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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылыметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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CONTENTS

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SOIL DEGRADATION PROBLEMS AND ECOLOGICAL ASSESSMENT IN THE AGROLANDSCAPES ALONG THE ARAZ RIVER OF THE NAKHCHIVAN AUTONOMOUS REPUBLIC

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Abstract. *Relevance.* Soil degradation in the agrolandscapes along the Araz River in the Nakhchivan Autonomous Republic poses significant threats to regional agricultural sustainability and food security, directly addressing UN Sustainable Development Goal 8 (SDG 8). Intensified anthropogenic pressures—such as improper irrigation, overgrazing, and unmanaged land use—lead to the annual loss of fertile lands. *Objective.* This study evaluates the ecological status, chemical characteristics, and spatial degradation dynamics of these key plain soils. *Methods.* Field investigations and sampling were conducted between 2014 and 2021 across 11 representative sampling points within three primary experimental sites: Nehram (Babek district), Khok (Kangarli district), and Boyukduz (Kangarli district). Soil profiles were sampled at standard depths of 0–25 cm, 25–50 cm, and 50–75 cm. Standard laboratory methods were utilized to evaluate pH, humus (Tyurin method), total nitrogen (Kjeldahl method), carbonation (Scheibler method), mobile phosphorus (Machigin method), exchangeable potassium (Protasov method), and water-soluble harmful salts. Sampling locations were mapped using ArcGIS 10.3. *Results and conclusions*. Soils across all sites are weakly alkaline (pH 7.41–8.26), low in topsoil organic matter (0.17–1.74%), and severely deficient in available

phosphorus (<10 mg/kg). While topsoils are mostly non-saline, deeper subsoils (25–75 cm) show moderate to severe salinization. Specifically, Khok exhibits severe chloride-sulfate salinization (dry residue 2.578–2.858%), and Boyukduz displays high carbonation (18.28–20.57%) with subsoil salt accumulation (1.025%), highlighting strong secondary salinization risks. Preventing further secondary salinization and land degradation requires immediate sustainable soil management interventions. Essential recommendations include systematic application of organic and mineral fertilizers, implementation of crop rotation, reconstruction and cleaning of collector-drainage networks, and the transition to water-efficient drip and sprinkler irrigation systems. These findings provide a scientific framework for land reclamation strategies in Nakhchivan. Ultimately, these adaptive measures are vital for restoring degraded agrolandscapes and securing regional agricultural productivity.

Keywords: land resources, degradation, ecological assessment, Nakhchivan AR, agrolandscapes

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НАХЧЫВАН АВТОНОМИЯЛЫҚ РЕСПУБЛИКАСЫНДАҒЫ АРАЗ ӨЗЕНІНІҢ БОЙЫНДАҒЫ ТОПЫРАҚТЫҢ ДЕГРАДАЦИЯСЫ ЖӘНЕ АГРОЛАНДШТЕЙНДЕРДІ ЭКОЛОГИЯЛЫҚ БАҒАЛАУ МӘСЕЛЕЛЕРІ

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Аннотация. *Өзектілігі.* Нахчыван АР Араз өзені бойындағы агроландшафтардағы топырақтың деградациясы БҰҰ-ның 8-ші Тұрақты даму мақсатына сәйкес келе отырып, ауыл шаруашылығының тұрақтылығы мен азық-түлік қауіпсіздігіне қауіп төндіреді. Антропогендік факторлар — дұрыс суармау, шектен тыс жайылым және ретсіз жер пайдалану — жыл сайын құнарлы жерлердің жоғалуына әкеледі. *Мақсаты.* Бұл зерттеу осы жазық территориялар топырағының экологиялық жағдайын, химиялық қасиеттерін және деградация динамикасын бағалайды. *Әдістері.* Далалық зерттеулер 2014–2021 жылдары Нехрам (Бабек ауданы), Хок және Бёюкдюз (Кенгерли ауданы) аймақтарындағы 11 нүктеде 0–25, 25–50 және 50–75 см тереңдікте жүргізілді. Зертханалық әдістермен pH, гумус (Тюрин әдісі), жалпы азот (Кьельдаль), карбонаттылық (Шейблер), жылжымалы фосфор (Мачигин), алмасатын калий (Протасов) және суда еритін тұздар анықталды. Үлгі алу нүктелері ArcGIS 10.3 арқылы картаға түсірілді. *Нәтижелері және қорытындылар.* Топырақтар әлсіз сілтілі (pH 7,41–8,26), органикалық заттар мөлшері төмен (0,17–1,74%) және фосфор тапшылығы жоғары (<10 мг/кг). Жоғарғы қабаттар негізінен тұзданбаған, бірақ тереңірек қабаттар (25–75 см) орташа және қатты тұзданған. Хокта қатты хлоридті-сульфатты тұздану (құрғақ қалдық 2,578–2,858%), ал Бёюкдүзде жоғары карбонаттылық (18,28–20,57%) және терең қабатта тұздың жиналуы (1,025%) анықталды, бұл қайталама тұздану қаупін білдіреді. Деградацияның алдын алу тұрақты басқаруды талап етеді: тыңайтқыштарды жүйелі түрде енгізу, ауыспалы егісті қолдану, коллекторлық-дренаждық желілерді тазалау және тамшылатып пен бүріккіш суаруға көшу. Бұл нәтижелер Нахчывандағы жерді мелиорациялау стратегияларының ғылыми негізін қалыптастырады. Түптеп келгенде, бұл бейімделу шаралары тозған агроландшафттарды қалпына келтіру және аймақтық ауыл шаруашылығы өнімділігін қамтамасыз ету үшін өте маңызды.

