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SUBSTANTIATION OF TECHNOLOGIES FOR THE RESTORATION OF DEGRADED SOILS BY REGULATING GROUNDWATER

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ABSTRACT: The purpose of the work was to substantiate and develop technologies for the desalinization of soils by regulating the level of groundwater. The research methodology included field experiments, laboratory analyzes and mathematical calculations using formulas. The ecological and reclamation zoning of the studied massif in the Bayzak district of the Zhambyl region of Kazakhstan was carried out by the research team. A study of the hydrophysical characteristics of soils showed that 25% of the lands were non-saline, 33.3% were highly saline, and 41.7% were moderately saline soil varieties. The article presents the results of improving the efficiency of washing and watering soils using various technologies for water supply, as well as chemical reclamation elements such as phosphogypsum and manure application. It has been established that it is possible to regulate groundwater when drains are cut at a distance of 100-125 m from each other when they are located at a depth of 3 m, and the alternation of drains of different configurations using a greenhouse-type structure ensures the flow of water purified from salts through condensation into the soil. Deep loosening and the introduction of phosphogypsum and manure increased the leaching capacity of soils by 2.0-2.5 times and also accelerated the outflow of leaching fluid by 33-40%. The studied technology for the restoration of degraded soils made it possible to reduce the leaching exposure by 2.5 times compared to the traditional method. Thus, in this paper, the principles of flushing saline soils with the help of groundwater regulation were substantiated.

Keywords: Saline lands; Irrigation; Drainage; Deep loosening; Wash rates.

1. INTRODUCTION

The relevance of this research lies in the global issue of soil degradation caused by human activities and climatic changes, which can lead to significant losses in agricultural productivity and biodiversity. Anthropogenic pressure, combined with abnormal arid climatic conditions, contributes to a reduction in plant diversity, a decrease in the area and productivity of forage lands, erosion, salinity and a decrease in soil fertility, which, in turn, leads to significant losses of agricultural products [1-6]. The area of saline soils in the Republic of Kazakhstan is more than 40%, while fields with natural (primary) mineralization prevail due to the presence of marine sediments [7]. Under arid conditions on saline soils, the yield of various crops decreased by an average of 20% in India [8], at 18-43% in Europe and Asia [7], and the decline in gross harvest reached 96% [4]. In order to develop agro-reclamation measures in the development of saline lands, it is required to carry out soil-reclamation zoning and to control the parameters of such soils based on the natural laws of salinization-soil desalinization.

Studies on soil desalinization using various agro-ameliorative methods in the region have been published in the works of several authors [4; 9-11]. The increase in the intensity of soil desalinization during leaching occurs due to a change in the rate of infiltration water flow, which is achieved by changing the amount of water supplied per cycle [9]. With prolonged interaction of the wash water with the soil, a more stable balance was achieved between the concentrations of soluble salts in the liquid phase of the soil and the filtrate. At the same time, a greater saturation with salts was observed in the wash water, which indicated an increase in salt recovery from the soil. A decrease in the water flow in a porous medium made it possible to reduce the rinsing rate, and the filtration rate of the rinsing waters is less than 0.02 m days contributed to an increase in the intensity of salt removal from the washed formation (Table 1).

Table 1 A technology for reclamation measures [10]

Operation	Value
Application of phosphogypsum	6-8 t/ha
Organic fertilizers	15-20 t/ha
Plowing depth	30-35 cm
Compacted soil layers loosening depth	60-70 cm

Given the research Zh.S. Mustafayev, K.B. Abdeshev and L.K. Zhusupova [11] developed a hydro bioecological method for the development of saline soils of primary and restoration of soils of secondary salinization using ecologically specific species of cultivated halophyte plants. Uzbek researchers M.Kh. Khamidov and K.Sh. Khamrayev [12] leached saline soils using Biosolvent. The authors proved that the use of this preparation ensured the maximum removal of water-soluble salts from the soil, even with a reduction in the required washing water by 30%. For example, a leaching rate of 2906 m^3/ha reduced the salt content in the soil layer up to 1 m deep from 0.376 to 0.204% by weight of dry residue and from 0.025 to 0.008% by weight of chloride ions, while the salinity coefficient was 1.84 (dry residue) and 3.13 (chlorine ion).

