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The Assessment of Irrigated Land Salinization in the Aral Sea Region

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ABSTRACT

Agriculture is one of the main industries of Kazakhstan, especially in the Kyzylorda Region. Before the reforms, agriculture in this region was better developed than the manufacturing industry; this is no longer the case. The main crop grown on the irrigated land of the region is rice. Inefficient distribution of cultivated areas, their excessive use, and the growing volume of fertilizers used in the soil increases the salinization of the soil on arable land. This necessitates the investigation of the soil on irrigated land through environmental and geographical monitoring. This research analyzes the current reclamation state of irrigated cultivated land in the Kyzylorda Region located in the Kazakhstani part of the Eastern Aral Sea region, in the lower reaches of the Syr Darya River. The causes and level of soil salinization in said areas were determined. In addition, the factors that affect land salinization in the Shieli-Zhanakorgan, Kyzylorda, and Kazaly-Aral irrigation sectors were determined. The research classifies the arable land in the Shieli, Zhalagash, Karmakshy, Kazaly, and Aral Districts in terms of salinization type, characterizes its peculiarities, and investigates ways of improving the salt regime of soil on irrigated arable land.

KEYWORDS
Irrigated Land, Agriculture, Cultivation, Salt Regime Of Soil, Salinization Level

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Introduction

Nowadays, science and technology are developing rapidly, while agriculture uses techniques that reduce soil fertility (Vlasova, Kirilova & Curteva, 2016). This is proven by the fact that land reserves in many regions dwindle: 200-300 hectares of irrigated land become unsuitable for farming annually, including 30-80% due to salinization, washout, and waterlogging (Nurgizarinov, 2008).

In Russia, the humus has reduced by 13% during the last 25-30 years; in Belarus and Kazakhstan – by 10%. The quality of arable land is declining rapidly; thousands of hectares of previously arable land become unsuitable for use; all this is indicative of the exhaustion of the land reserves potential. For instance, since

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1970, the area of land in Russia exposed to erosion, salinization, and acidification has increased by two times, to waterlogging – by two times, to petrification – by three times; the area of sandy soil has increased by eight times.

In this situation, the consumption of organic substances in the soil is replenished by only 50%. This reduced the crop yield in Russia to 10.0 hundredweight per hectare (Nurgizarinov, 2006).

At present, the crop rotation area in Kazakhstan, according to statistical data, is 214.0 million hectares, i.e. 83% of the country's territory; this includes 34 million hectares of arable land and 179 million hectares of pastures. During the last 30 years, 69.7 million hectares of crop rotation land have been exposed to erosion (Nurgizarinov, 2006).

The aggravating environmental situation in the Kazakhstani part of the Eastern Aral Sea region deteriorated the natural and economic system of the region [3]. Two-thirds of the Aral Sea and hundreds of lakes in the lower reaches of the Syr Darya River, which maintained the natural balance of the region, have dried out. The climate has become dry; the natural vegetation has been exhausted; the bare soil has been covered with salt. This harmed various industries, reduced the livestock numbers, and, consequently, the output. Fishery – one of the traditional sectors – has ceased to function (Nurgizarinov, 2008).

The situation in irrigation farming is especially difficult: the areas of cultivated land have reduced, as did the output.

The exhaustion of the reclamation state of irrigated land made a considerable part of it unsuitable for agricultural activity. All this had a negative effect on the socioeconomic status of the region (Xiao et al., 2015).

The irrigated areas in the lower reaches of the Syr Darya River are also exposed to an aggravating reclamation state of the land. This is proven by the fact that 58.5 thousand hectares out of the 277.7 thousand hectares of irrigated land in the Kyzylorda Region have become unsuitable for cultivation (Nurgisayev ed., 2002).

Literature Review

Until the 1960s, the areas in the lower reaches of the Syr Darya River – the main water source of the Kyzylorda Region – did not have extensive irrigation systems and large irrigated areas; this territory had unconventional small systems (Nurgizarinov, 2008). The construction of new engineering reclamation systems commenced in 1957; a waterworks facility on the Syr Darya River was launched. Since that time, rice growing has been developing in the irrigated areas of the Kyzylorda Region (Nurgizarinov, 2006).

The irrigated land located in the lower reaches of the Syr Darya River in the Kyzylorda Region can be divided into three natural sectors: Shieli-Zhanakorgan, Kyzylorda, and Kazaly-Aral (Table 1) (Nurgisayev ed., 2002).

However, in recent years, due to the shortage of funding, the agricultural physical infrastructure has not been updated, while the previous one has been wearing out. All this has an impact on the deterioration of agriculture year in and year out. Another negative impact comes from the harsh climate and unfavorable environmental situation in the Aral Sea region (Nurgisayev ed., 2002).

Table 1. Distribution of irrigated land in the Kyzylorda Region by sectors

Irrigated land sector	Area, thousand hectares	
	Total	Including irrigated land
Shieli-Zhanakorgan	4783.1	97.6
Kyzylorda	8537.8	143.1
Kazaly-Aral	9281	36.8
Total	24899.6	277.5

According to data as of 2006, the land area of the region was 215.9 thousand hectares, including 153.8 thousand hectares of irrigated land; as of 2012, these respective figures were as follows: 218.8 thousand hectares, including 159.8 thousand hectares in use; in 2013, 157.5 thousand hectares of land were irrigated; in 2014 – 156.4 thousand hectares (Agriculture in the Kyzylorda Region, 2015). In the territory of the region, 1143.5 thousand hectares of land are potentially suitable for irrigation, but there is insufficient water to reclaim this land (Nurgizarinov, 2006).