Түйін сөздер: жер ресурстары, деградация, экологиялық бағалау, Нахчыван облысы, агроландштейндер

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ПРОБЛЕМЫ ДЕГРАДАЦИИ ПОЧВ И ЭКОЛОГИЧЕСКАЯ ОЦЕНКА АГРОЛАНДШАФТОВ ВДОЛЬ РЕКИ АРАЗ В НАХЧЫВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКЕ

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Аннотация. *Актуальность.* Деградация почв в агроландшафтах вдоль реки Араз в Нахчыванской АР угрожает устойчивости сельского хозяйства и продовольственной безопасности, перекликаясь с ЦУР ООН № 8. Антропогенные факторы — ненадлежащее орошение, перевыпас и бессистемное землепользование — ведут к ежегодной потере плодородных земель. *Цель.* Данное исследование оценивает экологическое состояние, химические свойства и динамику деградации почв этих равнинных территорий. *Методы.* Полевые исследования проводились в 2014–2021 гг. на 11 участках в Нехраме (Бабекский район), Хоке и Бёюкдюзе (Кенгерлинский район) на глубинах 0–25, 25–50 и 50–75 см. Лабораторно определены pH, гумус (метод Тюрина), общий азот (Кьельдаль), карбонатность (Шейблер), подвижный фосфор (Мачигин), обменный калий (Протасов) и водорастворимые соли. Точки отбора картированы в ArcGIS 10.3. *Результаты и выводы.* Почвы слабощелочные (pH 7,41–8,26), с низким содержанием органического вещества (0,17–1,74%) и острым дефицитом фосфора (<10 мг/кг). Верхние слои преимущественно незасоленные, однако подпочвенные горизонты (25–75 см) средне- и сильнозасолены. В Хоке выявлено сильное хлоридно-сульфатное засоление (сухой остаток 2,578–2,858%), а в Бёюкдюзе — высокая карбонатность (18,28–20,57%) и накопление солей в подпочве (1,025%), что указывает на риски вторичного засоления. Предотвращение деградации требует устойчивого управления: систематического внесения удобрений, внедрения севооборота, очистки коллекторно-дренажных сетей и перехода на капельное и дождевальное орошение. Эти результаты формируют научную основу для стратегий мелиорации земель в Нахчыване. В конечном счете, эти адаптивные меры имеют жизненно важное значение для восстановления деградированных агроландшафтов и обеспечения региональной сельскохозяйственной продуктивности.

Ключевые слова: земельные ресурсы, деградация, экологическая оценка, Нахчыванская область, агроландшафты

Introduction. Research on soil degradation has been conducted by internationally renowned scholars such as N.Q. Kharin, T.G. Boychiev, Graciela Metternicht, Jan Nyssen, Elisabeth Huber-Sannwald, and others. Their studies have made significant contributions both at regional and global scales. T.G. Boychiev (1982) investigated the causes of soil degradation under arid and semi-arid climatic conditions in Bulgaria. Taking into account water erosion,

salinization, vegetation degradation, and the reduction of organic matter in the soil, he developed a comprehensive soil degradation map. N.Q. Kharin (1985) utilized satellite imagery to develop a soil degradation map for Turkmenistan, identifying vegetation degradation as the primary driver of land degradation in the region. Elisabeth Huber-Sannwald (2007) conducted research focused on addressing processes such as soil degradation, erosion, and salinization in arid zones. Her work also emphasized the study of socio-ecological systems and the impacts of land use on ecosystems. Graciela Metternicht (2008) carried out extensive research on the detection of soil salinization using remote sensing technologies. Her contributions have been instrumental in promoting the application of modern technologies in land degradation management. Her studies on soil health and productivity hold global significance. Jan Nyssen (2015) examined the impact of soil erosion on ecosystems in African and Asian regions. His research has been crucial for the development of scientific solutions aimed at sustainable land use and erosion control.

Unfortunately, extreme hunger and malnutrition remain a huge barrier to development in many countries. There are 821 million people estimated to be chronically undernourished as of 2017, often as a direct consequence of environmental degradation, drought and biodiversity loss (SDG 2).

Meeting the growing consumer demand of society necessitates the efficient use of land resources (Zaliubovska et al., 2023). As a result of rapid population growth, settlement, industrial development (Chen et al., 2022), improper construction of irrigation systems, and overgrazing, part of the useful land is subjected to degradation (Jingzhe et al., 2023). This leads to a decrease in the share of land per capita and the emergence of land scarcity (Afroz, 2014). In addition to anthropogenic factors, natural factors (Hetman, 2024) - historical-geological periods, global warming, and freshwater scarcity - also lead to a decrease in useful land areas (Hummatov et al., 2025).

Every year, as a result of the negative impact of natural and anthropogenic factors, lands become unusable and are removed from production (Batista et al., 2019). If land resources are not used efficiently (Chen et al., 2021), the future provision of people with agricultural products will be in question.

