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The Effects of the Degree of Soil Salinity and the Bio preparation on Productivity of Maize in the Shaulder Irrigated Massif

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Abstract: During the study on the Shaulder irrigated massif, the soil salinity maps with different degrees of salinity were compiled at the large-scale 1:10000 in the GIS environment. It was found that the area of saline soils increases with depth. In the upper 0-20 cm layer, 29% is salted and in the 50-100 cm layer, up to 44% is salted. The theory of soil reclamation shows a close relationship between the level of concentration of salts accumulating in the soil and the state of the current crop. Determination of the effect of biopreparation was carried out in field studies. Pre-sowing treatment of maize seeds was carried out using a working solution of C-1-1 adaptogen-preparations in optimal technological modes developed by U.U. Uspanov Kazakh Research Institute of Soil Science and Agrochemistry. Maize sowing was carried out in May to a depth of 6-8 cm in a common way with row spacing of 70 cm at the rate of 18-20 kg of seeds per 1 ha. Maize plants were sprayed in the phase of 4-5 leaves and 6-7 leaves; when corn forms the first and second tier of nodal roots, plants were sprayed with a biological product “BioEkoGum” with an aqueous solution. The study's findings showed that depending on the degree of soil salinity, the maize yield for grain increased on non-saline soils to 40.0% compared to the control of 71.1 c/ha. In lightly and medium-saline soils-81.2-83.9 c/ha at the control treatment (62.5-63.5 c/ha), the addition to yield was 30.0-32.1%, respectively. In highly saline soils, the yield of maize grain was 11.4 %, with the yield under control-47.1 c/ha. Application of biological preparation in the conditions of Shaulder irrigated massif allows making an income from 162.6 to 884.2 $ per 1 ha.

Keywords: Shaulder Irrigated Massif, Soil Salinity, Soil Fertility, Adaptogen-Preparations, Geographic Information Systems (GIS), Crop Yield

Introduction

Soil salinization is one of the main degradation processes limiting the soil fertility of arid territories in different countries of the world, including Kazakhstan. The changes in soil salinity are most often the result of anthropogenic influence. In recent years’ global climate changes have also had a significant impact on the dynamics of soil salinization (Pankova and Konyushkova, 2013; 2016). These two main factors lead to various results in different regions of the world. In Kazakhstan, both of these factors have a strong influence on the dynamics of soil salinity.

The proposal to establish the International Saline Soil Network (INSAS) was presented at the ninth working session of the International Technical group on Soils (ITPS), held at FAO headquarters, Rome (10-12 October 2018) and formally approved by the seventh VSP plenary meeting (5-7 June 2019). The International Saline Soil Network (INSAS) concept promotes the sustainable and productive use of saline soils for present and future generations. The mission of INSAS is to support and facilitate collaborative efforts for sustainable saline soil management to ensure food security, agricultural sustainability, and climate change adaptation and mitigation (FAO, 2019).

Sustainable management of saline soils is also relevant for our country. In the Republic of Kazakhstan, saline and solonetzic soils occupy 94 million hectares, which is 43.6% of the agricultural land area (MARK, 2019). The involvement of solonchaks in soil cover structure increases significantly in the southern half of the Republic as the closed inland area does not have free flow to open ocean basins.

In the years of the transition period of the Republic of Kazakhstan, extensive use of irrigated soil fertility and unsatisfactory condition of irrigation and collector-drainage networks, their technical parameters do not correspond to the design standards, led to a sharp deterioration of soil-reclamation conditions of irrigated massifs. For example, at present, in the irrigated areas of the Kyzylorda region, the area of irrigated lands with a groundwater level of 1.5-2.0 m is 31.8 thousand ha, 2.0-3.0 m-158.4 thousand ha. Soil areas with groundwater salinity of 5.0 g/L or more are 122.0 thousand ha (Sagymbayev, 2006). A similar situation has developed in the irrigated massifs of the South Kazakhstan region. Due to salinization on 42912 hectares, due to the rise in the groundwater level on 80005 hectares, both factors on 24909 hectares have an unsatisfactory reclamation state (Otarov *et al*., 2008). The results of an earlier study on the lands of Aktobe and Shilik rural districts of the eastern part of the Shaulder irrigated massif in Otyrar district showed that in the period from 1987 to 2014, due to the reduction of unsalted soils, low-saline soils increased by 10.4%, medium-saline-by 24.5% and highly saline-by 6.6%. This fact indicates the deterioration of the soil-reclamation situation in the research area (Laiskhanov *et al*., 2016).