Thus, the literature published data on various land reclamation measures on saline soils that require further improvement. The research was carried out in the Zhambyl region of Kazakhstan, the purpose of the work was to substantiate various technologies for the restoration of saline soils by regulating groundwater.

2. RESEARCH SIGNIFICANCE

The research presented in this study is significant in several ways. Firstly, it addresses the pressing issue of soil degradation due to salinization, which is a major problem in arid and semi-arid regions of the world. Secondly, the study evaluates different techniques for the desalinization of soils and provides evidence that regulating the level of groundwater can be an effective way to wash and restore saline soils. Thirdly, it introduces new techniques for regulating groundwater, such as cutting of temporary drains and the use of greenhouse-type structures to ensure the flow of water purified from salts through condensation into the soil.

3. MATERIALS AND METHODS

Studies on the leaching of saline soils carried out in the Limited Liability Partnership (LLP) “Kokozek”, located in the Bayzak district of the Zhambyl region of the Republic of Kazakhstan. The region was selected as a study area due to its significant soil degradation, which serves as a prime example of the negative impact of anthropogenic activities and arid climatic conditions on soil fertility. The region has been subject to intense agricultural and grazing activities, leading to the depletion of organic matter and the accumulation of salts in the soil. In addition, the region's arid climate with irregular rainfall exacerbates the problem of soil salinization. The total area of the experimental plot was 10 ha. Experimental plots (checks) had a size from 0.12 to 0.45 ha, depending on the slope, field shape, and soil structure. The height of the rollers was 35-40 cm. Temporary drains were cut through 25-50 m from each other, and there was a distance of 200-300 m between the group temporary drains. Water was supplied for washing the soil around the clock, while the checks were filled by 10-12 cm. The time interval between two single irrigations was 3 days on light loams, 5 days on medium loams, and 7 days on heavy loams. A single irrigation rate ranged from 700 to 1100 m3/ha. Soil desalinization experiments included three variants:

1. Plowing areas for checks to a depth of 30-35 cm; layout of experimental sites; cutting of temporary irrigation and hunting channels (drains); arrangement of rollers (cavaliers); washing the soil with water.

2. Carrying out deep loosening with a depth of 1-1.5 m without plowing; layout of checks on the field; cutting of temporary sprinklers and drainage with a depth of 0.8-1 m; roller device; filling checks with water.

3. Application of phosphogypsum (6-8 t/ha) and manure (25-30 t/ha) for plowing; plowing the field for experimental plots to a depth of 35 cm; carrying out deep single-column loosening to a depth of 1 m; layout of the experimental array; arrangement of irrigation and drainage channels; strengthening rollers; washing the soil with fresh water.

Furthermore, to increase the efficiency of soil desalinization on the experimental sites, large and small drains were cut in turn, the bottom of large furrows was covered with a waterproof film, and the surface of the leaching area was covered with a transparent film stretched over a frame. Mathematical calculations were carried out using the formulas A.S. Seytkaziyev [13]:

$$Q_0 = \frac{4 \times k \times h^2 \times l \times t}{R}, \quad (1)$$

Where: Q_0 – water flow to the drain, m^3; k is the filtration coefficient, m/day; h – pressure of groundwater between drainage channels, m; l is the length of the drainage, m; t – soil washing exposure, day; R is the distance between drains, m.

The water inflow to the drainage channel was calculated as follows:

$$q_0 = \frac{Q_0}{t}, \quad (2)$$

Where: q_0 is the module of the drainage runoff of groundwater, m^3/day.

Net washing rate was determined by the formula:

$$N_{HT} = \frac{Q_0 \times V \times E_k}{q_0}, \quad (3)$$

Where: N_{HT} – net flushing rates, m^3/ha; Q_0 – water flow to the drain, m^3; V is the filtration rate in saturated layers, m/day; E_k – environmental coefficient of the soil.