One of the important conditions for the efficient use of lands is to study the negative impacts on them and take timely measures (Akinyemi et al., 2021). For this, there is a great need for a comprehensive study of the lands of the area (Ni et al., 2023). In this regard, our research is devoted to a topical topic.

As a result of his research, S.A. Zakharov wrote the work “Lands of the Nakhchivan ASSR”. Subsequent research was conducted with reference to this work.

Later, at different times, A.G.Zeynalov (1988), H.A.Aliyev (1988), R.H.Mammadov (1963), Z.R.Bayramov (1964-1968), C.H.Maharramov (1966-1969), G.Sh.Mammadov (1988-1992), S.A.Hajiyev (1985-2006), A.G.Guliyev (1974-2001) were engaged in soil surveys.

In 2010, S.A. Hajiyev prepared a soil map of the Nakhchivan Autonomous Republic on a scale of 1:150,000 using the plastic method, taking into account the relief structure of the territory. As a recent research work and at the same time a more concise classification, it is more appropriate to give the soil types of the autonomous republic territory according to the division of H. Aliyev and A. Zeynalov. According to the given classification, 5 soil types and 14 sub-types are distinguished in the mountainous part, and 5 types and 16 sub-types in the plain zone. A broad characteristic of the soil types within each part is given.

The Nakhchivan Autonomous Republic is an integral part of the Republic of Azerbaijan, and its relief consists of plain and mountainous parts. The closest point of the territory to sea level is the bed of the Araz River (Hajiyeva et al., 2024) near the village of Kotam (600 m), and the highest point is Mount Gapijig (3904 m). The average height above sea level is 1400 m 1/3 of the territory is located at an average height of up to 800 meters, 2/3 at an altitude of 1000-2000 m, and 20 percent is located above 2000 m.

The area along Araz River is the largest plain and is located between 600-1200 m altitude (Seyidova, 2021, Seyidova et al. 2024) This zone is divided by ridges and elevations into plains such as Sadarak, Sharur, Boyukduz, Nakhchivan, Ordubad, etc.

Investigation of biotic and abiotic components based on Remote sensing is actual in modern time (Amanova et al., 2024).

Materials and methods. There are different approaches to assessing and mapping soil degradation. Some researchers have classified soil degradation into degrees by evaluating its development (T.G.Boychiyev, 1982; N.G.Kharin, 1985)

T.G.Boychiyev (1982) divided the causes of soil degradation in arid and semiarid climatic conditions in Bulgaria into two groups: The first group includes water and wind erosion, salinization and degradation of vegetation. The second group includes the reduction of organic matter in the soil, its hardening, compaction, and the accumulation of substances harmful to plants and animals, and took them into account in the preparation of degradation maps.

N.G.Kharin (1985) used satellite images to compile a soil degradation map in Turkmenistan and divided the degradation into four classes - weak, moderate, severe and very severe. He indicated vegetation degradation as the main reason. He evaluated the indicators of wind and water erosion as the second factor.

The research results were evaluated using the methodology of T.G.Boychiyev and N.G.Kharin in assessing soil degradation in agrolandscapes along the Araz River.

The research work we conducted was carried out in 3 stages. In the first stage of the study, the area where field work would be conducted was familiarized, cartographic materials and routes were selected, the purpose of the study was determined, in the second stage, field work was carried out, and in the third stage, the results of the study were analyzed in field and laboratory conditions.

The materials of the research conducted in the area by S.A. Zakharov, A.G.

Zeynalov, R.H. Mammadov, G.Sh. Mammadov, S.A. Hajiyev, A.G. Guliyev were used.

Soil and plant samples taken for analysis were performed in the laboratory "Soil and Plant Analyses" of the Scientific Research Institute of Crop Husbandry of the Ministry of Agriculture of the Republic of Azerbaijan in field and laboratory conditions. Soil analyses were performed using the following methods: humus according to I.V. Tyurin; reaction of the medium in water suspension – with a pH meter; carbonation ($CaCO_3$) - by the Scheibler method using a calcimeter; total nitrogen – by the Keldahl method; mobile phosphorus (P_2O_5) - according to B.P. Machigin; exchangeable potassium (K_2O) - according to P.V. Protasov; dry residue and chlorine (Cl-) - by titration with silver nitrate ($AgNO_3$); The results were obtained by precipitating sulfate ion (SO_4^{2-}) with barium sulfate reagent ($BaSO_4$). The results of field experiments, calculation of productivity, and accuracy of determination were checked using mathematical and statistical methods.

The coordinates of the areas where soil samples were taken were determined using GPS and the study area was mapped using ArcGIS 10.3 software.

Results. *The object of the study* is the plains along Araz River, which are most exposed to anthropogenic impacts. That is, since the plains along Araz River are the most exposed area of the territory to degradation and are widely distributed in terms of the diversity of anthropogenic factors, it is planned to conduct more detailed studies mainly on plain soils. Experimental areas have been allocated for conducting research at the facility. The research areas we have selected are the gray, primitive gray, gray-meadow, and swamp soils of the plain semi-desert zone of the Nakhchivan Autonomous Republic, which are saline, swampy, and eroded, with typical signs of degradation. These soils cover more than 36% of the total area, most of which are gray soils.