The problem of reclamation of saline soils, increasing their fertility, and obtaining a satisfactory crop yield on saline soils has become the focus of research by agricultural scientists in the countries of the arid region. At present, the problem of soil reclamation has sharply worsened in the irrigated areas of the Republic, and the area of so-called "unused," "abandoned" secondary saline lands has increased. Land plots with "unused" soils have been classified as fallow land due to a high degree of salinity. In such difficult conditions, it is almost impossible for farmers to obtain consistently high yields. In this regard, based on our previous accumulated experience (Duisekov *et al*., 2015; Laiskhanov *et al*., 2016; 2021), we studied the salinity of the irrigated fields of the research area and conducted experiments to identify the effect of biological products on corn yield. Maize is considered the main dominant agricultural crop of the irrigated lands of Shaulder irrigated massif. According to the SARK (2020), out of the total harvested area (33252 ha), 33.5% (11134 ha) were corn crops in 2019. Since corn is the main forage crop in the area, increasing its productivity also contributes to the development of animal husbandry.

Materials and Methods

The Shaulder irrigated massif, a core area of the irrigated system in the middle reaches of the Syr Darya river, was selected as the study area (ancient Otyrar oasis). In the South and South-East, the natural border is the ancient above-floodplain terrace of the Syr Darya river; in the East and North, it borders the Arys-Turkestan irrigated massif, in the West, it borders the left-bank floodplain of the Syr Darya river (Fig. 1). Most of the territory is used as pastures for grazing farm animals. Irrigated arable land is located in the subcommand territory of the Arys and Bugun rivers.

The test site is located in the Central part of the South Kazakhstan region between 42 53/and 43 37/North latitude and 58 10/and 58 30/East longitude. Its length from North to South reaches over 28 km, from West to East, also 28 km, and the total area is 35.4 thousand hectares. The Shaulder irrigated massif is located within the site. The main concept that determines the methods of obtaining and processing dates is the genetic approach, the foundations laid by Dokuchaev (1951) and so far, it is the basic one for solving both theoretical and applied problems of soil science (Sokolov, 2004; Simensen *et al*., 2018). The research is based on a comparative geographical method, which consists in comparing some soils with others, considering the conditions of soil formation, which makes it possible to study the Genesis of soils, establish both genetic relationships between the components of the soil cover and factors of its differentiation, as well as the main directions of the soil-forming process. At the stage of conducting route field studies, morphological methods were used to ensure the reliability and validity of field diagnostics of soils, soil mapping, and characteristics of the main morphological properties of soils. They play an essential role in determining research direction and are one of the main components of geographical and genetic research (Laiskhanov *et al*., 2018; Rozanov, 2004; Roger-Estrade *et al*., 2004).

There are also serozem-meadow (or semihydrophorphic) salt marshes that occupy mid-level surfaces and microrelief depressions, under halophytic-sagebrush, sagebrush-halophytic and halophytic vegetation with the participation of ephemera, as well as residual takyr salt marshes located on microrelief elevations that reach 20-30 (up to 50) cm of relative height under sparse halophytic vegetation (mainly Anabasis aphylla). Salt flats and salt marshes are formed on heavier and saline rocks in conditions of solid mineralization of medium-deep groundwater. In depressions of the relief with close (up to 3 m) groundwater, the following forms are formed: Meadow-bog saline soils under meadow-bog vegetation in very close (up to 1.5 m) weakly mineralized waters; gray-earth meadow solonchak solonetzes under halophytic and cereal-halophytic vegetation in nearby weakly and medium-saline waters; meadow salt marshes under halophytic and cereal-halophytic vegetation in nearby (1.5-3 m) weakly mineralized waters; common salt marshes under halophytic vegetation (*Halocnémum*) in nearby highly mineralized groundwater. When occurring in complexes and combinations, salt marshes usually occupy elevated areas of micro-and mesorelief. The prevailing type of salinity is chloride-sulfate and sulfate-chloride, sometimes with the presence of soda (Pachikin *et al*., 2014). All soils of the massif are carbonate and are characterized by high alkalinity (pH 8-9). The water-physical, physical, physical, and chemical properties of soils depend on the degree of salinity and salinization (Vyrakhmanova *et al*., 2020).

Ground-based studies have been carried out following the “All-Union Instructions ...” Ministry of Agriculture of the USSR, 1973 and the Guidelines (Varennikov *et al*., 1995). For conducting salt mapping along with the traditional method (laying cuts, drilling wells) and clarifying the contours of the soil from satellite images, the GPS 18 "Garmin" was used with the ASUS netbook and the global positioning system GPS "Garmin 66s" was used to determine the coordinates of the cut points.

For a general analysis, the methods described in the manual (Hesse, 1971) were used. The assessment of saline soils was based on three main criteria: The chemistry (type) of salinity, the degree of salinity, and the depth of the salt horizon. The chemistry of saline soils was determined by the composition of anions and cations (Shahid and Rahman, 2011; Ivushkin *et al*., 2019; Kubenkulov *et al*., 2013). Statistical processing was carried out by generally accepted methods (Bourgault *et al*., 1996; Meshalkina and Samsonova, 2008; Webster, 2001).