Soil salinity was determined by the formula:

$$\alpha = \frac{N}{10000 \times lg\frac{S_H}{St}}, \quad (4)$$

where: α is the soil salt recovery parameter; N – washing rate, m^3/ha; S_H is the initial soil salinity, %; S_t, – residual salinity, %.

Evaporation of moisture from the soil surface during leaching was calculated as follows:

$$E_0 = 0.0018 \times (25 + t)^2 \times (100 - a), \quad (5)$$

where: E_0 – evaporation of moisture during washing, m^3/ha; t is the air temperature, C; a – relative air humidity, %.

The coefficient of capillary moisture conductivity was determined by the formula S.F. Averyanov [14]:

$$K_{кв} = K_c \times (W_t - W_m | K - W_m)^{3.5}, \quad (6)$$

Where: $K_{кв}$ – coefficient of capillary moisture conductivity; K_c – filtration coefficient; W_t – full moisture capacity, taking into account compressed air; W_m is the high molecular weight water capacity in the range above the capillary level; K is the coefficient of soil porosity.

The analysis of soil samples from the experimental plots was carried out in the laboratory for the study of soil soils in the city of Taraz.

4. RESULTS

The studies were carried out in the Bayzak district of the Zhambyl region of the Republic of Kazakhstan. This region is characterized by specific agro-climatic conditions (dry summers, strong winds, large fluctuations in daily and annual temperatures, unstable snow cover in winter), as well as a flat terrain with small hills, low-water lakes and swamps. Efficient use of soils in such conditions is possible due to irrigation, soil leaching and other measures that take into account the reclamation assessment of agricultural land. Three areas were identified according to the depth of groundwater: A, B and C.

A – the area of optimal soil and insufficient surface moisture with the manifestation of hydromorphic and semi-hydromorphic solonchak process of soil formation. The groundwater level was 1-3 m from the surface. Mineralization of ground waters was 1.1-2.8 g/l (slightly brackish) and 3-9.8 g/l (brackish), and chemical analysis showed hydro carbonate-sulfate-sodium, sulfate-hydro carbonate-sodium and sulfate-chloride-sodium composition. The soils of this region are confined to a plain of alluvial-proluvial and lacustrine origin in a poorly drained and very poorly drained subregion. The soil cover was dominated by saline hydromorphic and semi hydromorphic soils, solonchaks and solonetzes. In terms of mechanical composition, heavy loams and clays were widespread in the northeastern part of the region, while light loams and sandy loams predominated in the central and southwestern parts.

B – an area of insufficient surface and soil moisture with a manifestation of a semi-hydromorphic solonetzic-saline soil formation process. Underground waters were located at a depth of 3.5-5 m. According to the mineralization of groundwater, two subdistricts were identified. The subregion adjacent to the foothill plain was characterized by fresh water (0.4-0.6 g/l), good drainage and outflow, and semi hydromorphic, nonsaline soils, predominantly of light mechanical composition. And the subdistrict, located in the northern part of the massif, had groundwater salinity from 1.2 to 6.9 g/l, sulfate-gyro carbonate-sodium and sulfate-chloride-sodium waters.

C – area of weak surface and ground moisture with the manifestation of an automorphic process of soil formation, confined to the deluvial-proluvial piedmont plain, located in the drained zone. Groundwater is fresh and, due to its deep occurrence, does not take part in soil-forming processes. The soils are automorphic, non-saline, non-saline, predominantly of light mechanical composition. The water-physical properties of the soils of this massif were studied on 12 experimental sites, 3 of them or 25% – non-saline soil varieties, 5 or 41. 7% – medium saline solonetzic 4 or 33.3% – highly saline soils and solonchaks, requiring leaching during development and combined with experimental sites for studying soil salinity. The characteristics of the soils on the experimental sites differed in various indicators and had an uneven distribution (Table 2).