Cereal, rice, sunflowers, vegetables, gourds, potatoes, and forage crops are grown on irrigated land. For instance, in 2014, the irrigated land in the Kyzylorda Region included areas for growing cereal (87,208 ha), rice (81,160 ha), industrial crops (925 ha), potatoes (5520 ha), vegetables (4892 ha), gourds (7571 ha), and forage crops (52,331 ha) (Agriculture in the Kyzylorda Region, 2015). The crop yield is not high – it ranges from high to low in different years. These figures are affected by the deteriorating state of the soil and excessive salinization of soil and water.

The human activity has caused degradation of the soil in the Syr Darya River delta, i.e. all land suitable for cultivation in the region has been fully reclaimed and adapted to irrigation farming.

Due to various measures for soil cultivation based on scientific and technological achievements, the soil types underwent considerable changes and lost their former genetic attributes. The physical, chemical, and biological properties of the soil changed; arable irrigated soils formed.

The formation of arable irrigated soil made it so different types of soil, which developed in different regimes and had different genetic origins as a result, acquired common attributes in terms of composition. Humus shortage reduces the biological activity of the environment, while a considerable part of elements that determine the fertility of the land is acquired through mineral fertilizers (Lopez-Sanchez et al., 2014).

Due to the regulation of the Syr Darya River flow, the natural and climatic conditions of the region were altered considerably. The river is the main factor that affects the landscape of the delta in the lower reaches: due to the river, the landscape has a complex geomorphological shape.

The zoning and characteristics of the natural landscapes in the lower reaches of the Syr Darya River have been investigated by many researchers (Valipour, 2013).

The regulation of the Syr Darya River flow reduced the volume of water that flows through the Kyzylorda Region and altered the chemical composition of the water significantly.

In turn, all these changes have a negative effect on the environmental and reclamation status of irrigated land.

Not all types of salt that enter the soil harm its fertility. The greatest harm to vegetation is done by alkali (HCO_3) and carbon trioxide (CO_3). This applies to the soil in the Syr Darya River delta. The concentration of alkali in the ion composition of the soil of this region is not very high, but research results show that the increasing amount of dry residuals in the surface soil incudes alkali formation (Saltanat et al., 2015).

Increase in the concentration of soluble salt, especially magnesium, in the soil solution and accumulation of NaCl and Na_2SO_4 generates excess calcium carbonate ($CaCO_3$), which, in turn, facilitates the formation of alkali (Ilyaletdinov & Suleymanova, 1971).

Several studies showed that during the irrigation of saline soil in Central Asia, many crops perish due to the increased concentration of alkali (Nurgizarinov, 2008; 2006). Increased concentration of alkali in the soil was found in areas used for growing rice by the end of the vegetation period (Sorg et al., 2014).

Rice was planted at the center of the Zhanadarya River bed on high ground, where undeveloped land lies under Haloxylon Ammodendron, as an experiment to obtain accurate data on the dynamics of alkali formation. Before the soil was flooded with water, the concentration of solid precipitation was 0.798%, while the concentration of alkali was 0.056%; by the middle of the vegetation period, an insignificant change in the concentration of alkali was found; however, by the end of the vegetation period, when the arable land was drained and the soil dried, the concentration of alkali increased to 0.058% (Koshkartov, 1997).

With a chloride-sulfate soil composition, the increasing alkali concentration therein is explained by salt hydrolysis by some researchers (Investigation of Dewatering and Ways of Economic Development, 2006), whereas other researchers argue that the increase in alkali ions does not result from salt dissolution (Pak, 2014).

Due to the alkali reactions that take place in the soil of the Syr Darya River delta, free hydrogen sulfide (H_2S) does not accumulate under water, especially if the environment contains a large number of ammonium cations.

In the soil that is used to grow rice, the concentration of cations is high, since cations from nitrogen compounds remain in moist soil. Their number is refreshed continuously due to the residuals of sulfate-ammonium fertilizers used on arable land, which facilitates the formation of ammonium sulfide. However, this reaction is slow.

The amount of this compound in the environment increases significantly if rice is planted on developed and fertilized soil that is rich in organic substances. In such areas, the crop yield of rice reaches 60.0 hundredweight per hectare or higher. Thus, one can assume that ammonium sulfide is good for plants (Uyttendaele et al., 2015).

In moist soils, carbon dioxide reacts with excess ammonium cations, which forms ammonium bicarbonate.

In the middle of summer, in very hot weather, ammonium bicarbonate disintegrates and forms salts:

$$NH_3 + CO_2 + H_2O = NH_4HCO_3; \; NH_4H\,CO_3 + NH_3 = (NH_4)_2\,CO_3$$

These types of salt are highly soluble in water; they increase the concentration of alkali in the soil (Golovanov & Koshkarov, 1996; Ramazanova & Nurgizarinov, 1981).

Aim of the Study

To conduct environmental and geographical monitoring of saline land in irrigated areas located in the Kazakhstani part of the Eastern Aral Sea region; to classify soils, depending on their level of salinization.

Research questions

Which processes occur during the interaction of various mineral fertilizers with the soil chemistry dynamics?

