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IMPACT OF SOIL SALINIZATION ON MELIORATIVE CONDITIONS OF IRRIGATED AREAS IN KARAKALPAKSTAN

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Abstract:
This article examines the salinization levels of irrigated lands in Karakalpakstan and their impact on soil melioration conditions. It discusses reasons behind soil salinization, the various types of salinity, and measures to mitigate salinity in the soil. Furthermore, the current state of agriculture and irrigation systems is assessed, along with proposed improvement measures. Lastly, the article discusses strategies to enhance soil fertility and increase crop yields.

Keywords: Soil salinization process, groundwater level, mineralization, melioration systems, irrigation norms, water scarcity, soil meliorative condition.

The territory of Karakalpakstan, situated in the lower basin of the Amudarya River, covers an area of 160,000 square kilometers. The total land suitable for melioration in Uzbekistan comprises 1.6 million hectares, representing 37 percent of the country's territory. Currently, only 517,000 hectares of this land are cultivated and exploited for agriculture. The process of land reclamation began in the 1960s

The implementation of irrigated agriculture and rice farming practices in the Amudarya basin has led to the full utilization of river waters for agricultural purposes. Consequently, this intensive water usage has contributed to a significant reduction in the flow of water to the Aral Sea, resulting in drought and soil degradation. In recent years, communities residing in the lower basin of the Amudarya River have experienced not only challenges related to insufficient water availability for agricultural activities but also constraints on other household economic activities.

The current condition of the Aral Sea is directly linked to water insufficiency, resulting in repeated vegetative phases each year. Agricultural activities in the upper and middle basin of the Amudarya River, particularly the expansion of rice farming areas, have contributed to a reduction in water flow to the lower basin. As a result, the agricultural sector in Karakalpakstan is undergoing significant structural changes

Currently, the total irrigated area is 517 thousand hectares, with 80-90 thousand hectares dedicated to cotton and 50-60 thousand hectares to autumn wheat. Preference is given to pulse crops, which require less water during the vegetative season. Additionally, over 170,000 hectares remain unutilized, accounting for 34% of the total irrigated area. Moreover, the volume of water supplied for agricultural crops and soil salinity management has decreased from 7 km³ in recent years to 4.2 km³ in 2022, representing a 40% reduction. Over the past decade, the drainage water volume derived from district drainage systems has averaged around 2.5-3 km³ annually. However, in 2022, this amount decreased significantly to 1.5 km³, representing a 60% reduction.

Meliorative conditions of irrigated lands are evaluated as good, satisfactory, or unsatisfactory based on several factors, including the level of underground waters, the degree of mineralization, and soil salinization. Meliorative conditions are considered unsatisfactory if the following conditions are met:

- The underground level of drainage water is within 1.5 meters of the land surface;
- the soil has a high level of salinization;
- Both of these conditions are present in the soil.

Table 1 illustrates the meliorative assessment of irrigated land areas in the Republic of Karakalpakstan. As of 2022, the areas classified as good and satisfactory have increased over the past 10 years (by 7% and 2%, respectively), while unsatisfactory lands have decreased from 19% to 10%

Table 1

The meliorative assessment of irrigated lands in Karakalpakstan

T/s	Indicators	Years		
		2022	2017	2012
1.	Toral irrigated area	517,0	510,5	515,2

	of which assessed as:			
2	Good	143,8 (28%)	145,5 (28%)	110,2 (21%)
3	Satisfactory	323,5 (62 %)	289,3 (57%)	307 (60%)
4	Unsatisfactory	49,7 (10%)	75,7 (15%)	97,9 (19%)
	of which due to:			
5	Underground drainage water is close to surface	24,3 (48%)	39,3 (52%)	50,4 (51%)
6	High soil salinization	18,5 (37%)	19,7 (26%)	30,2 (31%)
7	Both conditions are present	6,9 (13%)	16,7 (22%)	17,3 (18%)

The decrease in water supply for agriculture in 2022 compared to previous years is attributed to a decline in underground water levels, which have fallen below 1.5 meters. In the context of Karakalpakstan, underground drainage water primarily originates from the filtration of irrigated lands and reservoir systems.

Moreover, the dynamics of underground water are influenced by various factors, including hydrogeological conditions, soil mechanical properties, agricultural irrigation practices, canal efficiency coefficients, drainage system length, and drainage modulus. The average depth of underground water in Karakalpakstan was recorded at 282 centimeters in 2023, marking a decrease of 51 centimeters compared to 2021. It is worth noting that an increase in the average depth of underground water correlates with a decrease in annual water supply.

In recent years, the annual water supply plan has been based on supplying water during the non-vegetative period rather than the vegetative period. This change in approach is expected to impact the dynamics of underground water, as shown in Table 2

At present, only 31% of irrigated fields in Karakalpakstan remain free from salinization, which is lower by 20% than the indicator in 1996 (in 1996, 50% of the irrigated fields were free from salinization), and the remaining areas had varying degrees of soil salinity.

