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MODERN SOIL COVER OF NATURAL CENOSES AND AGROSENOSES LANDSCAPES OF THE KUR-ARAZ PLAIN

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Abstract. The article presents results of soil-ecological studies conducted in 2023-2024 on the soils of the Kur-Araz plain. Relationship between carbonic anhydrase activity and electron transport (correlation coefficient 0.87), carbonic anhydrase activity and lipid peroxidation (correlation coefficient 0.88), electron transport and hydrogen peroxide accumulation (correlation coefficient 0.65). The correlation between water content and the value of the osmotic potential is negative (-0.77). Most Cl salts in the incoming water predominate, which leads to oversaturation and poisoning of plants. Hydrotechnical and phytomeliorative measures are necessary at the Main Shirvan Collector. The possibility of using the cluster analysis method to assess the specificity of biochemical adaptation of plants to different types of environmental salinization is shown. In article, for the first time, a cluster analysis of the results of a study of the performance of the antioxidant system of *Triticosecale* sprouts in response to short-term stress caused by the presence of sodium chloride in the medium at a concentration of 119 mM was carried out. The aboveground phytomass varies from 0.02 kg/m^2 in the most arid conditions under desertified steppe with low projective cover: 10-30% to 0.144 kg/m^2; in the most typical conditions under steppe with projective cover of 40%, the aboveground phytomass is 0.040 kg/m.

Keywords: *Vegetation, salinization, cluster analysis, agrobiocenoses, phytomass, landscapes.*

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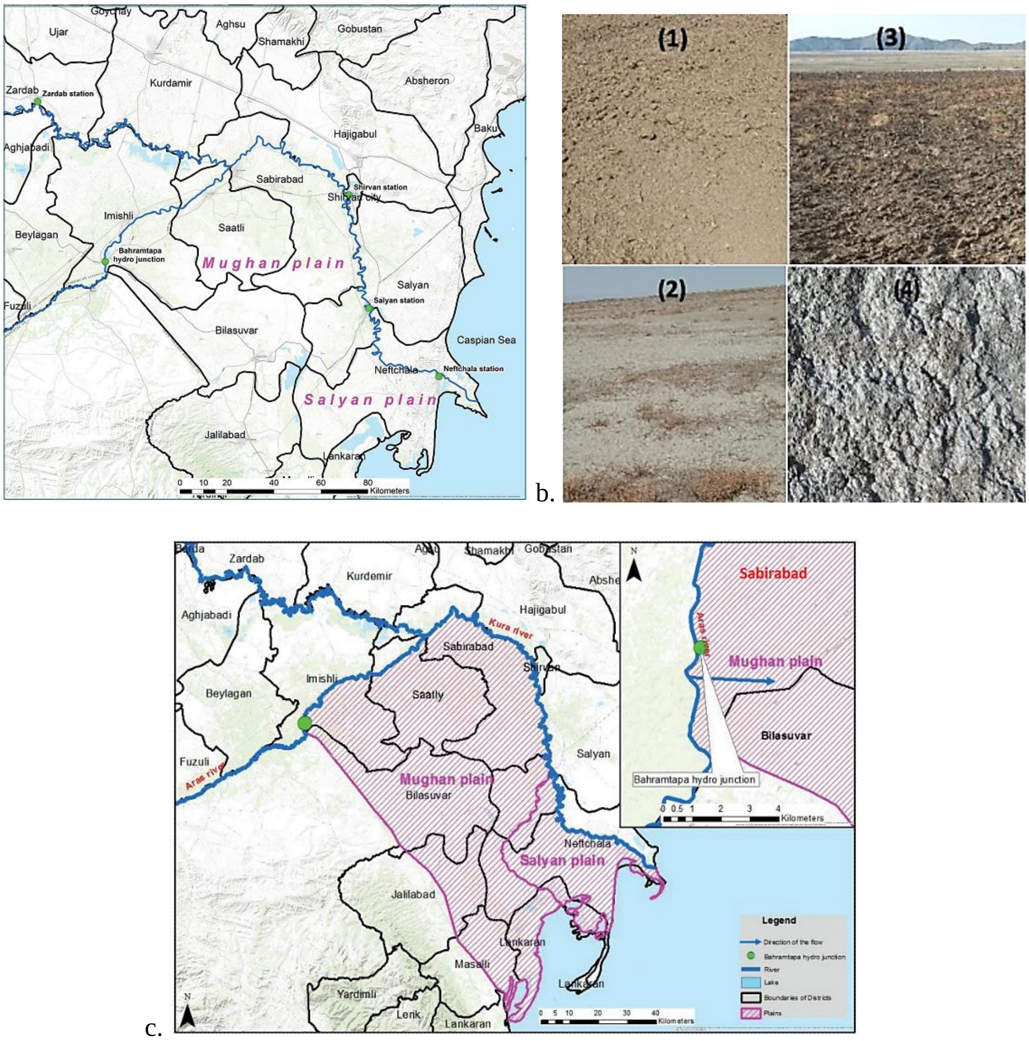
1. Introduction