How can one reduce the level of soil salinization?

Method

The research was done in 2012-2014 in spring (late March and early May) by a team from the Kyzylorda State University in collaboration with villages from five administrative districts of the Kyzylorda Region, located in the Kazakhstani part of the Aral Sea region.

The studied area is located in Southern Kazakhstan along the lower reaches of Syr Darya River; it occupies most of the Turan Depression with plain terrain. In the west, it includes the northern and eastern part of the Aral Sea; in the south – the northern part of the Kyzylkum Desert; in the north – the Aral Karakum, Aryskum Desert, and the desert plateaus on the outskirts of Central Kazakhstan. The absolute elevations range from 200 m in the southeast to 53 m in the west, on the Aral Sea coast.

The climate in the studied area is distinctly continental. The characteristics of the climate are determined by atmospheric processes that are typical for Central Asia and the transfer of air mass, in which cyclones play the major role. Humid western and cold northern air masses lower the air temperature and cause precipitation in this territory. In autumn and winter, this area is characterized by sunny dry weather. A stationary cyclone forms above the lower reaches of Syr Darya River during the cold season, which leads to cold weather with continuous precipitation.

Besides field studies, this research used traditional methods: chronological, statistical, chemical, and cartographical.

Studied areas: 130.75 ha of land in the Shieli District from the Shieli-Zhanakorgan irrigation sector; 95.75 ha of land in the Zhalagash District and 190 ha of land in the Karmakshy District from the Kyzylorda irrigation sector; 95.25 ha of land in the Kazaly District and 75.75 ha of land in the Aral District from the Kazaly-Aral irrigation sector. Soil samples were taken and the level of irrigated land salinization was assessed in these areas.

In order to study the level of soil salinization, soil samples were taken at a depth of least 25-30 cm from each lithological or surface layer of land in an even continuous layer; from deeper layers, samples should be taken at a depth of 50-100 cm.

The taken samples were stirred thoroughly; a sample of at least 0.5 kg was taken from this mass. The selected samples were sent for chemical, spectral, electrometric, mechanical, and other analyses.

The aerospace drone method was used to conduct soil-reclamation studies and determine the distribution of land by their level of salinization; a GPS device was used to determine the coordinates of settlements and their location; Map Info Professional software was used to visualize the obtained data in a GIS environment by drawing charts of land salinization, depending on various factors.

Data, Analysis, and Results

The chemical composition of saline soil in the Shieli, Zhalagash, Karmakshy, Kazaly, and Aral Districts includes anions of calcium, magnesium, sodium, potassium, chlorine, sulfate anions, and hydrogen carbonates.

The chemical results of soil samples from the Shieli, Zhalagash, Karmakshy, Kazaly, and Aral Districts are presented in Table 2.

The chemical composition of saline soil shows the prevalence of calcium, magnesium, sodium, and potassium cations, chloride and sulfate anions, and hydrogen carbonates (Ibadullayeva et al., 2014).

Table 2. Level of soil salinization in the Shieli-Zhanakorgan, Kyzylorda, and Kazaly-Aral irrigation sectors

Soil sampling station	Depth, m	Unit	Cations			Anions			Land salinization level	Land salinization type
			Ca++	Mg++	Na+K by variety	HCO_3	Cl	SO_4		
I. Shieli-Zhanakorgan sector (Shieli District)										
1	0.5	%	0.018	0.052	0.220	0.018	0.023	0.63	Slightly saline	Sulfate
	1.0	%	0.021	0.055	0.246	0.012	0.033	0.69		
2	0.5	%	0.036	0.104	0.451	0.036	0.049	1.267	Medium saline	Sulfate
	1.0	%	0.042	0.110	0.492	0.024	0.067	1.334		
3	0.5	%	0.055	0.157	0.671	0.054	0.072	1.897	Highly saline	Sulfate
	1.0	%	0.063	0.165	0.738	0.036	0.1	1.957		
II. Kyzylorda sector										
1. Zhalagash District										
1	0.5	%	0.026	0.058	0.246	0.024	0.029	0.68	Slightly saline	Sulfate
	1.0	%	0.032	0.064	0.252	0.030	0.035	0.128		
2	0.5	%	0.096	0.164	0.511	0.096	0.059	1.327	Medium saline	Sulfate
	1.0	%	0.102	0.170	0.517	0.102	0.065	1.333		
3	0.5	%	0.115	0.217	0.731	0.114	0.132	1.957	Highly saline	Sulfate
	1.0	%	0.121	0.223	0.737	0.120	0.138	1.963		

Table 2. (*continued*)

