH, CEC, organic matter, EC, N-P-K and micronutrients), determine the correlations between them and analyse their impact on agricultural productivity. The research results will provide a scientific basis for developing sustainable soil management strategies, reducing salinisation and increasing productivity.



Methodology

The study was conducted in two of Uzbekistan's main irrigated regions: Tashkent Province (the Ohangaron and Chirchiq valleys, and the areas surrounding Tashkent), and the Fergana Valley (Andijan, Fergana and Namangan provinces). These regions have the highest agricultural intensity in Uzbekistan, with predominantly Sierozem (Calcisols) and Gray soils (Fluvisols), as well as their saline variants. The total area covered is approximately 4.5–5 million hectares of irrigated land.

A total of 45 soil profiles were selected for sampling between 2022 and 2025.

- 25 typical (lightly saline or non-saline) sierozems and brown soils;

- 20 moderately and strongly saline soils ($EC > 4$ dS/m).

Samples were taken from the arable layer (0–30 cm) and the 30–60 cm layer of each profile (a total of 90 samples). Samples were collected in accordance with standard agricultural protocols (FAO and Uzbek Institute of Soil Science guidelines) and analysed in the laboratory.

Analysis methods:

- pH: in an aqueous suspension (soil: water = 1:2.5) using a pH meter (Hanna HI-98168).

- Electrical conductivity (EC): in a water extract (1:5) using a conductivity meter (in dS/m).

- Organic matter (OM): Walkley–Black method (organic carbon $\times 1.724$).

Cation exchange capacity (CEC): ammonium acetate method (pH 7.0), meq/100 g.

Available phosphorus (P_2O_5): Olsen method (0.5 M $NaHCO_3$ extraction), spectrophotometry.

- Exchangeable potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na): ammonium acetate extraction and atomic absorption spectrometry (AAS, PerkinElmer).

Micronutrients (Fe, Mn, Zn, Cu): DTPA extraction (Lindsay & Norvell, 1978) by AAS.



Statistical analysis was performed using SPSS 27 and R software.

Descriptive statistics (mean \pm standard deviation).

- Pearson correlation coefficient;
- One-way ANOVA (testing for differences by region and salinity level);

Regression analysis was performed to investigate the relationships between pH and CEC, OM and productivity. Data normality was tested using the Shapiro–Wilk test ($p > 0.05$).

Results

Mean values of the main chemical indicators

Indicator	Typical soils (n=25)	Saline soils (n=20)	Overall mean \pm SD	ANOVA (p-value)
pH (H ₂ O)	7.92 \pm 0.38	8.42 \pm 0.47	8.14 \pm 0.49	<0.001
EC (dS/m, 1:5)	1.18 \pm 0.55	6.75 \pm 2.12	3.68 \pm 3.05	<0.001
Organic matter (%)	1.42 \pm 0.48	0.82 \pm 0.32	1.15 \pm 0.51	<0.001
CEC (meq/100 g)	18.4 \pm 4.2	14.6 \pm 3.7	16.7 \pm 4.3	0.002
Available P ₂ O ₅ (mg/kg)	12.8 \pm 5.4	8.3 \pm 4.1	10.8 \pm 5.2	0.004
Exchangeable K (mg/kg)	315 \pm 82	285 \pm 68	302 \pm 78	0.112 (ns)
DTPA-Fe (mg/kg)	4.2 \pm 1.1	3.1 \pm 0.9	3.7 \pm 1.1	0.001
DTPA-Zn (mg/kg)	0.58 \pm 0.22	0.41 \pm 0.18	0.51 \pm 0.21	0.008

Significant correlations (Pearson, $p < 0.01$):

- pH and EC: $r = 0.81$
- organic matter and cation exchange capacity (CEC): $r = 0.84$
- pH and available P: $r = -0.76$

Salinity (EC) and micronutrients (Fe, Zn): $r = -0.68$ to -0.75 .

In the Tashkent region, the pH level and CEC were slightly higher, which is a characteristic of silty soils. In contrast, the salinity level was higher and the organic matter content was lower in the Fergana Valley.

Distribution by salinity level (based on EC):

- Weak (<2 dS/m): 55%
 - Medium (2–8 dS/m): 30%
- Strong (>8 dS/m): 15% (mainly in the outskirts of the Fergana Valley).

Discussion

The results confirm the strongly alkaline-carbonate nature of irrigated soils in Uzbekistan, which is consistent with other arid regions worldwide, such as Central Asia and North Africa. A pH above 8.0 causes phosphorus to convert to calcium



phosphate forms, sharply reducing the available phosphorus (Olsen P <15 mg/kg – deficiency threshold) content. This condition can reduce the yield of cotton, fruit, and vegetable crops by 20–35%.

The low organic matter content (an average of 1.15%) limits the CEC and accelerates nutrient leaching. In saline soils, a high proportion of Na⁺ (ESP 15–30%) disrupts soil structure, reduces water permeability and weakens the root system of plants.

According to the latest data (2023–2025), the proportion of saline irrigated land in Uzbekistan has increased to 53% (up from 44–45% previously), although a decrease has been observed in some regions due to improvements in irrigation systems. In the Fergana Valley, the increase in salinity (up to 35% in Namangan and Andijan) is linked to inadequate drainage systems and poor water quality.

Recommendations:

- Add organic matter (15–25 t/ha of manure per year).
- Limestone application (CaSO₄, 5–10 t/ha on saline soils).
- Phosphate fertiliser placement method.
- Minimum tillage and cover crops.

Continuous monitoring via space monitoring (Uzbekkosmos projects).

Limitations: The study only covered two regions, so long-term (10+ years) monitoring and yield-related field experiments are needed.

Conclusions: alkalinity (pH 8.1+), salinity (average EC 3.7 dS/m) and organic matter deficiency are the main limiting factors in the soils of the Tashkent and Fergana valleys in Uzbekistan. These factors reduce the availability of nutrients (especially phosphorus and micronutrients), which has a negative effect on agricultural productivity. Rational land reclamation, the use of organic fertilisers and modern monitoring techniques could increase yields by 15–30%. These results can be used to develop sustainable soil management strategies.

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