Washed-out soils are formed as a result of the violation of the rational ratio of land types and agricultural technology during the economic use of erosion-hazardous territories. A characteristic feature of washed-out soils is the complete or partial destruction of the upper horizons, as a result of which the middle horizon or the transitional horizon to the soil-forming (underlying) rock, which has been preserved to one degree or another, comes to the surface (Blanco, 2023; Babaev *et al.*, 2015).

Salinization is influenced by various environmental factors and linear regression methods may not provide accurate predictions, especially in areas with high temporal and spatial variations in soil salinity. Soil salinization is one of the natural phenomena that occurs for a number of reasons. Primary salinization is determined by the presence of excess of different salts, which is caused by geological reasons and uneven distribution of substances on the surface and underlying soil horizons (Chen *et al*., 2021; Corwin, 2021). The change in the degree of salinization is determined by many factors, among which are the unevenness of the processes of water supply to soils and water evaporation due to different properties of the soil itself. Temperature conditions do not play a significant role in this process. At the same time, global climate change contributes to the aggravation of this problem (Clay *et al*., 2024; Chaves *et al*., 2020). The problem would not be so important if it were not related to the production of agricultural crops that provide the world's population and farm animals with food (Gee & Bauder, 1986). As a result, the problem of secondary soil salinization associated with human activity arises. At the same time, the area of saline lands can reach 20 percent or more of agricultural land and in some regions of Azerbaijan, this may account for up to 45 percent of cultivated land.

a. b.



c.

Figure 1. a. Sabirabad region b. Research area

Note: b. (1) and (2) natural cenoses; (3) and (4) saline soils near collector

Source: By authors in 12 May 2024 year

Natural salinization of territories, which is largely facilitated by unfavorable global climate change, leads to a decrease in the productivity of biocenoses and their biodiversity (Che *et al*., 2022). As a result, one of the pressing environmental problems of our time arises - a constant increase in the areas of saline soils. This significantly affects the productivity of agrobiocenoses, resulting in large economic costs (Goovaerts, 2023). All this makes it necessary to analyze the state of the problem and determine the directions of modern research related to the study of the influence of this factor on plants. The following cycles of salt accumulation leading to the formation of saline soils are distinguished: continental cycles associated with the movement, redistribution and accumulation of carbonates, sulfates, chlorides, nitrates, alkalis and alkaline earths on vast continental plains, depressions and lowlands; coastal cycles associated with the accumulation of sea salts on coastal plains, along low tidal shores, shallow bays, lagoons and isolated coastal lakes; deltaic cycles are characterized by a complex combination of the transfer and deposition of salts brought from the continent by rivers and valley-delta groundwater; artesian cycles are associated with the release of ascending salt solutions to the surface along tectonic cracks and faults; anthropogenic cycles are associated with irrational human activity.

Saline soils are constantly and heavily moistened with salt water. In summer, a salt crust often forms on the surface of soils (Hasanova *et al*., 2021a). Saline soils are not saline on the surface, the upper layer is leached, structure less. The lower horizons are compacted and saturated with sodium ions. Saline soils are formed when salts are washed out. From a chemical point of view, the type of salinity can be determined by the content of anions in the soil and most often the following are distinguished: Cl^-, O_4S^{-2}, ClO_4S^{-3} and CO_3^{-2} (Didehban *et al*., 2025).