Table 2 The study of the density of soils

Soil Type	Soil Density (t/m3) Range
Upper humus horizon	Lowest density
Meadow soils	1.2 - 1.47
Meadow-marsh	0.87 - 1.32
Meadow-gray soils	1.23 - 1.42
Gray soil-meadow	1.3 - 1.45
Light gray soils	1.27 - 1.33

When desalination of saline areas at a distance to the level of the calculated layer, it is necessary to determine the content of hygroscopic moisture and compressed air for various soil groups. The total water-holding capacity in any soil composition varies with the total porosity of the soil (Table 3). In the study region, there were soils of different compositions (Table 4), which had certain characteristics of absorption and retention of moisture.

Table 3 Air containing porosity in a meter layer of soils of various types

Soil Type	Air Containing Porosity (%) Range
Meadow soils	17.5 - 26.5
Meadow-gray soils	15 - 26.5
Gray soil-meadow	25 - 30
Light gray soils	15 - 24.5

To calculate the leaching rates, the lowest moisture capacity was used and, depending on the soil composition, its values varied from 19.3 to 23.9 %. In the Bayzak district, capillary moisture permeability was 0.01-0.53 m/day. The study of the mechanisms of the transfer of soluble salts in the calculated soil layer showed the dependence of soil salinity on: salt content, type of salinity, water permeability, etc. (Table 5).

α was at the level of 1.2-1.35. In such areas, the absorption of 4000 m^3/ha of water lasted 382 hours. The low soil permeability depended on the chemistry of soil salinization. On experimental sites with a high salt recovery index (1.43-3.14) and high-water permeability, the absorption of 8000 m^3/ha of irrigation water took from 24 to 53 hours. To accelerate the leaching of soluble salts with washing water, in addition to the drainage located at a depth of 3 m at a distance of 100-125 m from each other, temporary drains were cut at a depth of 0.8-1.0 m at a distance of 25-50 m and deep loosening was carried out to a depth of 1.0 m. The leaching of salts increased by 2.0-2.5 times, and the removal of wash water accelerated by 33-40%; the flushing time was reduced by 2.5 times.

To increase the efficiency of soil washing in the experimental plots, large and small furrows were cut by alternating them, and the bottom of the large furrows was covered with a film of waterproof material, and the surface of the washing plot was covered with a transparent.

Maintaining the depth of groundwater at a certain level is possible with a distance between drains of 100-125 m and a depth of their incorporation of 3 m, and better flushing of saline soils when arranging drains of various sizes using a greenhouse structure. Carrying out deep loosening with the use of phosphogypsum and manure against the background of temporary drainage also increased the efficiency of soil washing. Carbon dioxide contributed to the transition of soil phosphates into water-soluble forms accessible to plants (Table 6).

Table 4 Hydro physical parameters of soils of experimental plots, LLP “Kokozek”, Bayzak district, Zhambyl region

The mechanical composition of the soil	Soil density, t/m^3	Solid phase density, t/m^3	Porosity, %	Effective porosity, %	Full moisture capacity, %	Lowest moisture content %	Hygroscopic moisture capacity, %	Pinched air, %	Capillary moisture permeability, m/day
Sandy loam	1. 32	2. 72	51.5	46	38.7	19.3	2.2	3.1	0.53
Light loam	1. 33	2. 65	49.8	44	37.5	22.6	3.1	3.0	0.24
Medium loam	1. 42	2. 67	46.8	41	33.1	23.0	3.5	2.5	0.07
Loamy	1. 45	2. 65	45.3	40	31.0	23.3	4.0	2.0	0.02
Clayey	1. 47	2. 63	44.1	39	29.9	23.9	4.5	1.5	0.01

Table 5 Salinity and return of salts of soils during soil leaching against the background of drainage in LLP “Kokozek” of Bayzak district of Zhambyl region