*Selected experimental areas***.** Experimental sites were selected in 3 different areas that are most exposed to anthropogenic impacts in the agrolandscapes along the Araz River. The areas where soil surveys were conducted using modern technology were mapped (Figure 1).

The first experimental area is a 20-hectare land plot located in the northeast of the Nakhchivan sloping plain, 6.4 km north of the shore of the "Araz water junction", in the territory of the Nehram municipality of the Babek region. The experimental area is located at 39°13' north latitude and 45°48' east longitude. The Nakhchivan plain is surrounded by the Jahri-Duzdagh ridge from the west, the Araz River from the southwest, the Nehram-Araz elevation from the southeast, and the foothills of the Sirab, Nahajir, and Khachaparag mountains from the northeast, forming the largest part of the Araz plains (Isgandarova, 2022; Isgandarova et al., 2025). The plain is composed of calcareous sandstones, calcareous, sandstone and silty clays, and marls from the Jurassic and Cretaceous periods.

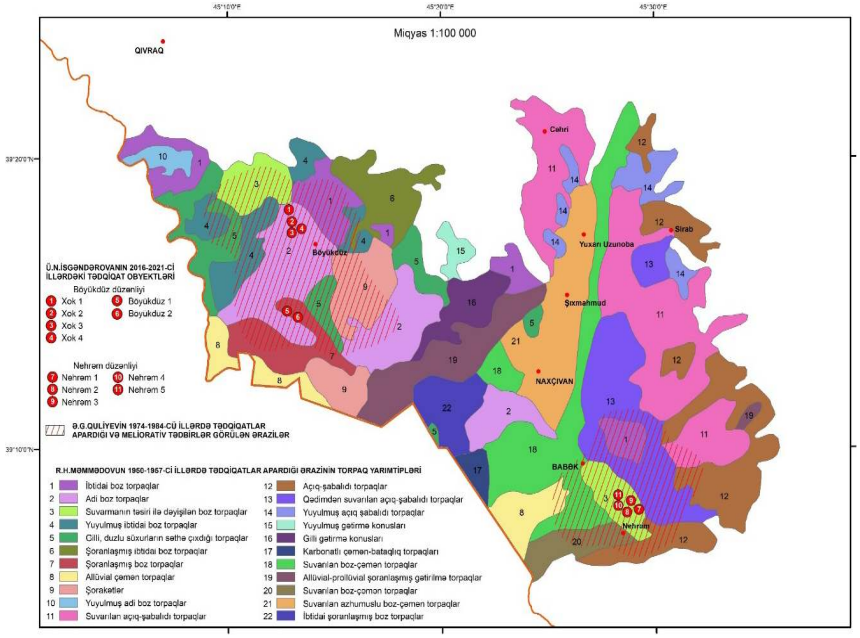

Figure 1. Map of research areas in the plains along Araz River of the Nakhchivan Autonomous Republic.

The base of the Nakhchivan depression is composed of thick saline sedimentary layers of the Miocene and Oligocene, and the surface is covered with alluvial-prolluvial sediments of the Quaternary period. The annual number of sunny hours here is 2500-2800 hours, and the amount of solar radiation is 145-150 kcal/cm^2. The average annual temperature varies between 12-14 degrees, the average annual precipitation is 250 mm, and the possible evaporation is 1200-1400 mm. The groundwater level varies from 10 m to 1 m starting from the foothill plains towards the Araz River. The highest salinity is in the southeastern and southwestern parts of the plain. Light chestnut, gray-brown, light gray, meadow-gray soils are widespread in the study area, where the summer is dry and semi-desert and dry steppe climate type prevails. Ephemeral plants have developed in the semi-desert landscape under dry climatic conditions.

The second experimental site is a 10-hectare plot of land located between 39°30’ north latitude and 45°20’ east longitude in the southeast of the Boyukduz sloping plain in the territory of the Khok municipality of the Kangarli district.

The third experimental site was selected on a 5-hectare plot located between 39°24’ north latitude and 45°21’ east longitude in the south of the Boyukduz sloping plain in the territory of the Boyukduz municipality of the Kangarli district, 2.5 km north of the “Araz water junction”.

The second and third experimental areas are on the Boyukduz inclined plain. The experimental area is located at an absolute altitude of 860 meters. The

Boyukduz plain is bordered by the low hills of the Duzdag ridge to the east, the Kangarli ridge to the west, the Süst inclined plain with an absolute altitude of 900 meters to the north, and the Araz River to the south. It extends from north to south for 19-20 km, and its average width is 10 km. Alluvial-proluvial deposits of the upper part of the Quaternary period: siltstone, sand, clay, siltstone, sand; alluvial deposits of the middle part: shale, gravel, pebble, sand; gypsum-salt sandstones of the Middle Miocene: siltstone, clay and conglomerates are widespread in the Boyukduz plain.

The Boyukduz Plain, where the experimental area is located, is located on a poorly dissected foothill sloping plain formed by a thick alluvial-proluvial cover of the Upper Pleistocene, on deformed sedimentary rocks of the Pliocene and Pleistocene. The annual number of sunny hours in the Boyukduz Plain, located in a semi-desert dry-steppe climate type, is 2500-2800 hours, and the amount of total solar radiation is 145-150 kcal/cm^2. The amount of atmospheric precipitation is less than 250 mm. It is the driest area of the autonomous republic. Possible evaporation is approximately 3 times more than atmospheric precipitation. Gray, light gray, medium humus gray in the west of the plain, stony-gravelly gray in the eastern part, saline gray in the areas near the Araz River, saline, gray-meadow and sandy soils are widespread in the Boyukduz Plain. Here, in the areas near the Araz, sedge, reed, sedge, saltwort, and wormwood are widespread, and cereals are widespread in the transition zone to the Süst slope plain. The semi-desert landscape dominates the plain, and a desert landscape with glades is also found.