2. Karmakshy District										
1	0.5	%	0.016	0.055	0.308	0.012	0.113	0.739	Slightly saline	Sulfate-alkali
	1.0	%	0.024	0.053	0.133	0.012	0.119	0.384		
2	0.5	%	0.096	0.036	0.384	0.018	0.518	0.46	Medium saline	Sulfate-chloride
	1.0	%	0.092	0.031	0.359	0.012	0.44	0.499		
3	0.5	%	0.108	0.029	0.064	0.012	0.142	0.317	Slightly saline	Sulfate-chloride
	1.0	%	0.06	0.029	0.191	0.018	0.163	0.422		
4	0.5	%	0.144	0.07	0.101	0.012	0.334	0.374	Medium saline	Chloride-sulfate
	1.0	%	0.136	0.067	0.239	0.012	0.326	0.643		
5	0.5	%	0.136	0.077	0.577	0.006	0.966	0.528	Medium saline	Chloride
	1.0	%	0.116	0.67	0.501	0.006	0.866	0.422		
6	0.5	%	0.12	0.05	0.584	0.012	0.951	0.422	Medium saline	Chloride-sulfate
	1.0	%	0.06	0.032	0.324	0.006	0.341	0.49		
7	0.5	%	0.055	0.157	0.671	0.054	0.072	1.897	Highly saline	Sulfate
	1.0	%	0.063	0.165	0.738	0.036	0.1	1.957		
8	0.5	%	0.12	0.05	0.584	0.012	0.951	0.422	Slightly saline	Chloride
	1.0	%	0.06	0.032	0.324	0.006	0.341	0.49		
9	0.5	%	0.056	0.158	0.670	0.055	0.072	1.897	Highly saline	Sulfate
	1.0	%	0.063	0.165	0.738	0.036	0.1	1.957		
10	0.5	%	0.018	0.052	0.220	0.018	0.023	0.63	Slightly saline	Sulfate-alkali
	1.0	%	0.021	0.055	0.246	0.012	0.033	0.69		
III. Kazaly-Aral sector										
1. Kazaly District										
1	0.5	%	0.096	0.036	0.384	0.018	0.518	0.46	Medium saline	Sulfate-chloride
	1.0	%	0.092	0.031	0.359	0.012	0.44	0.499		
2	0.5	%	0.055	0.157	0.671	0.054	0.072	1.897	Highly saline	Sulfate
	1.0	%	0.063	0.165	0.738	0.036	0.1	1.957		
3	0.5	%	0.109	0.029	0.064	0.012	0.142	0.317	Slightly saline	Sulfate-chloride
	1.0	%	0.07	0.029	0.191	0.018	0.163	0.422		
4	0.5	%	0.15	0.08	0.102	0.012	0.334	0.374	Medium saline	Chloride-sulfate
	1.0	%	0.142	0.076	0.240	0.016	0.326	0.643		
5	0.5	%	0.062	0.158	0.671	0.074	0.08	2.497	Highly saline	Sulfate
	1.0	%	0.073	0.165	0.738	0.053	0.14	2.557		
6	0.5	%	0.12	0.05	0.584	0.012	0.951	0.422	Slightly saline	Chloride
	1.0	%	0.06	0.032	0.324	0.006	0.341	0.49		
7	0.5	%	0.026	0.058	0.246	0.024	0.029	0.68	Slightly saline	Sulfate
	1.0	%	0.032	0.064	0.252	0.030	0.035	0.128		
8	0.5	%	0.036	0.104	0.451	0.036	0.049	1.267	Medium saline	Sulfate
	1.0	%	0.042	0.110	0.492	0.024	0.067	1.334		
9	0.5	%	0.096	0.164	0.511	0.096	0.059	1.327	Medium saline	Sulfate
	1.0	%	0.102	0.170	0.517	0.102	0.065	1.333		
10	0.5	%	0.048	0.054	0.221	0.018	0.023	0.63	Slightly saline	Sulfate-alkali
	1.0	%	0.051	0.057	0.247	0.012	0.033	0.69		

Table 2. (*continued*)

2. Aral District										
1	0.5	%	0.097	0.037	0.394	0.018	0.518	0.48	Medium saline	Sulfate-chloride
	1.0	%	0.093	0.032	0.369	0.012	0.44	0.519		
2	0.5	%	0.056	0.152	0.671	0.053	0.092	1.897	Highly saline	Sulfate
	1.0	%	0.063	0.167	0.738	0.036	0.18	1.957		
3	0.5	%	0.040	0.120	0.453	0.036	0.108	1.268	Medium saline	Sulfate
	1.0	%	0.046	0.116	0.484	0.024	0.203	1.344		
4	0.5	%	0.062	0.158	0.671	0.074	1.6	0.88	Highly saline	Chloride
	1.0	%	0.073	0.165	0.738	0.053	2.5	1.557		
5	0.5	%	0.096	0.164	0.511	0.096	0.059	1.327	Medium saline	Sulfate
	1.0	%	0.102	0.170	0.517	0.102	0.065	1.333		
6	0.5	%	0.13	0.062	0.587	0.012	0.951	0.423	Slightly saline	Chloride
	1.0	%	0.08	0.042	0.327	0.006	0.341	0.47		
7	0.5	%	0.115	0.217	0.731	0.114	0.132	1.957	Highly saline	Sulfate
	1.0	%	0.121	0.223	0.737	0.120	0.138	1.963		
8	0.5	%	0.096	0.164	0.511	0.096	0.059	1.327	Medium saline	Sulfate
	1.0	%	0.102	0.170	0.517	0.102	0.065	1.333		
9	0.5	%	0.026	0.058	0.246	0.024	0.029	0.68	Slightly saline	Sulfate
	1.0	%	0.032	0.064	0.252	0.030	0.035	0.128		
10	0.5	%	0.138	0.078	0.578	0.008	1.068	0.56	Medium saline	Chloride
	1.0	%	0.118	0.68	0.502	0.007	0.998	0.48		

Table 3 and the offered analysis show that in terms of salinization level, the soil is divided into three main categories: slightly saline, medium saline, and highly saline.