The use of instrumental methods is associated with laboratory analytical studies of selected samples that were carried out according to generally accepted methods (Sagymbayev, 2006; Zhang *et al*., 2011; Tanirbergenov *et al*., 2020): Humus according to Tyurin, total nitrogen by Kjeldahl method, hydrolyzed nitrogen-the method of Tyurin-Kononova, mobile phosphorus and potassium according to Machigin; pH-by the potentiometric method, CO_2-by a calcimeter, absorbed bases of Ca, Mg-by the trilonometric method, K, Na-by a flame photometer.

In the course of field experimental work, pre-sowing treatment of seeds with the adaptogen preparation C-1-1 and spraying with an aqueous solution of the Bioecogum biopreperate was carried out in the phase of 4-5 leaves and 6-7 leaves, when corn forms the first and second tier of nodal roots.

Bioekogum is a dark brown liquid suspension, obtained from vermicompost, processed by compost worms in special nurseries of various organic raw materials, by enrichment with nutrients in a form accessible to plants. Composition of the preparation: Content of humic acids, % of absolutely dry matter-0.18-0.24, acidity, pH KCl-7.5-8.5. Mass fraction of nutrients (per 100 g mg/kg dry matter), mg: Total nitrogen-1000 mg, total phosphorus, in terms of P_2O_5-1700 mg, total potassium, in terms of K_2O-5000 mg. Mass fraction of impurities of toxic elements (gross content), including individual elements, no more: Cadmium-0.5, lead-32 (Suleimenov and Seitmenbaeva, 2021).

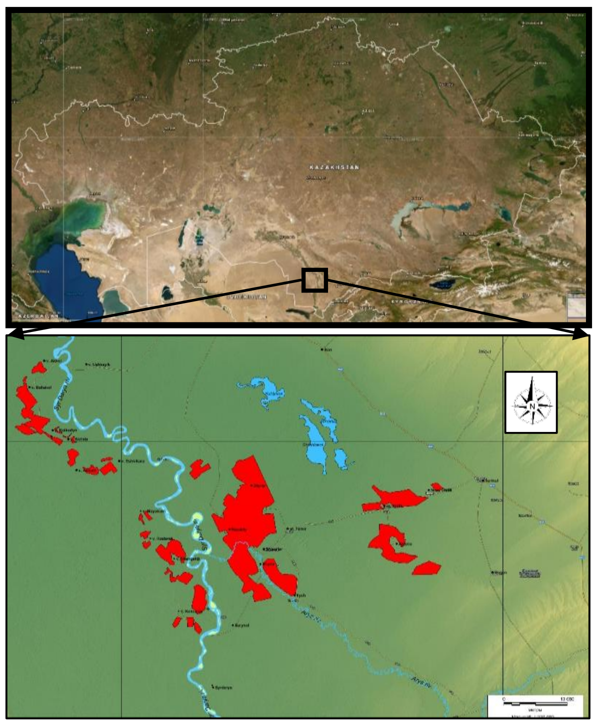

Fig. 1: Geographical location of the research object

Results

To select the sites, a field reconnaissance survey was conducted in the Central part of the Shaulder massif from the Syr Darya river to the Timor station, during which soil cuts were laid, and soil samples were taken to determine their physical and chemical properties. The determination of a quantitative value characterizing the degree of degradation is of great practical importance since it allows to calculate the cost of restoring lost soil fertility. Based on economic calculations, a decision is made on the nature of further use of the soil. In this regard, the basis for determining the degree of soil degradation of the territory was adopted by the regulatory documents of the Republic of Kazakhstan, created with the participation of leading experts in the field of soil science (MEBRK, 1996; MARK, 2005).

Traditional ground large-scale salt mapping (1:10 000) of the research area was carried out by laying soil cuts with a sampling of soil samples for chemical analysis from three depths-0-20, 20-50, and 50-100 cm 445 samples of soil samples were selected. Figure 2 shows the farm's layout and an enlarged view of soil sampling points and their numbers.

Using the formed Geoinformation System (GIS) of the research object in the MapInfo professional environment, maps of the degree of soil salinity of all farms were compiled. Based on its studies, the basic elements of the information system (GIS technology) of the Shaulder irrigated massifs farms have been created, which will be additionally supplemented both in the territorial aspect and in soils that limit the properties of adequate fertility of irrigated soils. This system will allow local soil monitoring of these farms and system analysis of the obtained data, which, in the end, will allow the application of existing and develop new methods for improving soil fertility (Ivushkin *et al*., 2019). According to the results of the salt mapping, it was found that the areas of saline soils increase with depth. In the upper layer, 0-20 cm is salted at 29%, and in the 50-100 cm layer up to 44%. Thus, the assessment of the soil of each farm by the degree of salinity on the area of 500 hectares was obtained.