Salinized soil refers to soil that is partially or wholly affected by the presence of minerals harmful to vegetation. The accumulation of salts in soil is called the salinization process. This process occurs naturally through factors such as inadequate soil leaching, the introduction of salts into plant communities (phytocenosis), and salt deposition by wind. Additionally, artificial processes such as irrigation and soil drying can exacerbate the salinization process

The primary reason for vegetation mortality in salinized soil is high osmotic pressure, which prevents plants from absorbing adequate water from the soil into their cells. This results in reduced transpiration, assimilation, moisture absorption, and hindered nutrient uptake by plants. Consequently, plant development is slowed, ultimately leading to plant death.

Secondary salinization of soil occurs gradually over time as most water supplies contain saline to some extent, including rainfall. As plants absorb water from the soil, salts are left behind, leading to the accumulation of a critical amount of salts in the soil over the years. Since soil salinization negatively impacts plant development and crop yield, measures can be taken to mitigate salinity. One such method is leaching, which involves applying excess water to the soil to flush out the accumulated salts below the root zone of plants. Secondary salinization primarily occurs in areas where underground drainage is inadequate and in agricultural regions where water with high salinity levels is extensively used.

Table 2

The dynamics of underground water distribution in irrigated fields of Karakalpakstan

#	**Months**	**Years**											
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	January	265	234	244	231	207	215	213	248	204	299	328	327
2	February	270	214	253	231	206	225	216	241	212	286	321	319
3	March	246	207	233	214	186	205	188	215	201	258	287	262
4	April	218	209	211	216	199	196	191	213	200	250	281	247
5	May	225	218	220	222	208	203	214	209	205	256	281	260
6	June	217	232	233	220	213	204	226	208	210	263	280	280
7	July	208	229	228	213	206	198	231	204	212	259	289	273
8	August	203	218	219	202	199	193	240	201	229	271	290	268

9	September	212	222	221	205	212	203	250	208	245	285	296	272
10	October	231	240	240	225	231	221	265	222	260	295	304	290
11	November	230	254	253	235	244	234	280	236	270	310	326	304
12	December	231	252	257	221	230	233	272	227	280	323	339	304
	Annual average	231	227	234	220	212	211	232	219	227	268	302	282

The main reasons for soil salinization include:

- High level of mineral content in main water supply of region - Amudarya river in some periods of year (1.6-1.8 g/l on average);
- Uneven land relief exacerbates soil salinization which impede proper drainage, preventing water movement away from the area.
- Proximity of high mineral content underground water sources to the soil surface.
- Migration of salts from hills towards the root zone due to the flow of underground water
- Low efficiency of collector-drainage systems in removing excess water from the soil
- Excessive water use in the leaching process and failure to consider ground level
- Improper irrigation practices, including excessive use of water and inadequate leaching
- Direct leaching of excess water from irrigated fields into drainage channel

The harmful salts detrimental to plant growth are categorized into the following groups:

- Most harmful salts: Na_2CO_3, $NaHCO_3$, $NaCl$
- Harmful salts: $CaCl_2$, $MgCl_2$, Na_2SO_4
- Less harmful salts: $MgSO_4$, $CaSO_4$

The classification of soil salinity types is determined based on the relationship between chloride ions and sulfate ions.

$$I_o = Cl^- / SO_4^2$$

Table 3 below provides different soil salinity types based on this ratio.

In soils with low salinity, the yield is approximately 25% less than in non-saline soils. In moderately saline soils, the yield decreases by 50%, while in highly saline soils, it drops by around 75%. In extremely saline soils, there is a complete yield loss, resulting in a 100% reduction compared to non-saline soils.

Table 3

Salinity type determination by Chloride-Sulfate coefficient

« I_o » indicator	Type of salinity
2,5 and more	Chloride
1,0-2,5	Sulfate-chloride
0,2-1,0	Chloride-sulfate
0,2 and less	Sulfate

Table 4

Soil classification based on the content of harmful salts (as a percentage of soil mass) based on N.I. Bazilevich and E.I. Pankova.

Soil salinity level	Type of salinity			
	Chloride	Sulfate-chloride	Chloride-sulfate	Sulfate
Saline free	<0,03	<0,06	<0,10	<0,15
Low salinized	0,03-0,10	0,05-0,12	0,10-0,25	0,15-0,30
Moderately saline	0,10-0,30	0,10-0,35	0,25-0,50	0,30-0,60
Highly salinized	0,30-060	0,35-0,70	0,50-0,90	0,60-1,40
Extremely salinized	>0,60	>0,70	>0,90	>0,40

CONCLUSION

In the context of water scarcity in agricultural activity:

- Groundwater levels decrease, nutrition of plants from ground water decreases, resulting in increase in irrigation norm;
- Absence of leaching during vegetation period and low efficiency of leaching increase soil salinity levels;
- Sandstorms contribute to the deterioration of irrigation and drainage systems.
- Decrease income from agriculture activity;
- Ecological sustainability is distrupted .

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