A cartogram of these districts was drawn to determine the level of soil salinization due to the effect of highly soluble salts. Simultaneous space and aerial imagery, which provides for a comprehensive and continuous study, was used to draw the salinization maps of irrigated arable land located across vast areas. The cartography of irrigated arable land distribution is presented in Figures 1-5.

Table 3. Distribution of saline soil in the areas of irrigated land masses Shieli-Zhanakorgan, Kyzylorda, and Kazaly-Aral

Districts	Total studies area, ha	Nature of soil in terms of salinization level							
		Slightly saline		Medium saline		Highly saline		Extremely saline	
		ha	%	ha	%	ha	%	ha	%
Shieli	130.75	38.00	29	43.75	33.5	49.00	37.5	-	-
Zhalagash	95.75	4.50	4.7	51.00	53.3	40.25	42	-	-
Karmakshy	190.0	69.75	36.7	98.25	51.7	22.00	11.6	-	-
Kazaly	95.25	21.5	22.6	61.25	64.3	12.5	13.1	-	-
Aral	75.75	24.5	32.3	39.0	51.5	12.25	16.2	-	-

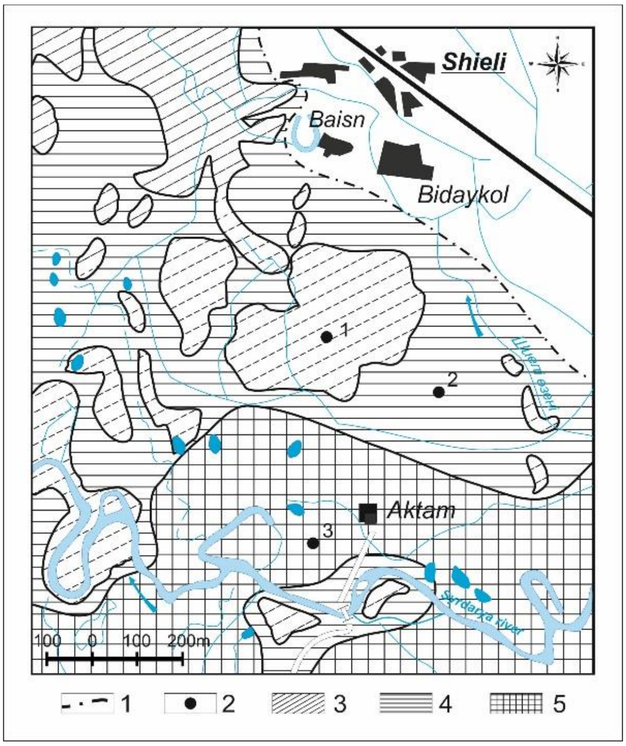

Figure 1. Salinization map of the Shieli District (Kyzylorda Region)
1 – border of the studied plot; 2 – sampling stations; 3 – slightly saline soil; 4 – medium saline soil; 5 – highly saline soil

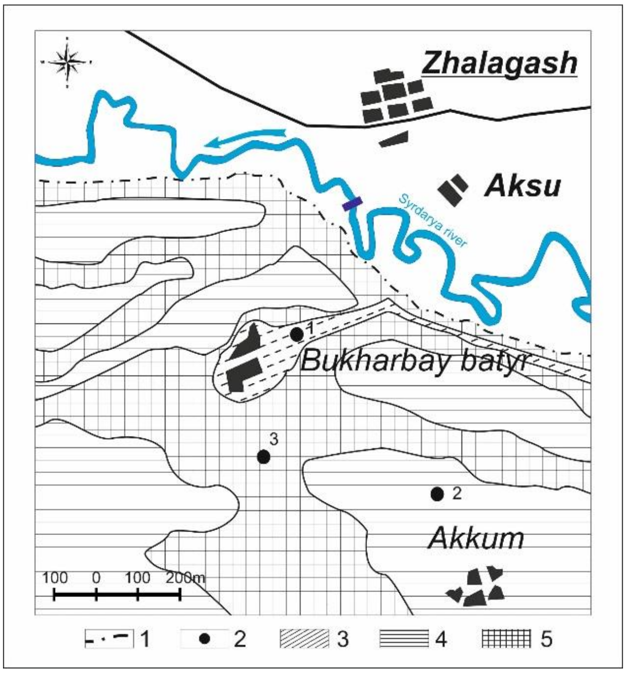

Figure 2. Salinization map of the Zhalagash District (Kyzylorda Region)
1 – border of the studied plot; 2 – sampling stations; 3 – slightly saline soil; 4 – medium saline soil; 5 – highly saline soil