The most dangerous for plants is salinity caused by excess sodium carbonate, since in the presence of water in the soil this salt undergoes partial hydrolysis, forming a slightly alkaline environment, which is an additional stress factor for plants (Hassani *et al*., 2021). All the salts listed above are highly soluble in water, so that in a humid climate they are usually washed out of the soil by precipitation and remain in it in negligible quantities. In a dry or hot climate, not only does the soil not get washed out by rain, but, on the contrary, the salt solutions rise with the ascending current of soil water from the depths of the substrate. The water evaporates and the salts remain in the upper layers of the soil. Technogenic salinization is often caused by the introduction of compounds containing sodium and chlorine ions (Khan *et al*., 2005). Such pollutants include emissions from industrial enterprises, as well as multi-component mixtures of exhaust gases. Also, technogenic causes of soil salinization include the introduction of various salts contained in the salt-sand mixture of some anti-icing agents (Kazeev *et al*., 2012). The situation in the city is aggravated by the entry of heavy metals with emissions from vehicles, as well as industrial enterprises. In the Sabirabad region, saline soils are formed mainly due to high levels of anthropogenic pollution. Exceeding the maximum permissible concentration of sulfates and carbonates in the soils of the Kura-Araz plain was found. It may well be associated with the introduction of salts by groundwater with a high content of calcium salts such as sulfates and carbonates. The presence of these ions is associated with the presence of gypsum and limestone deposits in these areas.

The negative impact of excess salts in the soil on various biological objects is caused by high osmotic pressure, alkaline reaction of the environment, toxic action of easily soluble salts, as well as unfavorable water-physical properties of the soil due to deterioration of water permeability due to an increase in the content of physical clay, as well as an increase in the mineralization of organic matter. In such soils, the level of potential fertility decreases and the availability of macro- and microelements for plants decreases (Moreau *et al*., 2019).

These factors lead to mineral starvation of plants, which leads to their increased susceptibility to pathogens and pests and as a consequence, to a decrease in survival. This determines the relevance and importance of studying the problem of soil salinization and the impact of this factor on the growth and development of plants (Moussa *et al*., 2020). Excessive concentration of salts also acts as toxic substances, disrupting nitrogen metabolism and promoting accumulation of protein breakdown products. Among the features of absorption of chemical elements by plants, it is possible to note the predominance of this function in the root system, as a result of which it plays the main role in sorting ions entering the plant due to mechanisms of absorption of necessary and release of toxic elements (Husein *et al*., 2021). This is due to the work of antiporters and pumps. Such mechanisms allow resistant plants to maintain cytosolic concentration of sodium ions approximately 10 times lower than that observed in unstable varieties. An important role in the processes of plant resistance also belongs to the redistribution of ions within the organism, which is achieved with the help of special mechanisms for their accumulation in vacuoles or release outside the cells. The influence of salts significantly affects the biochemical characteristics of plants. This is achieved through the biosynthesis of compatible metabolites (represented by various low-molecular substances - monosaccharides, amino acids, alcohols) (Abd El Baki *et al*., 2025). The development of oxidative stress leads to the induction of the synthesis of antioxidant enzymes, the accumulation of antioxidant metabolites. Increased synthesis of individual hormones causes an imbalance between their concentrations. As a result, profound changes occur that even lead to modification of the basic plant process - photosynthesis. In these studies on *Triticosecale* - a hybrid of wheat and rye with high potential in agricultural production, a number of studies were conducted on the effect of different types of salinity of the environment on the physiological and biochemical characteristics of seedlings at an early stage of plant ontogenesis. An increase in the concentration of salts providing the main types of salinity ($NaCl$, Na_2SO_4 or Na_2CO_3) in the nutrient medium led to a change in a number of characteristics, both in the roots and shoots.

Among the effects found, one can note a change in osmotic pressure, proline content (F4IIS6), development of oxidative stress, changes in the functioning of the antioxidant system, etc. At the same time, the dynamics of plant characteristics and the specificity of the action of different types of salinity required an unconventional approach to the analysis of the research results, since a simple statement of the facts of a more or less pronounced toxic effect of a particular salt did not provide new criteria for assessing the specificity of the action of an environmental factor, which in this case is a different type of salinity (Ismayil *et al*., 2025).