Soil name	Salinity type	Net wash rate (N_{nt}), m^3/ha	The content of salts in the washing layer (S_n), %	Residual salinity (S_t), %	lgS_n/S_t	Salt recovery index (α)
Meadow salt marsh	chloride sulfate	2000	0.98	0.71	0.140	1.43
		4000	0.98	0.56	0.243	1.65
		6000	0.98	0.52	0.275	2.18
		8000	0.98	0.40	0.389	2.06
Meadow-gray soils, highly saline	chloride-sulfate, with the participation of soda	2000	1.84	1.53	0.080	2.50
		4000	1.84	1.29	0.154	2.59
		6000	1.84	0.82	0.351	1.71
		8000	1.84	0.41	0.652	1.23
Meadow-gray soils, highly saline	sulfate-chloride, with the participation of soda	2000	1.40	1.18	0.074	2.69
		4000	1.40	1.04	0.129	3.10
		6000	1.40	0.68	0.314	1.91
		8000	1.40	0.30	0.669	1.20
Meadow-marsh, desertificatio, highly saline	chloride sulfate	2000	1.69	1.38	0.088	2.27
		4000	1.69	1.26	0.128	3.14
		6000	1.69	0.69	0.389	1.54
		8000	1.69	0.43	0.594	1.35

Table 6 Washing rates of a meter layer of saline soils in LLP "Kokozek" Bayzak district of Zhambyl region

Soils by texture	Soil density, t/m^3	Moisture capacity, %	Saturation rate, m^3/ha	One-time washing rate, m^3/ha	Evaporation, %	Warm water for washing, m^3/ha	Flushing rate for salt displacement, m^3/ha	General washing rate, m^3/ha
Sandy loam	1.32	19.3	2035	700	0.13	4500	810	3308
Loamy	1.45	23.3	3270	900	0.14	5500	1096	4380
Clayey	1.47	23.9	3690	1100	0.17	6000	931	4839

One of the key factors affecting the state of soil salinity is the evaporation of moisture from the surface of groundwater, which determines the need to calculate this parameter for soils with different hydrophysical parameters. For this, sites without vegetation were allocated in the experimental plots. It was found that a certain degree of mineralization of groundwater corresponded to the specific amount and chemical composition of salts in soils. During the study period, the groundwater level varied from 1 to 4 m. The results of the experiments are shown in Table 7.

It has been established that stronger evaporation from the surface of groundwater was observed when groundwater was located at a depth of up to 1 from the surface, and weaker – at a depth of 2-3.5 m. Thus, the reclamation measures for washing saline soils in arid conditions of the Bayzak district of the Zhambyl region showed high efficiency, which made it possible to preserve the natural processes of soil desalinization and to prevent secondary salinization of lands.

5. DISCUSSION

Ecological and reclamation zoning is one of the reliable methods for reclamation assessment of agricultural land, it is based on a systematic approach to the spatial division of the territory, taking into account the specifics of the soil cover. This method makes it possible to carry out rational, environmentally friendly land reclamation measures and predict the appearance of negative processes: soil degradation, secondary salinization, reduced fertility, and depletion of the soil cover. In turn, this makes it possible to realize the natural potential of soils in full [15].

According to Yu. Bezborodov, K. Beysenbin, N. Khozhanov and Auganbaeva Zh. [4], the current ecological and reclamation state of irrigated lands in the steppe zone of Kazakhstan requires a revision and modernization of the structure, placement and ratio of cultivated crops depending on the height of the terrain. Moreover, existing cultivation technologies that have exhausted the possibilities of increasing soil fertility also need to be improved. The continuous irrational exploitation of resources has led to an increase in the adverse anthropogenic impact on the environment, on the condition of the soil, which could not but affect the sustainability of steppe agriculture and, as a result, led to a decrease in soil fertility and gross harvest.

There are two types of soil salinization in the study area: primary (of natural origin) and secondary, resulting from human activities. This process is observed in areas with arid climatic conditions, most often in lowland plains. The natural accumulation of salts in soils is due to a certain form of terrain, geomorphological and hydrogeological conditions. It is observed in places with elevated levels of groundwater, insufficient flow and drainage [7].