For example, maps of the degree of salinity of soil layers 0-20, 20-50, and 50-100 cm of farms "Margulan" are presented (Fig. 3). The total content of soil salinity in the upper layer of 0-20 cm of the study area varied widely between 0.06 and 1.64 mg-eq. Meanwhile, median soil salinity lines are 0.20 mg-eq and belong to a non-saline degree and outliers are 21 from 445 soil samples and a standard deviation of 0.67 mg-eq. The soil salinity in another second (20-50 cm) and third layers (50-100) of soil varied between 0.08, 0.07, and 1.66, 1.67 mg-eq, the median lines on the two layers of 0.27 mg-eq, they belonged to the degree of weakly saline and outliers are 3 and 4 samples and standard deviation of 0.50, 0.52 mg-eq. The relatively high mean salinity indicated that the depending on the soil layers were salt-affected in the irrigated lands of the Shaulder massif (Fig. 3d).

Soil salinity reduces the productivity of crops and sometimes leads to their mass withering. It has been proven that there is a close relationship between the amounts of salts accumulating in the soil (a degree of soil salinity) and the current crop's state. Salt tolerance of crops, depending on the degree of soil salinity is visible in the growth phase and yield. In non-saline soils, according to the degree of soil salinity, plants-growth and development are good, without insult plants, normal harvest and in the weakly saline have been weak inhibition and yield reduction to 10-20%, also in the degrees of average saline, highly saline and solonchak, the average, strong oppress the plants and the yield decreases from 30-50 to 50-80%, then in the last stage individual plants are surviving, the crop dies almost completely (Mamytov and Mamontov, 2012). A high concentration of salts increases the osmotic pressure in the soil and reduces the microbiological activity of the landscape as a whole. In such landscapes, the biological waste decomposes slowly and, as a result, the process of soil formation is very slow (Laiskhanov *et al*., 2018).

Violation of the nutritional conditions of agricultural plants during the accumulation of readily soluble salts in the soil can be due to various reasons. For example, a high concentration of salts in the soil solution reduces the degree of dissociation and promotes the precipitation of several elements from the solution into the sediment in the form of hard-to-reach compounds. Thus, in soils with an alkaline environment, the mobility of Ca, Fe, and many trace elements will be significantly limited due to the formation of carbonates. Ion antagonism is sharply manifested during the process of soil salinization. In particular, excessive accumulation of sodium ions in the soil solution will prevent the entry of Ca2+, Mg2+", K+, and other cations into plants. Excess chlorine adversely affects the uptake of anions by crops.

The toxic effect of salts is associated with damage to the cytoplasm of cells, as a result of which the selective absorption of chemical elements is replaced by a passive one and leads to an abnormally high accumulation of salts in the organs of the plant (Sharif *et al*., 2019).

The degree of soil salinity may have to vary with the same amount of salts with different compositions. This is due to variability in the toxicity of various salts and ions to plants. Therefore, when agronomically evaluating saline soils, the qualitative composition of salts is of particular importance. After the detection of toxic salts, the degree of soil salinity is determined. Before determining the type and degree of salinization, taking into account the content of toxic salts, determined the threshold of toxicity and calculated the toxic and non-toxic salts using the analysis of aqueous soil extract.

The threshold of toxicity is defined as the limiting amount of salts in the soils above which there is inhibition of growth and development in moderately salt-tolerant plants (Rhoades *et al*., 1999) For individual ions, the following toxicity thresholds are as follows: mg-eq per 100 g of soil: $CO3_2$-0.03; HCO_3-0.8; Cl-0.3; SO42-1.7 (Fig. 4.).