Salicornia L., *Salsola nodulosa*, *Salsola dendroides* Pall., *Salsola* L., *Glycyrrhiza glabra* L., *Alchagi camelorum* Fisch, *Artemisia lerchiana*, *Hippophae rhamnoides* L., *Anabasis* L., *Suaeda Forsk*, *Thymys* L., *Cotinus adans coggyria*, *Euphorbia* L., *Elaeaqnus angustifolia* L., *Achillea* L., *Berberis* L., *Amygdalys* L., *Rhamnus* L., *Paliurus-spina chisti* Mill., *Pistacia mutica* L., *Juniperus* L., *Colutea L.*, *Punica qranatum* L., *Rubus fruticosus* sp. and other natural plants grows in saline soils.

2. Methods

The use of the cluster analysis method allows us to detect the specificity of carbonate and sulfate salinization of the environment through the manifestation of new relationships between the properties (characteristics) of the object (Steven, 2017).

Cluster analysis of physiological and biochemical characteristics of plants allows us to detect the specificity (in this case, biochemical) of adaptation of triticale shoots to each type of salinity, which can be explained through different strategies for changing metabolic processes in shoots (Negacz *et al*., 2021). This is the first study to show such specificity of biochemical adaptation to the influence of different types of salinity on a plant, manifested through a change in the hierarchy of characteristics of the object of study. Such a picture allows us to focus on those connections between the indicators of the organism that may have greater or priority significance in the adaptive or protective reactions of the plant under different stress conditions. If, with sulfate and carbonate types of salinization, the change in the glutathione content is most closely associated with the formation of hydrogen peroxide (a first-order cluster is formed), then, with chloride salinization, glutathione forms a first-order cluster with ascorbic acid (Rowel, 1999; Shukla & Varma, 2011).

To create a domestic database of "Reflection spectra and digital indicators of soils", it is important to conduct such studies. The database developed by the authors contains an original algorithm for establishing a connection between the reflectance spectra of soils in the visible range, color coordinates in the international CIELAB system, color according to the Munsell system and color characteristics known from open publications of researchers (Goet *et al*., 2024).

Alterations in the activity of antioxidant enzymes (catalase, ascorbate peroxidase, guaiacol peroxidase, glutathione reductase), the content of low molecular weight antioxidants (ascorbic acid, glutathione and proline), as well as indicators of oxidative stress (hydrogen peroxide, superoxide radical, lipid peroxidation - LPO) in the shoots of triticale under short-term (0-96 h) sodium chloride stress (120 mM) were studied with statistical methods: principal component analysis (PCA) and cluster analysis (Figures 2, 3). When considering each tillage system separately, the increase in the shoot mass fraction was particularly high in the RT treatment.

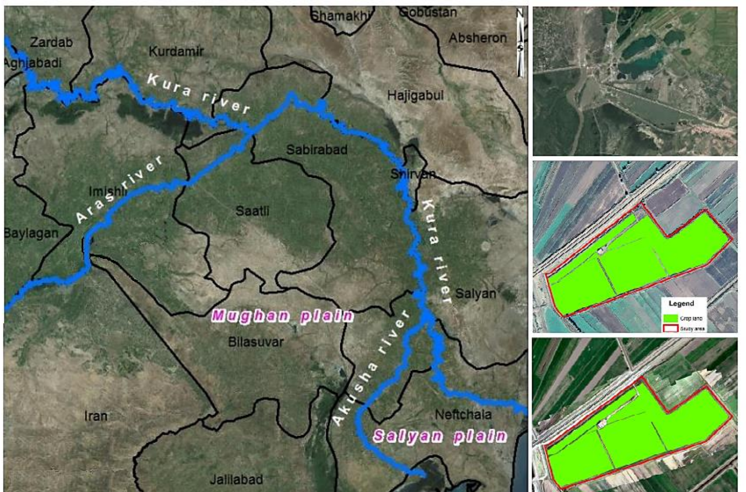


Figure 2. Research areas of triticale shoots (2024 year)