As a result of stationary observations conducted in all three experimental areas during 2014-2021, the soil type, plants planted in the observation objects during the study period and their productivity, irrigation method, source of irrigation water supplied to the area, soil care, and the current status of collector-drainage networks in the area were studied. During field studies, the exact geographical coordinates of the places where soil samples were taken from the experimental areas were determined. Soil samples were taken from different depths in characteristic areas located 100 meters apart in each study area. Agrochemical analysis of the soil samples taken was carried out in order to assess the current reclamation status of the study area.

Characteristic features of the soils of the study area. In order to characterize the soils of the study area, soil samples were taken from a total of 11 characteristic points in the anciently irrigated gray soils of Nehram municipality in the northeast of the Nakhchivan plain, gray soils of Khok municipality in the southeast of the Boyukduz plain, and saline gray soils in the south of the Boyukduz plain, 2 km north of the “Araz water junction”, and the results were analyzed.

The main components and water content analysis indicators of soil samples taken from the Nehram municipality of the Nakhchivan inclined plain, which we chose as the first research object, are given in the table below (Table 2).

Table 2. Main components and water content analysis results of irrigated gray soils of Nehram municipality.

Section No.	Depth, in cm	pH in water		CaCO$_3$ %		Organic carbon, %		Total humus %		Total Nitrogen, %		Mobile phosphorus (P_2O_5), mg in 1 kg of soil		Exchange-able potassium (K_2O), mg in 1 kg of soil		Amount of harmful salts (dry residue) (in %)		Chlorine (Cl) ion In %		Bicarbonate ion (HCO_3) in %		Sulfate ($SO4^{-2}$) ion, in %	
		Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.
Nehram Sample 1 (N_1)	**0-25**	7,96	7,93	13,15	12,53	0,804	0,817	1,387	1,41	0,117	0,110	5,2	5,5	434	429	0,241	0,210	-	-	0,038	0,038	0,092	0,102
		7,91		11,92		0,830		1,431		0,104		5,8		425		0,180		-		0,038		0,112	
	25-50	7,98	7,91	12,55	12,52	0,402	0,383	0,694	0,66	0,053	0,048	4,4	4,7	256	252	0,220	0,222	0,036	0,036	0,032	0,035	0,091	0,092
		7,85		12,50		0,364		0,628		0,044		5,1		249		0,224		0,036		0,038		0,073	
	50-75	7,91	7,87	13,24	13,08	0,182	0,201	0,314	0,35	0,031	0,028	4,3	4,3	140	135	0,228	0,209	0,044	0,040	0,038	0,035	0,074	0,067
		7,83		12,92		0,221		0,381		0,026		4,3		131		0,190		0,036		0,032		0,061	
Nehram Sample 2 (N_2)	**0-25**	7,84	7,79	13,32	13,63	0,722	0,715	1,245	1,23	0,094	0,098	6,7	6,4	252	249	0,647	0,642	0,044	0,048	0,032	0,032	0,364	0,356
		7,74		13,95		0,708		1,222		0,102		6,2		247		0,638		0,053		0,032		0,349	
	25-50	7,67	7,74	12,33	12,74	0,540	0,523	0,931	0,90	0,073	0,068	5,1	4,9	220	219	1,240	1,210	0,036	0,036	0,018	0,021	0,774	0,763
		7,81		13,15		0,506		0,873		0,064		4,8		218		1,180		0,036		0,025		0,752	
	50-75	7,66	7,70	12,49	12,92	0,379	0,380	0,654	0,66	0,046	0,048	5,0	4,7	201	203	1,038	1,048	0,027	0,022	0,028	0,027	0,649	0,658
		7,74		13,35		0,382		0,659		0,051		4,4		205		1,059		0,018		0,025		0,668	
Nehram Sample3 (N_3)	**0-25**	7,81	7,80	12,33	12,13	0,992	1,016	1,711	1,74	0,137	0,129	8,5	8,3	558	550	0,337	0,344	0,022	0,023	0,032	0,028	0,195	0,187
		7,79		11,92		1,033		1,780		0,122		8,2		543		0,351		0,025		0,025		0,179	
	25-50	7,86	7,82	13,15	13,25	0,607	0,617	1,047	1,06	0,077	0,079	5,4	5,3	414	415	1,088	1,071	0,018	0,018	0,025	0,028	0,676	0,684
		7,78		13,35		0,628		1,082		0,082		5,3		417		1,055		0,018		0,032		0,693	
	50-75	7,74	7,78	12,50	12,80	0,607	0,613	1,047	1,06	0,079	0,079	4,9	4,8	407	414	1,217	1,200	0,027	0,027	0,025	0,023	0,778	0,766