The main soluble ions concentrations, i.e., bicarbonate (HCO_3-) in the upper layer 0-20 cm of the study area, varied widely between 0.28 and 0.99 mg-eq, median lines are 0.67 standard deviations of 0.14 mg-eq. In the 20-50 and 50-100 cm layers HCO_3- varied between 0.20, 0.16 and 0.89, 0.84 mg-eq. Compared to the median line in this layer, it decreases to 0.64, 0.61 mg-eq from the first layer. These two layers had a similar outlier (1 sample) and standard deviation of 0.16, 0.19 mg-eq. Carbonate ($CO3_2$) in the three layers had a similar range between 0.001, 0.008, and 0.13 mg-eq, the median lines of the soil layers are 0.03 mg-eq with outlier are 1 in 0-20 and 50-100 cm layers, and standard deviation of 0.04, 0.03 and 0.05 mg-eq, respectively. In layers of 0-20 cm Chloride ion (Cl-) varied widely between 0.001 and 2.71 mg-eq, in layers 20-50 cm 0.003-4.68 mg-eq and 50-100 cm varied from 0.03 to 4.79 mg-eq, median lines are 0.23, 0.34 and 0.36 mg-eq, outlier are 20 in 0-20 cm, 20-50-7 and 50-100 cm-6 and standard deviation of 1.79, 1.97 and 1.94 mg-eq. The sulfate ($SO4_2$-) content in the soil of the study area varied in the soil layers, in the 0-20 cm layer between 0.03 and 12.38 mg-eq, median lines are 1.37 outlier is nine and standard deviation of 4.43 mg-eq. In the 20-50 cm from 0.14 to 14.88 mg-eq and in the 50-100 cm between 0.22 and 16.23 mg-eq. Compared to the median line as a result of this layer, it increases to 2.44, 2.50 mg-eq mg-eq from the first layer, the outlier is 2 in the 20-50 cm and 3 in 50-100 cm layer and standard deviation of 4.35 and 4.90 mg-eq. Compared to the median line according to the boxplot, carbonate in the three layers, the chloride, and sulfate in the second and third layers of the soil are above the toxicity thresholds (Fig. 4).

Rational use of low physiologically active preparations-adaptogens with multifunctional properties on saline lands that increase the ecological stability of crops to extreme environmental conditions (soil salinity, adverse agrometeorological conditions, etc.,) with other methods of differentiated agricultural technology provides a reliable means to increase maize productivity with minimal dependence on the harsh soil-reclamation features (Atakulov *et al*., 2020).

Pre-sowing treatment of maize seeds was carried out using a working solution of C-1-1 adaptogen-preparations in optimal technological modes developed by U.U. Uspanov Kazakh Research Institute of Soil Science and Agrochemistry. Maize sowing was carried out in May to a depth of 6-8 cm in an ordinary way with row spacing of 70 cm at the rate of 18-20 kg of seeds per 1 ha. Maize plants were sprayed in the phase of 4-5 leaves and 6-7 leaves, when corn forms the first and second tier of nodal roots, plants were sprayed with a biological product "BioEkoGum" with an aqueous solution. The consumption rate of the working solution is 200 l per 1 ha. Watering plants for the season is 2-3 times. Harvesting of maize was carried out in the phase of full ripeness of grain.

The studied methods of cultivation had a different effect on biometric indicators and some elements of the yield structure. The use of biological preparations led to an increase in the linear growth of plants, the average height of plants was 238 cm, which is 36.3 cm more than without the use of biopreparations (Table 1).

Seed treatment reduces this stress factor and the most positive effect was obtained on the treatment with a biological preparation, where the height of plants increased by 63 cm, while on the control (without treatment) -by 15 cm. The height of attachment of the lower developed cobs varied in treatments from 72.6 cm to 106.5 cm and was sufficient for mechanized harvesting without losing the most valuable part of the yield-the cobs. On average, the number of cobs per 100 plants increased by 14.5 pieces, or by 15.3%. The number of leaves, depending on the studied technological techniques, varied on average 9.5-14.5 leaves were formed on the plant. In lightly and medium-saline soils with a yield of 81.2-83.9 c/ha, the addition to yield was 30.0-32.1%, respectively, compared to the control (62.5-63.5 c/ha). In highly saline soils, the use of the biopreparation made it possible to obtain a yield within 53.4 c/ha against 47.1 c/ha at the control, i.e., the addition to yield was 11.4%.

Table 2 shows data on maize grain yield depending on the degree of salinity of the soil and the use of a biopreparation, so treatment with a biopreparation, the grain yield was 110.2 c/ha, which is 40.0% higher than the yield in the control treatment of 77.1 c/ha.

Thus, on the area of 500 hectares of farms, the possibilities of obtaining sufficiently high maize yields in the unfavorable reclamation conditions of the Shaulder irrigated massif were demonstrated.

The efficiency of agricultural production depends on the level of material costs, the outputs, and the material interest of employees in the final results of labor. One of the reasons for high resource expenditures in agriculture is low soil fertility, salinization, dehumidification, non-compliance with agrotechnological requirements, insufficient use in production and processing of raw materials, and lack of alternative technologies, etc.

An important strategic direction for the development of agriculture is the acceleration of scientific and technological progress, which is based on innovative technologies that allow increasing crop productivity based on the development of science and technology.