3. Results

3.1. State of mineralization of water of the main Shirvan collector

Salinity and water scarcity are among the major environmental challenges requiring the use of non-conventional water sources and the adoption of salt-tolerant crops. Most irrigation systems (both main and on-farm canals) have become unusable and have not been repaired for a long time, which has led to large losses of water in irrigation systems (Naorem *et al.*, 2023). The quality of water supply facilities and water distribution to consumers has serious shortcomings. There are no hydrometric devices and posts for measuring the volume of water supplied. Failure to comply with irrigation standards and technologies in irrigated agriculture leads to large-scale water losses, deterioration of the melioration state of lands and a decrease in productivity. Economic efficiency has decreased due to spontaneity, lack of consolidation between land users: entrepreneurs and farmers. The waters of the main collector, as well as the drainage networks feeding them, have different mineral and chemical compositions. Based on world experience in using highly mineralized waters for irrigation, collector-drainage waters with a low mineral content and satisfactory chemical composition can be used for irrigation directly or with the addition of fresh water in the event of low water in arid conditions

Currently, the country has $1{\cdot}10^6$ $451{\cdot}10^3$ 100 hectares of irrigated soils, which is 12-$15{\cdot}10^9$ m^3 of irrigation water per year. The areas of the Main Shirvan Collector along the Kura-Araz Lowland consist mainly of gray-meadow soils. In the village of Garalar in the Sabirabad region, the degree of mineralization of the water sample from the collector was 2.93 g/l (40°03′06″N 48°32′30″E). At M≤0.5 g/l, water is completely suitable for irrigation, at M=0.5–2.0 g/l, M=2.0–5.0 g/l it is considered less useful, at M>5 g/l it is considered dangerous to carry out irrigation. The mineralization of water taken from the collector is considered unsuitable for irrigation, since it is less than the permissible limit (5.0 g/l) and more than 2.1 g/l (2.93 g/l). Due to the (SAR = Na'/√(0,5 (Ca^'+Mg^')) relative potential coefficient of sodium adsorption ratio (SAR) (Na) SAR = 7.9, the collector water can be fully used for irrigation. From the results of the analysis of water samples, it follows that the mineralization of water in the collector does not exceed the limit used for irrigation. Therefore, the use of collector water for irrigation in the Sabirabad region, which has an arid climate, can be considered appropriate. In the village of Kurkendi, Sabirabad region, coordinates partly to the east of the starting point - 40°01′57″N 48°29′08″E from the lower Shirvan collector, entering the Main Shirvan collector from the right bank, the analysis of the water sample differed sharply from the water in the collector main. The mineralization of the water sample taken from the area was 7.27 g/l. The mineralization of water coming from the right bank was more than 2.5 times higher than the mineralization of water taken from the main collector. Therefore, drainage water coming to the Main Shirvan collector from the right bank is completely unsuitable for use. Due to the relative potential coefficient of sodium (Na) (SAR), the collector water can not be used for irrigation. Water samples taken from the channel entering the collector from the right bank in the area with the coordinates of the Main Shirvan collector passing through the territory of the Sabirabad region correspond to 39°59′39″N 48°36′15″E. The mineralization of the water sample taken from this area was quite high - 18.02 g/l. Cl - 10.81 g/l and SO_4 - 1.169 g/l acidic salts prevailed here. The mineralization of water taken from drainage is considered completely unsuitable for irrigation, as it is 4 times higher than the permissible norm (5.0 g/l) (17.92 g/l). Due to the relative potential coefficient of sodium (Na) (SAR), canal water cannot be used for irrigation (Na/(Ca+Mg) it is unsuitable. The use of irrigation water leads to salinization of soils of agrocenoses *Triticosecale*.

3.2. Stress indices

Under salt stress, excessive energy headed for molecular oxygen activates the oxygen poisoning by over-production of singlet oxygen, superoxide ion, hydrogen peroxide and other free oxygen radicals. The value of lipid peroxidation (MDA) under such conditions is closely related to catalase suggesting an important role of this enzyme in protecting membranes from oxidative stress, while under carbonate stress a more important role in protecting membranes belongs to another enzyme - ascorbate peroxidase and to all the studied (Rzążewska & Gąsiorowska, 2023) antioxidant enzymes - in the case of sulfate salinity of the environment (Figures 3a and 3b). Such free radicals are damaging for proteins, lipids, nucleic acid and other macromolecules. The inclusion of an additional indicator in the analysis – proline, which is considered an active antioxidant (along with glutathione and ascorbate), also shows different options for the significance of this metabolite in the relationships between the studied characteristics.