Among the main sources of salinization of soils are parent rocks with a rich content of salts, mineral groundwater, as well as surface flows and eolian movement of salts. The secondary salinization of soils is facilitated by the rise of groundwater as a result of irrigation and land flooding, the influx of salts with irrigation water, and other factors.

Therefore, in order to prevent soil degradation, before the start of irrigation activities, it is necessary to assess the suitability of lands for irrigation, taking into account a number of indicators. In the Bayzak district of the Zhambyl region, three districts were identified with different depths of groundwater, with different types and degrees of soil salinity. It was established that soils with medium salinity (41.7%) dominated, 25% of the territory was occupied by nonsaline soil varieties, and 33.3% by highly saline soils. This indicates the need for reclamation and restoration measures on the third part of the studied lands.

According to a number of researchers [16], irrigation negatively affects the condition of soils and the landscape. This leads to the search for ways to use degraded lands as a result of secondary soil salinization. There is even the concept of "roaming farming" and its various variations. Thus, it is proposed to take soils out of the irrigation system for some time for restoration and desalinization, switching to a rainfed regime and growing drought-resistant crops. The hydrochemical regime of soils can be regulated by influencing the level of groundwater; for this, various reclamation measures are carried out: watering, washing soils, deep loosening of drainage areas.

Table 7 Salt content, mineralization and surface evaporation of groundwater in LLP "Kokozek" of Bayzak district of Zhambyl region

Groundwater mineralization, g/l	The reserve of salts in the soil		Groundwater depth, m						
	(0-1 m)		0.5	0.75	1.0	1.5	2.0	3.0	3.5
	%	t/ha	Surface evaporation of groundwater, m^3						
Loamy soils			1289	905	633	302	139	22	6.6
1.2	0.34	49	1.289	0.905	0.633	0.302	0.139	0.022	0.007
			0.645	0.453	0.317	0.151	0.070	0.011	0.003
2.4	0.56	80	2.578	1.810	1.266	0.604	0.278	0.044	0.013
			0.848	0.595	0.416	0.199	0.091	0.014	0.004
3.8	1.2	172	3.197	2.263	1.583	0.755	0.348	0.055	0.016
			1.372	0.971	0.679	0.324	0.149	0.024	0.007
5.3	1.6	229	3.836	2.715	1.899	0.906	0.417	0.066	0.018
			1.835	1.299	0.909	0.433	0.200	0.032	0.009
6.9	2.1	300	5.115	3.620	2.532	1.208	0.556	0.088	0.024
			2.570	1.819	1.272	0.607	0.279	0.044	0.012

Note: $\gamma = 1.45$ t/m^3; $n = 1.1$; $H_{vps} = 4$ m.

It should be noted that hydro physical and physicochemical processes also influence the water-salt, thermal and nutrient regime of soils. It has been proven that in order to regulate groundwater, it is required to adhere to certain rules for the manufacture of a drainage system. Thus, the distance between drains of 100-125 m at a depth of 3 m made it possible to achieve a good outflow of water, and the use of a greenhouse-type structure in combination with drains of different sizes made it possible to effectively use local waters for washing saline soils without their desalination and heating.

According to N.P. Karpenko, A.S. Seytkaziyev and A.K. Maymakova [10], simultaneous plowing and deep loosening of the soil led to a significant acceleration of the leaching season by 2.5-3 times to the preservation of soil fertility from the removal of various mineral and organic substances and also contributed to the accelerated movement of soluble concentrations of harmful salts through the capillaries of the calculated soil layer. This operation made it possible to preserve the fertility of the soil, as well as to improve the water-physical properties of the studied soils. The authors argue that deep loosening against the background of temporary drainage is an effective means of extracting salts from gypsum-bearing and heavy loamy solonchak soils. Also, some authors [17] argue that chemical reclamation on alkaline soils using phosphogypsum reduces soil salinity by 3-5% of exchangeable sodium from Σ soil absorption complex, and to enhance the reclamation effect, it is necessary to add organic matter and carry out deep loosening. At the same time, the density and structure of soils are optimized and the humus content increases.