Rep.-repetition, ave.- average

Continuation of Table 2

Section No.	Depth, in cm	pH in water		$CaCO_3$ %		Organic carbon, %		Total humus %		Total Nitrogen, %		Mobile phosphorus (P_2O_5) mg in 1 kg of soil		Exchange-able potassium (K_2O) mg in 1 kg of soil		Amount of harmful salts (dry residue) (in %)		Chlorine (Cl) ion In %		Bicarbonate ion (HCO_3) in %		Sulfate ($SO4^{-2}$) ion, in %	
		Rep.	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**orta**	**təkrar**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**
Nehram Sample 4 (N_4)	**0-25**	7,71	7,67	12,33	12,71	0,787	0,778	1,357	1,34	0,083	0,079	8,0	8,1	598	596	0,560	0,554	0,027	0,027	0,022	0,022	0,321	0,333
		7,64		13,10		0,769		1,327		0,076		8,3		594		0,548		0,027		0,022		0,346	
	25-50	7,65	7,68	12,33	11,99	0,546	0,536	0,941	0,92	0,071	0,068	6,6	6,3	436	431	1,057	1,062	0,036	0,036	0,025	0,023	0,672	0,661
		7,72		11,65		0,526		0,908		0,066		6,1		427		1,067		0,036		0,022		0,651	
	50-75	8,08	8,13	13,45	12,97	0,425	0,415	0,733	0,71	0,057	0,053	5,5	5,5	400	398	1,410	1,397	0,044	0,040	0,025	0,021	0,859	0,867
		8,18		12,50		0,405		0,698		0,049		5,5		396		1,384		0,036		0,018		0,876	
Nehram Sample 5 (N_5)	**0-25**	7,98	7,92	12,75	13,03	0,709	0,708	1,222	1,22	0,941	0,093	6,1	6,0	373	374	0,290	0,281	0,027	0,027	0,034	0,029	0,138	0,144
		7,87		13,32		0,708		1,219		0,919		5,9		375		0,273		0,027		0,025		0,151	
	25-50	7,64	7,68	12,85	12,17	0,579	0,559	0,999	0,96	0,063	0,067	4,6	4,7	261	260	0,305	0,305	0,062	0,057	0,025	0,023	0,143	0,136
		7,73		11,10		0,540		0,932		0,072		4,8		259		0,306		0,053		0,022		0,129	
	50-75	7,74	7,77	12,76	13,13	0,402	0,381	0,694	0,65	0,051	0,047	4,6	4,6	256	258	0,618	0,574	0,062	0,057	0,025	0,025	0,307	0,318
		7,81		13,51		0,360		0,620		0,043		4,6		261		0,531		0,053		0,025		0,329	

Rep.-repetition, ave.- average

Based on total humus content, the area is classified into two distinct groups: in samples N_1, N_2, N_4, and N_5, the topsoil layer (0–25 cm) contains 1.22–1.44% humus (low quality), whereas sample N3 exhibits a higher average of 1.74% (moderate quality). Humus levels exhibit a typical decrease along the soil profile with increasing depth (25–50 cm and 50–75 cm).

Mobile phosphorus (P_2O_5) availability in the 0–25 cm layer ranges from 5.5 to 8.3 mg/kg, indicating a severe phosphorus deficiency (< 10 mg/kg). Conversely, exchangeable potassium (K_2O) supply varies by location: moderate in N_2 (249 mg/kg), good in N_5 (374 mg/kg), high in N_1 (422 mg/kg), and very high in N_3–N_4 (550–596 mg/kg).

Toxic salt content in the upper horizon (0–25 cm) fluctuates between 0.210% and 0.642%; since sulfate salts predominate, this layer remains non-saline across all sites. Samples N_1 and N_5 show no salinization throughout the entire profile (0–75 cm). However, in samples N_2–N_4, harmful salt concentrations increase to 1.048–1.397% at depths of 25–50 cm and 50–75 cm, characterizing these subsoil layers as moderately saline with sulfate-type salinization. Overall, the soils represented by samples N_1–N_5 are fully suitable for cereal crop cultivation (Table 3).

In the studied soil samples (X_1–X_4), the pH ranges from 7.41 to 8.26 across depths and sampling sites, indicating slightly alkaline conditions. Based on calcium carbonate ($CaCO_3$) content, the soils are categorized into three groups: weakly carbonated in X_1 (3.91–4.43%), moderately carbonated in one group (13.40–14.83%), and highly carbonated in another (16.43–23.43%).

The total humus content in the topsoil (0–25 cm) varies between 0.17% and 1.46%, classifying the area into two fertility groups. Samples X_2 and X_4 exhibit low soil quality with 1.19–1.46% humus, whereas X_1 (0.17%) and X_3 (0.70%) are of very poor quality. The virtually absent humus content in X_1 reflects severe degradation associated with high salinity.

Mobile phosphorus (P_2O_5) availability across all sites (0–25 cm) is critically low, ranging from 4.7 to 6.6 mg/kg (< 10 mg/kg). Conversely, exchangeable potassium (K_2O) supply splits into two distinct levels: low in X_1 (187 mg/kg) and very high in X_2–X_4 (502–613 mg/kg).

The research sites exhibit sharp contrasts in salinization levels. Profile X_1 is strongly saline throughout, with toxic salts (dry residue) ranging between 2.578% and 2.858% (chloride-sulfate type). In contrast, the topsoil (0–25 cm) of X_2–X_4 remains non-saline (0.210–0.339%). Entire profile of X_4 (0–75 cm) shows no salinization (0.212–0.274%), whereas X_2 experiences severe chloride-sulfate salinization in the subsoil layers (25–50 and 50–75 cm), reaching 1.441–1.482%.