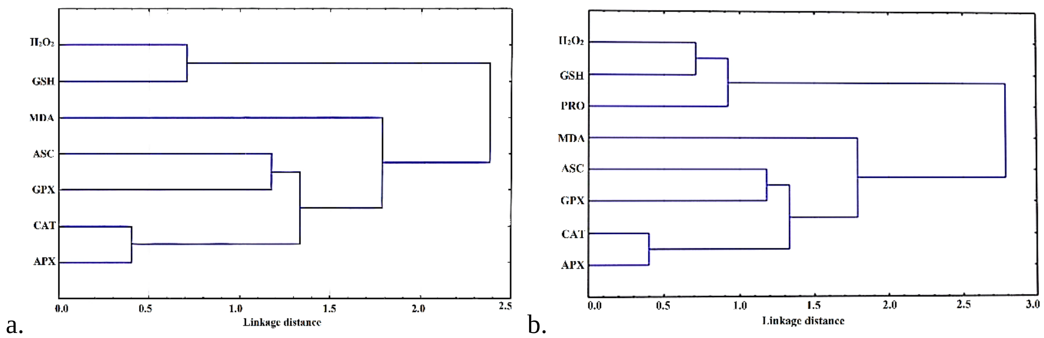


Figure 3. Hierarchy of the studied stress indices and antioxidant system of triticale shoots under conditions of sulfate salinity of the environment (a) and the same in the presence of proline (b)
Note: APX - ascorbate peroxidase; GSH - glutathione; MDA - malonic dialdehyde; H_2O_2 - hydrogen peroxide; CAT - catalase; ASC - ascorbic acid; GPX - guaiacol peroxidase; PRO - proline

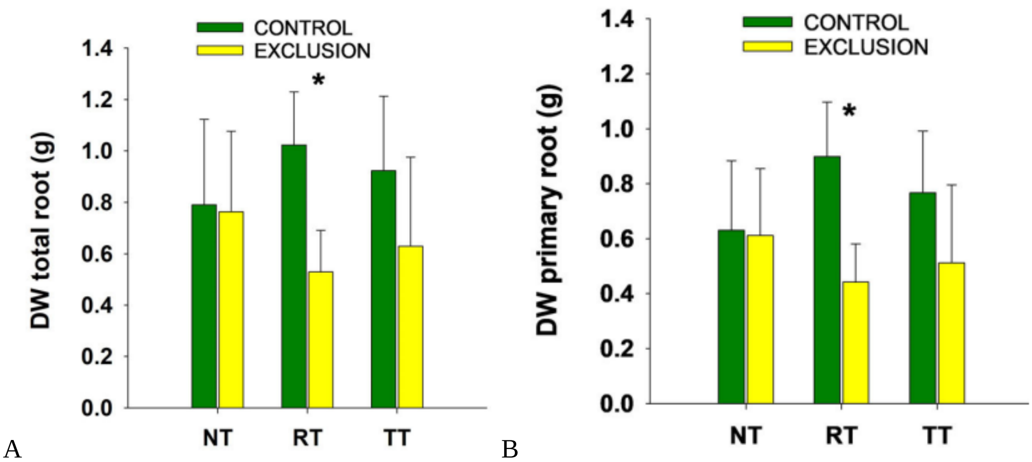


Figure 4. Biomass of different root fractions of plants (a) total root; (b) primary root growing in the three tillage systems and in control and rainfall exclusion plots. The asterisk (*) indicates significant differences (p < .05) between the control and the rainfall exclusion treatments for each tillage system. DW: Dry weight; TT: traditional tillage, RT: reduced tillage; NT: no tillage

Cluster analysis of physiological and biochemical characteristics of plants allows us to detect the specificity (in this case, biochemical) of adaptation of triticale shoots to each type of salinity, which can be explained through different strategies for changing metabolic processes in shoots (Negacz *et al*., 2022). This is the first study to show such specificity of biochemical adaptation to the influence of different types of environmental salinity on a plant, manifested through a change in the hierarchy of characteristics of the object of study. Such a picture allows us to focus on those connections between the indicators of the organism that may have greater or priority significance in the adaptive (protective) reactions of the plant under different stress conditions. Irrigation with 150 mM NaCl has most significantly affected plant height, number of tillers, number of spikes, total fresh biomass and total dry biomass, followed by 50 mM NaCl and freshwater, respectively. There were no significant differences among all treatments in spike width. The application of 150 mM NaCl H_2O had a significant effect on both spike length and weight of 100 grains, while no difference was found between 50 NaCl H_2O and freshwater. Rainfall exclusion and tillage did not have any significant effects on the shoot mass of individual plants. Rainfall only had some impact on the patterns of biomass allocation to the roots in triticale plants, especially in the RT system (Figures 4a and 4b).