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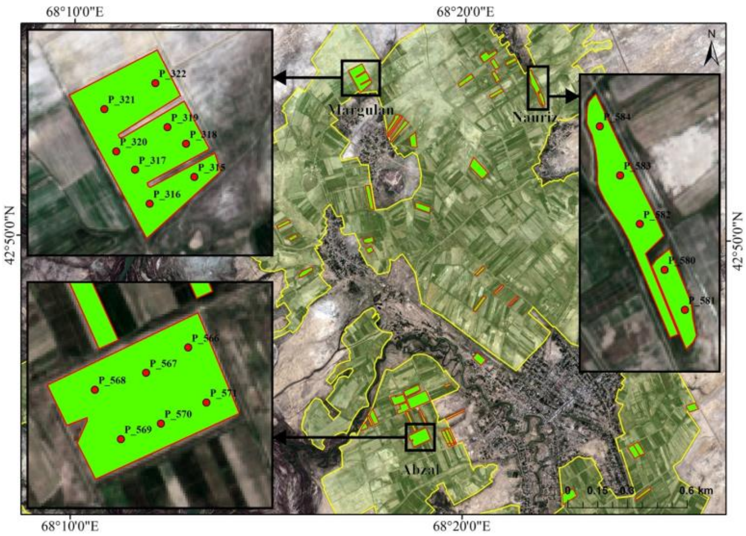

Fig. 2: Farms layout and enlarged view of selection points soil samples and their numbers

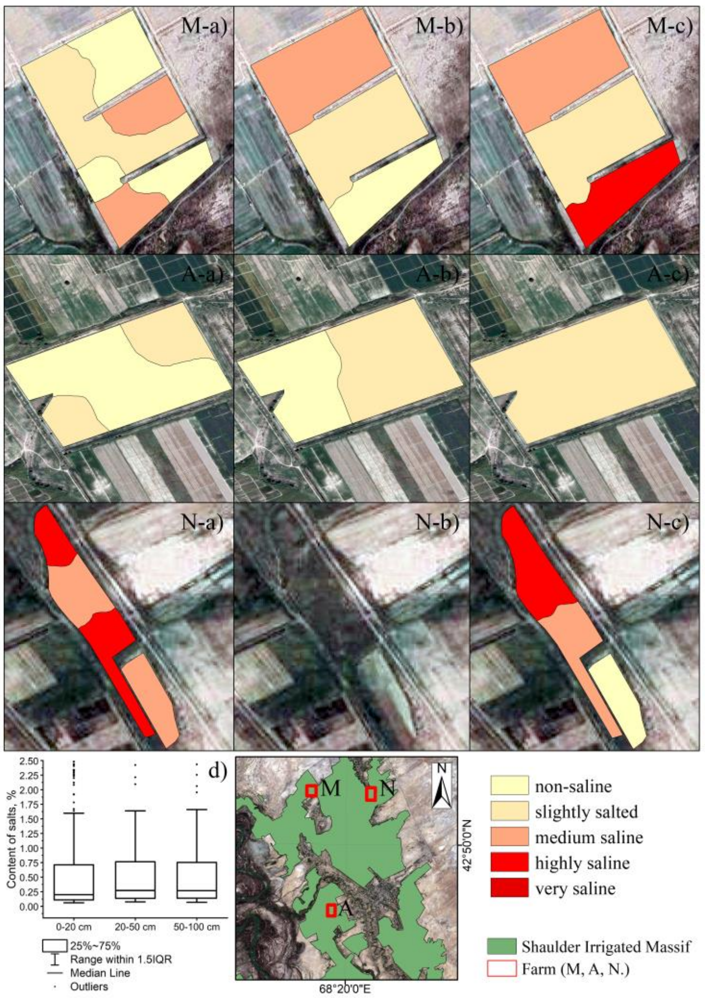

Fig. 3: Map of the degree of salinity of soil layers (a) 0-20, (b) 20-50, and (c) 50-100 cm of the farm "Margulan", (d) box plot and distribution of soil salinity for the whole of the Otyrar district, Turkestan region