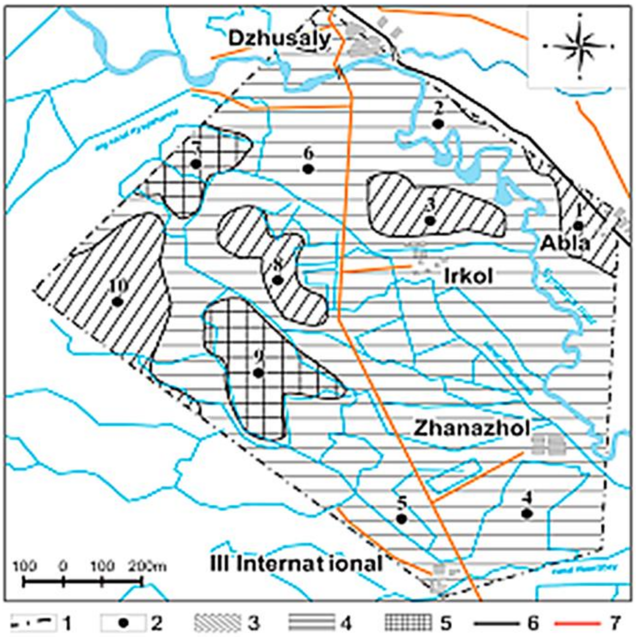

Figure 3. Salinization map of the Karmakshy District (Kyzylorda Region)
1 – border of the studied plot; 2 – sampling stations; 3 – slightly saline soil; 4 – medium saline soil; 5 – highly saline soil; 6 – railroads; 7 – motorways

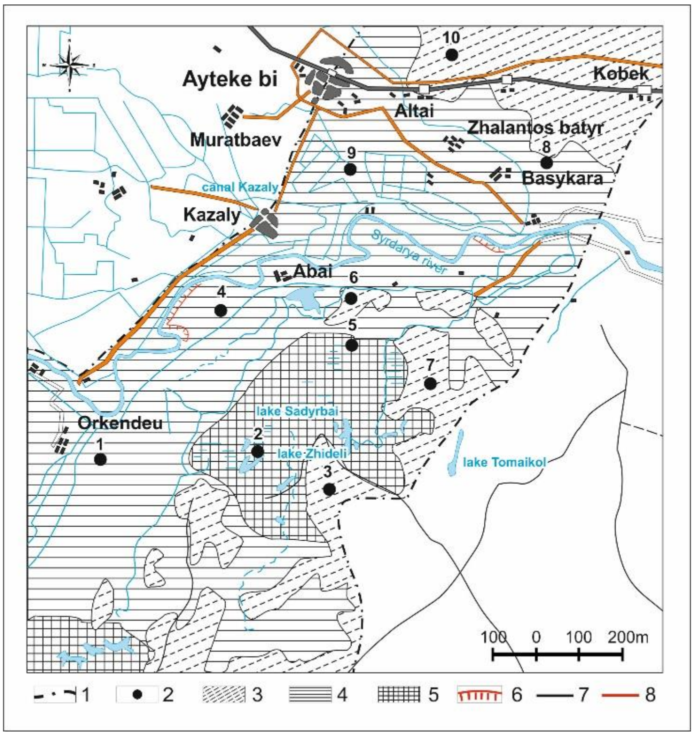

Figure 4. Salinization map of the Kazaly District (Kyzylorda Region)
1 – border of the studied plot; 2 – sampling stations; 3 – slightly saline soil; 4 – medium saline soil; 5 – highly saline soil; 6 – cliffs; 7 – railroads; 8 – motorways

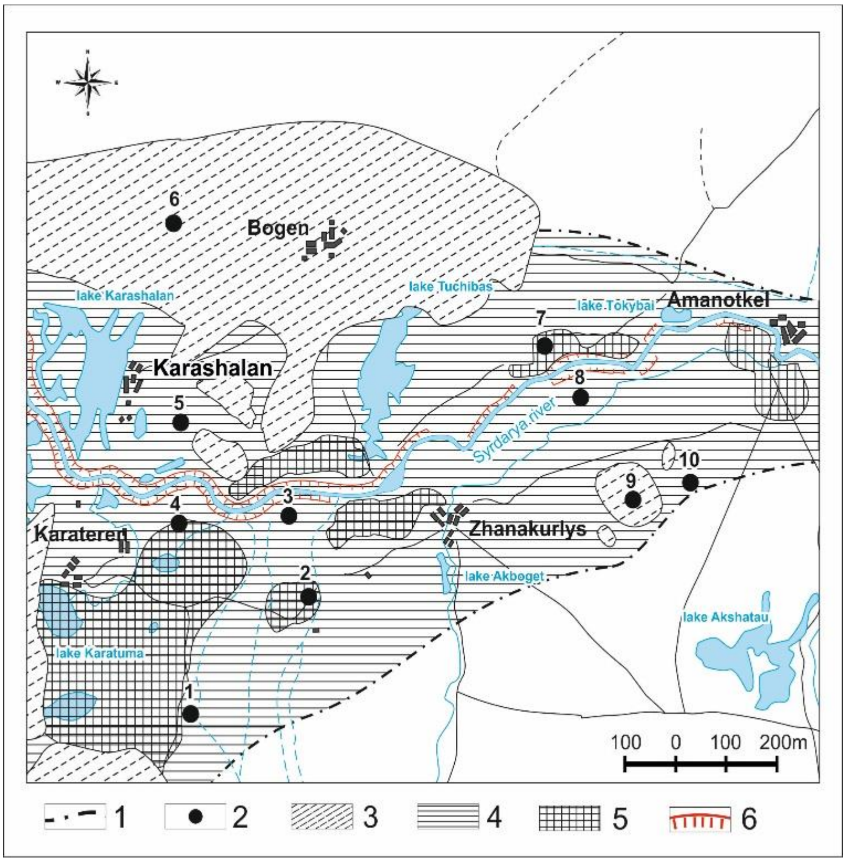

Figure 5. Salinization map of the Aral District (Kyzylorda Region)
1 – border of the studied plot; 2 – sampling stations; 3 – slightly saline soil; 4 – medium saline soil; 5 – highly saline soil; 6 – cliffs