3.3. Landscapes

Slightly, moderately, strong, extreme and non-saline soil spectra of reflectance are shown in Figure 3. We have carried out single determinations of natural cenoses phytomass on three sections of arid soils of the landscape-altitude series in Sabirabad. According to these determinations, the aboveground phytomass varies from 0.02 kg/m^2 in the most arid conditions under decertified steppe with low projective cover: 10-30% to 0.144 kg/m^2; in the most typical conditions under steppe with projective cover of 40%, the aboveground phytomass is 0.040 kg/m^2 (Figure 5). Saline soils are widespread in the zone of dry steppes, semideserts and deserts and are also found in the steppe and forest-steppe zones, i.e. where the annual amount of precipitation is less than evaporation. The long process of upward movement of solutions of even weak concentrations and evaporation of water from the soil in quantities exceeding atmospheric precipitation leads to salinization (Figure 6).

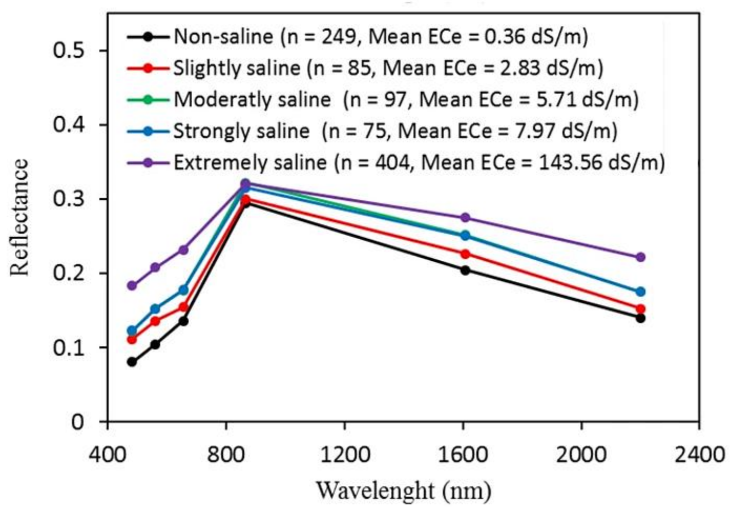


Figure 5. Reflectance spectra for different types of saline soils in the Sabirabad region
Source: By authors in 2023-2024 years