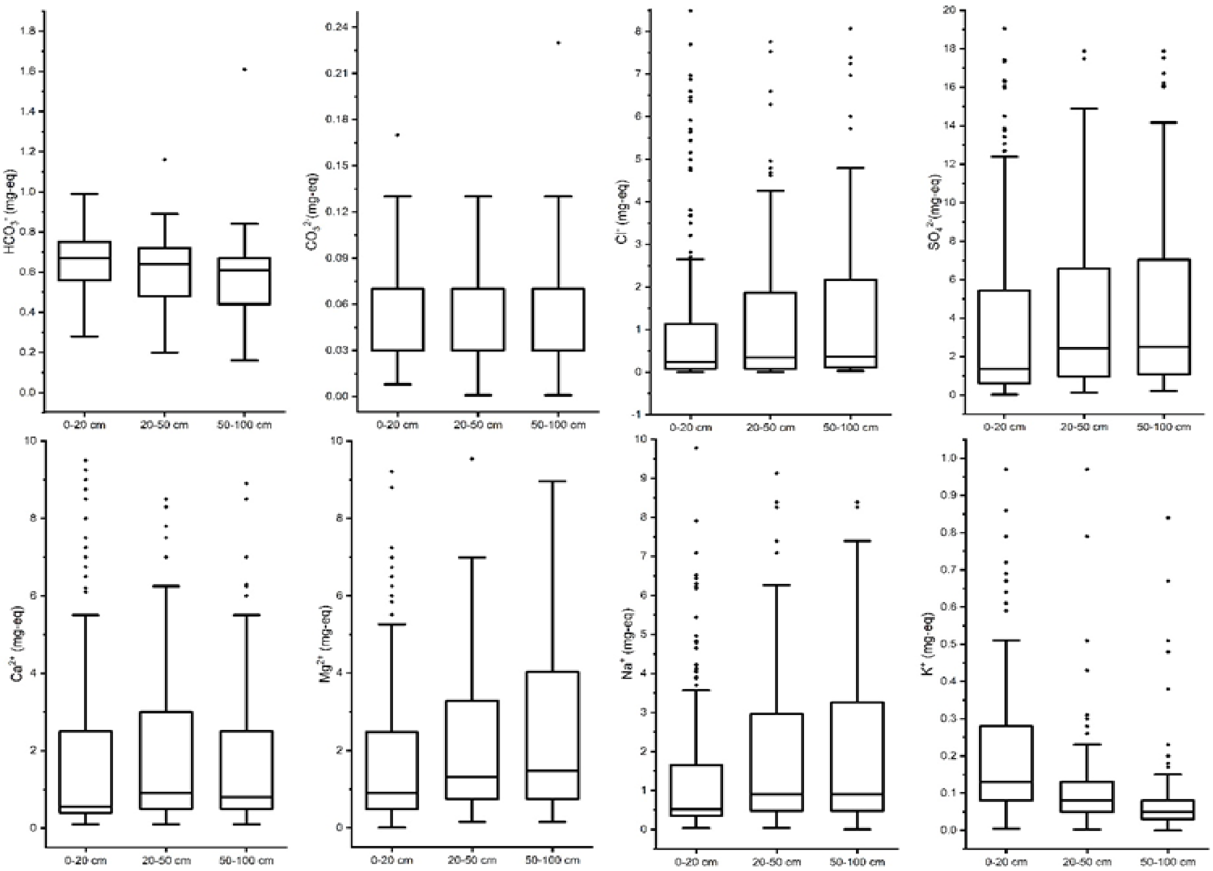

Fig. 4: Box plot for the maximum, minimum, and average of the chemical constituents in soil (all values in mg-eq)

If there is a shortage of means of production, priority should be given to large-scale production not only because of its undeniable advantages but also because small-scale production has always been and remains more capital-intensive (3-5 times), more labor-intensive (2-3 times). Furthermore, most importantly, it is impossible to implement modern high-performance technologies that provide high-quality and competitive products (Stroyev, 2004).

Discussion

Many scientists define economic efficiency concerning agriculture as the degree of rational use of land and other means of production, as well as the cost recovery of agricultural production (Shafronov, 2003; Adamišin *et al*., 2015; Ogloblin, 2005).

Experience in implementing effective, innovative technologies allows us to study resource-saving technologies' organizational, technological and economic foundations.

Based on the research results, an analysis of the economic efficiency of implementation in the cultivation of maize for grain on soils of different degrees of salinity was carried out. At estimating the economic efficiency of production, the entire technological process of growing maize for grain in the Shaulder irrigated massif was considered. The technological map included all the costs of mechanized and manual work, the cost of fuel and lubricants, fertilizers, seeds, pesticides, irrigation water, as well as overhead costs. Total costs, profit, cost recovery, cost of production, and the profitability of production on plantations with the use of existing technology and plantations using an innovative drug were determined. Economic efficiency was estimated in comparison with the existing technology of growing maize for grain.

Integrating all economic indicators revealed that the proposed innovative technology in the conditions of Shaulder irrigated massif in varying degrees of saline soils allows making a profit of 162.6 to 884.2 $ per 1 ha (Table 3).

While, with the existing cultivation technology, the profit varied from 85.3 to 456.3 $ per 1 ha. It should be noted that the efficiency decreased with an increase in the degree of salinity. At the same time, as expected, the cost of production of maize grain decreased with the improvement of the reclamation state of the soil. The lowest cost of grain production, regardless of the technology, was noted on non-saline soils-0.45-0.63 $/kg, while 0.88-0.99 $/kg on highly saline soils. The profitability of production was 82.9-156.3% on non-saline soils and 15.9-30.1% on highly saline soils.