The investigations yielded the following results: Shieli District: area of slightly saline land is 38 ha (29%), medium saline land – 43.75 ha (33.5%), highly saline land – 49 ha (37.5%); Zhalagash District: area of slightly saline land is 3.5 ha (4.7%), medium saline land – 51.0 ha (53.3%), highly saline land – 40.25 ha (42%); Karmakshy District: area of slightly saline land is 69.75 ha (36.7%), medium saline land – 98.25 ha (51.7%), highly saline land – 22 ha (11.6%); Kazaly District: area of slightly saline land is 21.5 ha (22.6%), medium saline land – 61.25 ha (64.3%), highly saline land – 12.5 ha (13.1%); Aral District: area of slightly saline land is 24.5 ha (32.3%), medium saline land – 39 ha (51.5%), highly saline land – 12.25 ha (16.2%) (Table 3, Figure 6).

In addition, it was found all the soil in the irrigated areas was saline; all areas were exposed to salinization of varying degree.

Table 3 shows that the Shieli, Zhalagash, and Karmakshy Districts are characterized by a high level of salinization. This conclusion is illustrated in Figure 6.

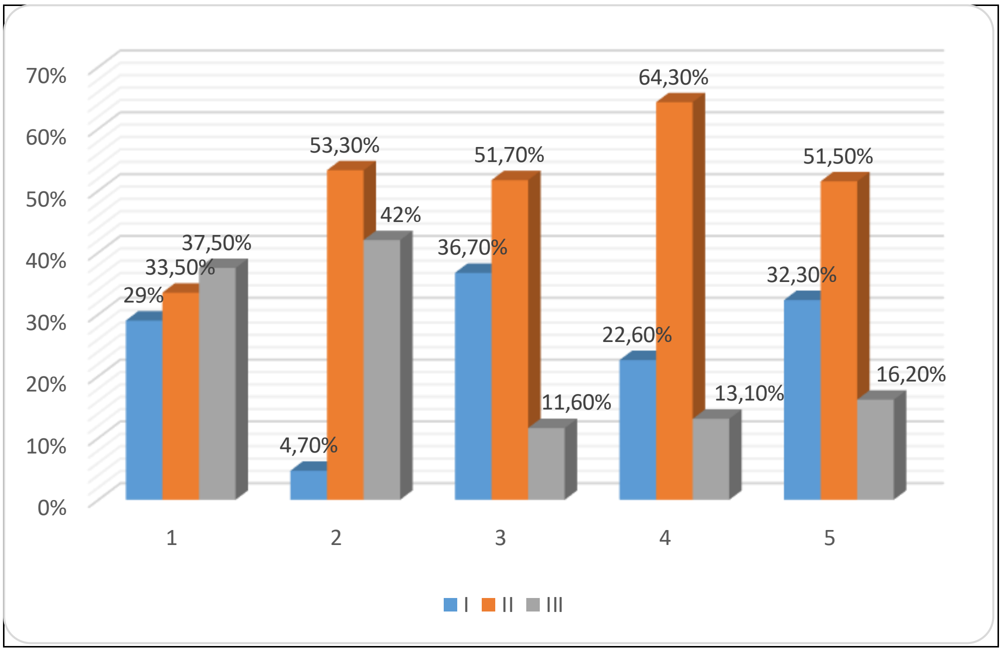

Figure 6. Distribution of soil with different level of salinization by districts of the Kyzylorda Region, in percentages.
I - slightly saline; II - medium saline; III - highly saline
1 - Shieli District; 2 - Zhalagash District; 3 - Karmakshy District; 4 - Kazaly District; 5 - Aral District

The conclusion is that the medium and high level of soil salinization prevails in the irrigated land that is used to grow rice; in areas that are used to grow other crops, slightly saline irrigated land prevails.

The investigation of the reclamation state of the soil on irrigated land over the course of several years found that the use of this land reduced the reserves of humus and nutrients, deteriorated the water and physical properties of the soil, exposed the soil to erosion, enhanced salinization, and reduced soil fertility.

The results of studies and experiments confirm that it is possible to improve the fertility and long-term efficient use of irrigated areas located in the lower reaches of the Syr Darya River – an environmentally unfavorable area – only in areas that use crop rotation. Growing rice on the same plots without rotation involving other crops is dangerous, because weed will start growing intensively on this land (Nurgizarinov, 2008).

Many plots that are used to grow rice use crop rotation; rice is mostly rotated with Medicago. The world experience showed that Medicago enriches the soil with organic substances and transforms it into a highly fertile biologically active environment.

In order to confirm these data, soil samples were taken from the Shieli-Zhanakorgan sector, namely from irrigated plots located near the Zhanakorgan village: a plot that was used to grow rice for three successive years, from a plot that was exhausted by rice planting and that was used for growing Medicago for one year, from a plot that was used to grow Medicago for two years, and from a plot that was used to grow Medicago for three years and was prepared for growing rice.

The soil samples were taken at three depths: 0-20 cm, 20-35 cm, and 35-50 cm. The results are presented in Figure 7.