The results of laboratory analysis of soil samples taken from the third research object are given in Table 4.

Across depths and sampling locations, the soil pH in samples B1–B2 ranges from 7.67 to 7.81, indicating a weakly alkaline medium. The average calcium carbonate ($CaCO_3$) content varies between 18.28% and 20.57%, classifying the area as highly carbonated.

The soils exhibit very low overall fertility and quality: the topsoil (0–25 cm) total humus content is only 0.65–0.75% ($< 1.0\%$) and decreases progressively with depth. Similarly, total nitrogen in the upper layer is critically low at 0.050–0.062%.

Nutrient analysis reveals severe mobile phosphorus (P_2O_5) deficiency in the 0–25 cm horizon (7.6–9.6 mg/kg). Conversely, the exchangeable potassium (K_2O) supply in the topsoil is very high, ranging from 521 to 529 mg/kg.

Regarding salinity, most profile layers (0–25 cm, 25–50 cm, and 50–75 cm, excluding B1 at 50–75 cm) remain non-saline, with dry residue (toxic salts) varying between 0.125% and 0.249%. However, the subsoil layer (50–75 cm) of sample B1 exhibits moderate sulfate-type salinization, with total harmful salts averaging 1.025% (1.022–1.027%).

Table 3. Main components and water content analysis results of the light gray soil type of Khok municipality.

Section No.	Depth, in cm	pH in water		$CaCO_3$ %		Organic carbon, %		Total humus %		Total Nitrogen, %		Mobile phosphorus (P_2O_5) mg in 1 kg of soil		Exchange-able potassium (K_2O) mg in 1 kg of soil		Amount of harmful salts (dry residue) (in %)		Chlorine (Cl) ion In %		Bicarbonate ion (HCO_3) in %		Sulfate ($SO4^{-2}$) ion, in %	
		Rep.	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**	**Rep.**	**Ave.**
Khok Sample 1 (X_1)	**0-25**	7,87		4,75		0,101		0,174		0,015		4,6		190		2,875		0,941		0,016		1,015	
		7,81	7,84	4,11	4,43	0,101	0,101	0,175	0,17	0,014	0,014	4,8	4,7	185	187	2,841	2,858	0,918	0,929	0,018	0,017	1,031	1,023
	25-50	8,34		3,72		0,095		0,176		0,017		4,5		139		2,578		0,739		0,013		0,972	
		8,15	8,24	4,52	4,12	0,100	0,097	0,170	0,17	0,012	0,014	4,4	4,4	142	140	2,559	2,578	0,730	0,734	0,009	0,011	0,998	0,985
	50-75	8,32		3,72		0,089		0,172		0,013		3,4		135		2,778		0,623		0,013		1,227	
		8,21	8,26	4,11	3,91	0,098	0,094	0,173	0,17	0,012	0,012	4,7	4,0	140	137	2,759	2,768	0,615	0,623	0,016	0,014	1,206	1,222
Khok Sample 2 (X_2)	**0-25**	8,00		15,85		0,687		1,185		0,095		6,4		621		0,345		0,062		0,025		0,151	
		7,76	7,88	17,12	16,43	0,698	0,692	1,203	1,19	0,107	0,101	6,8	6,6	605	613	0,333	0,339	0,053	0,057	0,018	0,021	0,167	0,159
	25-50	7,51		19,07		0,378		0,652		0,053		5,2		444		1,444		0,125		0,016		0,841	
		7,31	7,41	18,49	18,78	0,378	0,378	0,652	0,65	0,048	0,050	5,4	5,3	429	436	1,439	1,441	0,134	0,129	0,018	0,017	0,818	0,829
	50-75	7,57		16,85		0,404		0,697		0,055		5,3		445		1,472		0,232		0,022		0,828	
		7,37	7,47	17,09	16,97	0,352	0,378	0,607	0,65	0,046	0,050	4,9	5,1	426	435	1,492	1,482	0,223	0,227	0,018	0,020	0,855	0,841
Khok Sample 3 (X_3)	**0-25**	7,90		13,96		0,404		0,697		0,058		5,8		496		0,214		0,036		0,022		0,098	
		7,82	7,86	12,85	13,40	0,404	0,404	0,697	0,70	0,065	0,061	6,5	6,1	507	502	0,207	0,210	0,027	0,032	0,028	0,025	0,083	0,090
	25-50	7,61		13,56		0,242		0,417		0,033		5,1		434		0,577		0,027		0,022		0,342	
		7,52	7,56	14,05	13,80	0,242	0,242	0,417	0,42	0,036	0,034	4,7	4,9	441	437	0,504	0,540	0,027	0,027	0,018	0,020	0,324	0,333
	50-75	7,36		15,28		0,243		0,419		0,032		5,2		421		0,522		0,018		0,022		0,308	
		7,62	7,49	14,38	14,83	0,211	0,227	0,384	0,40	0,033	0,032	4,4	4,8	436	428	0,532	0,527	0,018	0,018	0,025	0,023	0,337	0,322
Khok Sample 4 (X_4)	**0-25**	7,61		20,21		0,850		1,464		0,124		5,9		562		0,286		0,036		0,044		0,125	
		7,58	7,59	19,80	20,20	0,850	0,850	1,464	1,46	0,118	0,121	6,6	6,2	571	566	0,262	0,274	0,027	0,031	0,032	0,038	0,106	0,115
	25-50	7,49		21,24		0,242		0,417		0,031		4,5		299		0,207		0,044		0,032		0,078	
		7,62	7,55	23,63	22,43	0,242	0,242	0,417	0,42	0,038	0,034	4,1	4,3	286	292	0,185	0,196	0,044	0,044	0,028	0,030	0,056	0,067
	50-75	7,80		23,01		0,182		0,314		0,028		4,2		287		0,234		0,009		0,025		0,093	
		7,77	7,78	23,35	23,18	0,209	0,195	0,362	0,34	0,021	0,024	3,7	3,9	294	290	0,224	0,229	0,009	0,009	0,018	0,021	0,087	0,090