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Table 1: Biometric indicators of maize, 2019

Treatments	Degree of salinity	Plant height, cm	The height of the cob attachment, cm	Number of cobs per 100 plants, pcs.	Number of leaves, pcs.
Control (without treatment)	Non-saline	211	80.6	100	13.2
	Lightly saline	203	79.4	96	12.9
	Medium saline	197	76.4	93	11.1
	Highly saline	196	72.6	90	9.5
The use of a biopreparation	Non-saline	275	106.5	120	14.5
	Lightly saline	240	94.7	110	13.7
	Medium saline	225	91.6	106	11.6
	Highly saline	212	81.2	100	10.1

Table 2: Effect of salinity and biopreparation on yield of maize grain, t/ha

	Yields of maize grain, t/ha		Addition to yield, t/ha	
Degree of salinity	Control (without treatment)	The use of a biopreparation	t/ha	%
Non-saline	7.71±0.006	11.02±0.400	3.15±0.402	4.00±0.51
Lightly saline	6.35±0.051	8.39±0.123	2.04±0.148	3.21±0.25
Medium saline	6.25±0.117	8.12±0.179	1.87±0.096	3.00±0.14
Highly saline	4.71±0.001	5.34±0.124	0.55±0.124	1.14±0.26

Table 3: Economic efficiency of innovative technology of maize cultivation for grain on soils of different salinity degrees

	Non-saline		Lightly saline		Medium saline		Highly saline	
Economic indicators	Existing technology	The use of an biopreparation	Existing technology	The use of an biopreparation	Existing technology	The use of an biopreparation	Existing technology	The use of a biopreparation
Total expenses, $	550.30	565.80	544.50	553.90	543.90	552.60	537.10	540.0
Total grain yield, tons	7.70	11.00	6.40	8.40	6.30	8.10	4.70	5.3
Cost of grain, $/ton	131.60	131.60	131.60	131.60	131.60	131.60	131.60	131.6
Total selling cost, thousand $/ha	1006.60	1450.00	835.50	1103.90	822.40	1068.40	622.40	702.6
Conditional net income, $/ha	456.30	884.20	291.10	550.00	278.40	515.80	85.30	162.6
Cost of 1 kg of grain, $	0.63	0.45	0.75	0.58	0.76	0.60	0.99	0.88
Profitability. %	82.90	156.30	53.50	99.30	51.20	93.30	15.90	30.10
Payback. $/$	1.83	2.56	1.53	1.99	1.51	1.93	1.16	1.30
Economic efficiency of innovative technology. $/ha	-	427.90	-	258.90	-	237.40	-	77.40

The economic efficiency of maize for grain with biopreparation in comparison with the existing technology varied from 427.9 $/ha on non-saline soils to 77.4 $/ha on highly saline soils.

Cost payback is also used as an indicator of the comparative economic efficiency of capital investments when choosing the best technology options. The analysis of the payback period due to the implementation of the technology showed that the cost recovery ($/$) for the existing technology varied from 1.16 to 1.83 $ for the innovative technology it varied from 1.30 to 2.56 $.

Conclusion

A large-scale salt mapping (M 1:10000) was carried out on 500 ha of the studied farms. In the GIS environment, large-scale (1:10000) salt maps were compiled according to the degree of salinity, maps of the chemistry of soil salinity, and the depth of salinity of the 1st salt horizon. It was found that the area of saline soils increases with depth. In the upper 0-20 cm layer, 29% is salted and in the 50-100 cm layer up to 44% is salted. There is a close relationship between the concentration of salts accumulating in the soil and the state of the current crop. The salt resistance of crops, depending on the degree of salinity of the soil, is visible in the growth phase and yield of crops, including corn.

Experimental work to study the effect of adaptogen-preparations on the growth and development of corn and its yield was carried out on corn crops of 26 farms with a total area of 500 hectares. As a result of the use of adaptogen-preparations, depending on the degree of soil salinity, the maize yield for grain increased on non-saline soils to 40.0% compared to the control of 71.1 c/ha. In lightly and medium-saline soils-81.2-83.9 c/ha at the control treatment (62.5-63.5 C/ha), the addition to yield was 30.0-32.1%. Respectively, in highly saline soil, the addition in the yield of maize grain was 11.4%, with the yield under control-47.1 C/ha. The innovative technology of the Institute in the conditions of Shaulder irrigated massif on saline soils allows making an income from 162.6 to 884.2 $ per 1 ha.

The economic efficiency of implementing the Institute's innovative technology for growing maize for grain in comparison with the existing technology varied from 427.9 $/ha on non-saline soils to 77.4 $/ha on highly saline soils. Cost payback ($/$) for the existing technology ranged from 1.16 to 1.83 $. for the innovative technology ranged from 1.30 to 2.56 $.

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Author's Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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