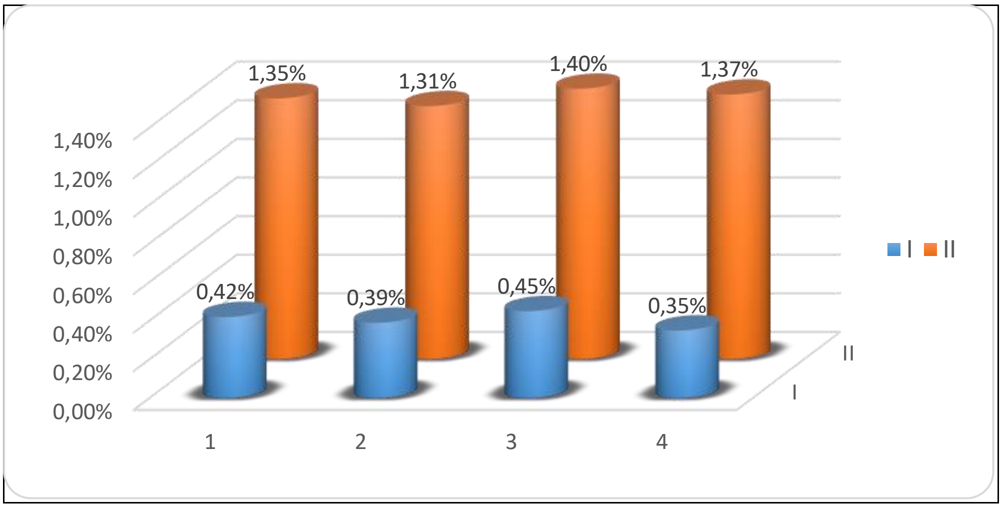

Figure 7. Concentration of salt and humus in the soil of arable plots in the territory of Zhanakorgan village

I - Total salts; II - Humus, in %.

1 - three years of rice-growing; 2 - one year of Medicago-growing; 3 - two years of Medicago-growing; 4 - three years of Medicago-growing

Since the main crop was rice grown on irrigated arable land through flooding, a high concentration of salt in the surface soil was found. In the soil that was used to grow Medicago, the salt is gradually mineralized and deposited in the substratum, which gradually reduces the concentration of salt.

The concentration of humus at a depth of 0-50 cm in the plot that was used to grow rice for three years, provided continuous and timely mineral fertilization, was 1.35%; in the plots that were used to grow Medicago without mineral fertilization, the concentration of humus increased from 1.31 to 1.37-1.40%.

Discussion and Conclusion

The investigation of the Aral Sea region land in terms of humus concentration found that the studied land had very poor respective reserves and required organic fertilizers. The concentration of labile forms of phosphorus and potassium was uneven, which is why the fertilization with appropriate chemical elements should observe the recommended doses in accordance with the cartograms of soil nutrient reserves.

It was found that the soil in the Shieli and Zhalagash Districts were dominated by sulfate salinization (from 1.957% to 1.963%), that in the Karmakshy District – by sulfate-chloride (from 0.642% to 1.053%) and chloride-sulfate salinization (from 0.586% to 1.237%), that in the Kazaly District – by sulfate-chloride (from 0.642% to 1.129%) and sulfate salinization (from 1.062% to 4.104%), that in the Aral District – by sulfate (from 0.962% to 3.54%) and chloride salinization (from 0.942% to 3.107%).

Thus, the main factors that affect soil degradation in the irrigated sectors of the Kyzylorda Region are salinization, dehumification, and loss of main nutrients.

Soil formation in the studied areas takes place in a distinct continental desert climate that is characterized low precipitation (not more than 100 mm per annum), high evaporation rate (1500-1700 mm per annum), high summer and low winter temperature, and significant fluctuation of daily temperatures (Vorozhtsov, 2008). Therefore, the presence of moisture here is the critical condition that determines the effectiveness of agriculture and sets the course of soil formation.

The entering of excess water into the territory of the region deteriorates the reclamation state, causes waterlogging and re-salinization of soil. Water shortage causes the death of cultivated crops and alters the soil formation towards desertification.

Therefore, a set of measures aimed at fighting soil re-salinization was offered.

It includes the technical upgrade of irrigation systems, channel lining, and transfer of farms to pipeline and trough networks, which will increase the energy conversion coefficient of the network and the water-use culture. At present, even simple anti-filtration operations in rice paddies, sedimentation of mainlines, and other measures against loss of irrigation water are ignored.

Secondly, it is necessary to construct and maintain a header-and-drainage network. At present, the parameters of both the main header and minor headers do not meet the designed standards: they are silted and overgrown with reed and other marsh plants.

This caused an elevation of mineralized groundwater and general re-salinization of soil. The deeper the groundwater, the quicker the desalinization of the root layer.

Implications and Recommendations

The salinization of studied irrigated soil is sulfate-chloride, sulfate, chloride, and chloride-sulfate. The anion salinization of soil includes chloride ions, hydrogen carbonates, and sulfate anions. Irrigation farming in such conditions should use intensive technologies that maintain soil fertility, such as biological reclamation and proper crop rotation involving crops that are adapted to such natural conditions.

In order to prevent soil salinization, each farm should adhere to the requirements of scientifically substantiated agricultural technologies and soil-protection measures, since the economic efficiency of agriculture and the environmental safety of the soil and products depend primarily on the observance of technological discipline and proper conduction of organizational and economic activity.

Disclosure statement

No potential conflict of interest was reported by the authors.

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