Rep.-repetition, ave.- average

Table 4. Main components and water content analysis results of light-gray soils of Boyukduz municipality.

Section No.	Depth, in cm	pH in water		$CaCO_3$ %		Organic carbon, %		Total humus %		Total Nitrogen, %		Mobile phosphorus (P_2O_5) mg in 1 kg of soil		Exchangeable potassium (K_2O) mg in 1 kg of soil		Amount of harmful salts (dry residue) (in %)		Chlorine (Cl) ion In %		Bicarbonate ion (HCO_3) in %		Sulfate ($SO4^{-2}$) ion, in %	
		Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.	Rep.	Ave.
Boyukduz Sample 1, (B_1)	**0-25**	7,66	7,69	19,72	16,64	0,467	0,435	0,805	0,75	0,058	0,062	9,3	9,6	538	529	0,176	0,157	0,027	0,022	0,041	0,033	0,058	0,050
		7,73		19,56		0,404		0,697		0,067		9,9		521		0,139		0,018		0,025		0,043	
	25-50	7,78	7,79	19,08	18,71	0,358	0,363	0,618	0,63	0,053	0,049	7,3	7,4	429	428	0,118	0,125	0,044	0,040	0,022	0,023	0,029	0,023
		7,81		18,35		0,368		0,634		0,046		7,5		427		0,131		0,036		0,025		0,018	
	50-75	7,80	7,78	19,72	19,84	0,179	0,179	0,308	0,31	0,028	0,025	4,8	4,8	277	273	1,022	1,025	0,027	0,027	0,022	0,023	0,658	0,650
		7,76		19,96		0,179		0,308		0,023		4,9		269		1,027		0,027		0,025		0,642	
Boyukduz Sample 2, (B_2)	**0-25**	7,80	7,81	20,37	20,57	0,375	0,379	0,645	0,65	0,052	0,050	6,8	7,6	525	521	0,189	0,216	0,089	0,089	0,028	0,025	0,039	0,037
		7,82		20,78		0,384		0,662		0,049		7,1		517		0,243		0,089		0,022		0,035	
	25-50	7,70	7,72	18,49	18,28	0,338	0,338	0,583	0,58	0,047	0,045	5,7	5,9	331	328	0,223	0,235	0,089	0,089	0,028	0,026	0,055	0,046
		7,75		18,07		0,338		0,583		0,043		6,1		325		0,247		0,089		0,025		0,038	
	50-75	7,64	7,67	19,72	19,51	0,279	0,280	0,481	0,48	0,039	0,035	5,8	5,9	318	320	0,275	0,249	0,116	0,111	0,028	0,025	0,041	0,035
		7,68		19,31		0,282		0,487		0,032		6,0		323		0,223		0,107		0,022		0,029	

Rep.-repetition, ave.- average

Conclusion. In general, it is clear from the analysis of the results of the analysis that the upper layers of the soil (0-25 cm) in the Nehram experimental-observation site are poorly supplied with nutrients, and salinization is moderate in the lower layers (25-75 cm). In order to increase the productivity of the soil in this research object, it is necessary to use organic and mineral fertilizers and apply a crop rotation system. In order to prevent re-salination in the research area, the collector-drainage network should be reconstructed, the filled irrigation canals should be cleaned, and the irrigation regime should be strictly observed. As a result of the analysis conducted in the Khok experimental area, it was found that these soils are poorly supplied with nutrients and the amount of harmful salts is increasing towards the lower layers (25-75 cm). In this experimental area, it is possible to prevent re-salination by using organic and mineral fertilizers to restore soil fertility, and by applying an excess irrigation rate (25-30%) to direct harmful salts to the lower layers. At the same time, it is more appropriate to use drip irrigation and sprinkling methods for irrigation here.

The results obtained from the Boyukduz experimental site showed that these soils are very poorly supplied with humus and nutrients, and the area has been subjected to moderate salinization, with a high content of harmful salts at a depth of 50-75 cm of the soil. The increase in the content of harmful salts in the lower layers of the soil creates the basis for repeated salinization in these areas in the future. In order to prevent possible repeated salinization in the experimental site, it is necessary to restore the collector-drainage networks that have been filled or broken due to neglect, strictly follow the irrigation norms, and apply the spraying method.

The results of soil analysis conducted at all three experimental sites are a valuable source for future research.

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