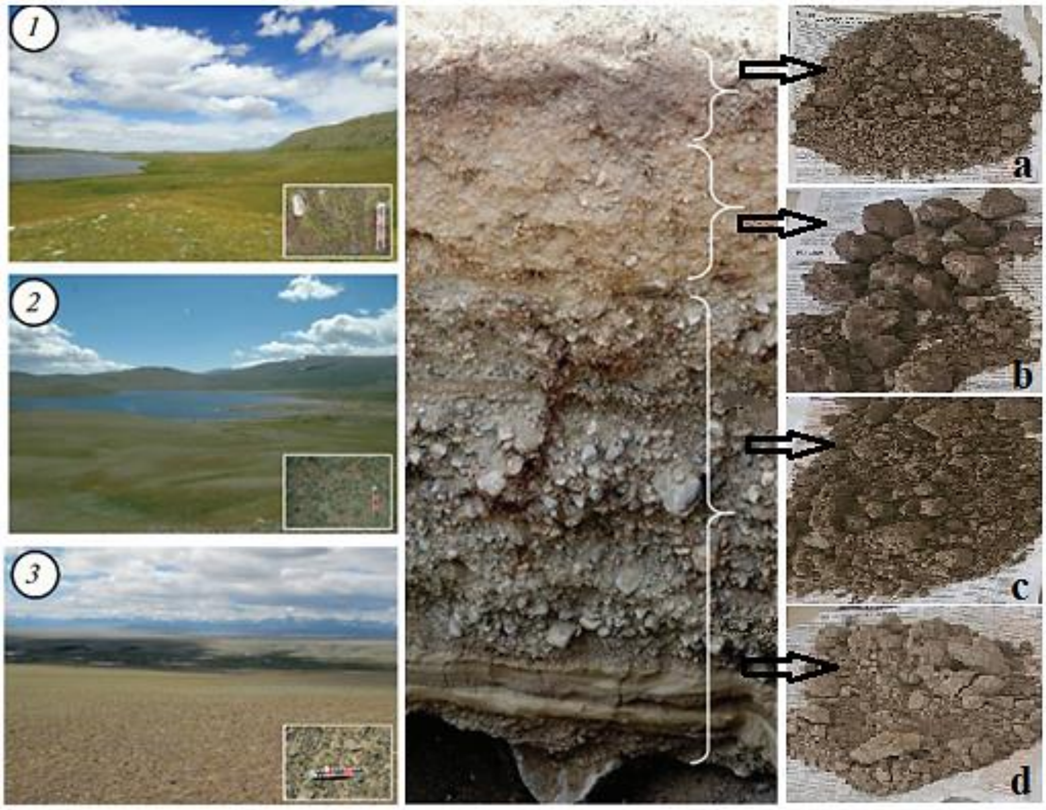


Figure 6. Characteristic landscapes, typical profile and key points of soil structure
Natural landscapes: 1 - Garalar village; 2 - Near to Main Shirvan Collector; 3 - Kurkendi village.
Key features of soil structure: a - brown AK horizon, lumpy-powdery structure and abundance of plant residues; b - pale yellow B_p horizon with clayey-silty films on mineral grains; c - accumulation of dead root detritus at the lithological contact between Bp and 2BCA1 horizons;
d - multilayered cutans on rock fragments in BC_z horizons

The results of this scientific and practical work will show how useful the approaches used to analyze the situation during the period of "analog" methods of studying soil characteristics can be to modern arrays of big data and digital solutions in soil science. Consequently, the opportunity will appear and be substantiated to significantly expand the number of information resources involved in scientific research.

Soil salinity around the collector is relatively high, but can be used in agriculture as a result of melioration measures. The results of a comparative analysis of the influence of different types of salinization on agricultural plants are presented. Due to the high mineralization of most of the water on the right and left banks flowing into the reservoir, they cannot be used as irrigation water during the growing season. The results of the study revealed that the neutralization of hydrogen peroxide is most closely related to the work of the glutathione-glutathione-reductase system and the leading role in membrane protection is assigned to catalase. The application of saline irrigation in the form of NaCl solution may have detrimental impacts on crop growth depending on the concentration level used and crop tolerance to salinity. The formation and work of the antioxidant system in triticale shoots were not directly related to the accumulation of salt ions.

4. Conclusion

The article reflects the results of large-scale soil-ecological studies conducted in 2023-2024 on the soils of the Kur-Araz plain. The use of PCA and cluster analysis methods in the analysis of the results of short-term salt stress made it possible to detect a close relationship between carbonic anhydrase activity and electron transport (correlation coefficient 0.87), carbonic anhydrase activity and lipid peroxidation (correlation coefficient 0.88), electron transport and hydrogen peroxide accumulation (correlation coefficient 0.65). Close relationship between the water content and the value of the osmotic potential, the correlation between them is negative (-0.77). The aboveground phytomass varies from 0.02 kg/m^2 in the most arid conditions under desertified steppe with low projective cover: 10-30% to 0.144 kg/m^2; in the most typical conditions under steppe with projective cover of 40%, the aboveground phytomass is 0.040 kg/m. All this makes it possible to detect such relationships between the characteristics of an object that stimulate the setting up of new experiments on this basis for a deeper understanding of the problem of plant resistance at the biochemical level. The use of irrigation water leads to salinization of soils of agrocenoses *Triticosecale.* The entire complex of soil formation conditions forms a significant volume of root phytomass that can exceed the aboveground mass by 3-22 times against the background of exceptionally low winter temperatures, low precipitation, highly permeable and low moisture-absorbing substrate, low diversity and abundance of soil fauna, which determines the uniqueness of the accumulative-humus horizon of arid soils.

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