It has been experimentally proven that in LLP "Kokozek" the use of deep loosening of soils, phosphogypsum and organic fertilizers against the background of the use of temporary drains made it possible to increase the removal of salts by 2.0-2.5 times, and also to accelerate the removal of wash water by 33-40%, while it was observed reduction of flushing time by 2.5 times compared to other technologies. Modern research is increasingly based on environmental aspects (Table 8).

That is, to improve the state of saline soils, along with traditional parameters, it is necessary to take into account the radiation index (Rн) of a particular area. M. Schück and M. Greger [18], M. Shaygan and T. Baumgartl [19], M. Hasanuzzaman and M. Fujita [6] are sure that the removal of salts by halophyte plants is the most effective way to remove salts harmful to crops from the soil, and drainage, flushing and flushing irrigation mode only contribute to the redistribution of salts and do not allow them to be removed from the biological cycle. To radically improve the reclamation state of land for a long time and increase soil fertility, salts must be removed from the soil.

Table 8 The main factors affecting the reclamation regime of soils in the arid zone [4]

Factors	Proportion (%)
Total solar radiation	42
Soil fertility	15
Soil salinity	9
Air temperature	9
Humidity air	8
Precipitation	4
Wind speed	4
Water availability	3
Groundwater salinity	1
Soil lithology	1
Irrigation water salinity	1

This is possible with the implementation of biotic land reclamation with the cultivation of salt-tolerant crops. In their opinion, this improves the soil, hydrological and biological conditions of farmland and also makes it possible to introduce a large amount of inconvenient land into the crop rotation. Y. Yue, W.N. Guo, Q.M. Lin, G.T. Li and X.R. Zhao [20] also came to similar conclusions, L.V. Khudolyeyeva and N.K. Kutsokon [21]. The authors used halophytic plants in experiments and proved their effectiveness in combating erosion and deflation of soils, which contributed to an increase in the productive potential of crops [22-25]. Thus, there is a need for further research and development of various technologies for the restoration of degraded soils, not only with the regulation of the groundwater level but also in combination with agrotechnical, chemical, biological, and other types of land reclamation.

6. CONCLUSION

In order to develop technologies for restoring degraded soils by regulating groundwater, a study was conducted on soil leaching in the LLP “Kokozek” located in the Bayzak district of the Zhambyl region in Kazakhstan. Three regions were identified based on the depth of groundwater: those with the optimal ground and insufficient surface moisture, those with groundwater occurrence up to 3 m (A), those with insufficient soil and surface moisture and groundwater at a depth of 3.5-5 m (B), and those with weak surface and ground moistening and deep occurrence (more than 5 m) of fresh groundwater (C). The study revealed that 25% of the soils were non-saline, 33.3% had strong salinity, and 41.7% had medium salinity. The water-physical properties of the soils were also analyzed, showing that the upper humus layer had the lowest density and the lowest moisture capacity.

To wash saline soils effectively, it was found that a water supply rate of 2000 to 8000 m3/ha could achieve a salt recovery index of 1.2-3.14. Drains placed at a distance of 100-125 m and a depth of 3 m, along with the use of a greenhouse structure, proved to be effective in regulating groundwater and washing saline soils. Deep loosening, combined with the introduction of phosphogypsum and manure, contributed to an increase in salt removal by 2.0-2.5 times, an acceleration of the removal of wash water by 33-40%, and a reduction in washing time 2.5 times compared to traditional technology. The study also revealed a correlation between the degree of mineralization of groundwater and the salt composition of the soils, and showed that moisture evaporated more strongly from the surface of groundwater occurring at a depth of up to 1 m. Overall, the study provided important insights into technologies for the restoration of degraded soils through the regulation of groundwater in the Bayzak district of Kazakhstan.

Thus, the practical significance of this work was to substantiate and develop reclamation measures to restore degraded soils using groundwater-level regulation techniques. The results obtained from the study of soil degradation and restoration techniques in the Bayzak district of the Zhambyl region of Kazakhstan have country-wide applicability.

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