Pol. J. Environ. Stud. Vol. 32, No. 1 (2023), 789-805
DOI: *10.15244/pjoes/155087* ONLINE PUBLICATION DATE: 2022-12-13

Original Research

Assessment of the Current Soil-Reclamation State of the Soils of Myrzashol in the Kazakhstan Part (The Hungry Steppe)

Aigul A. Tokbergenova[1]*, Kanat B. Zulpykharov[1], Damira M. Kaliyeva[1], Meirzhan Y. Essanbekov[2]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]Republican State Institution South Kazakhstan Hydrogeological and Reclamation Expedition, Shymkent, Kazakhstan

Received: 3 June 2022
Accepted: 2 October 2022

Abstract

Central Asia is well-known for its productive irrigated lands and pastures. However, the region is currently dealing with serious land degradation and soil salinization issues.

This article discusses the problem of soil salinization in the Kazakh part of the Myrzashol massif (The Hungry Steppe), where irrigated agriculture is developed.

The reclamation state of the soil cover in this massif was assessed using field and laboratory studies from 1995 to 2014 and from 2014 to 2020. In the study area, in the period from 2015 to 2020, several samples were continuously taken before the growing season, as well as after the growing season at 529 wells for sampling the level and mineral composition of groundwater and the chemical composition of the soil.

If in 1995, out of 125.4 thousand hectares of irrigated land, 31.8 thousand hectares (25.4%) were moderately and heavily salted, then in 2020, out of 146.5 thousand hectares of land, 57 thousand hectares (38.7%) were subjected to secondary salinization. Over the last 25 years, the area of moderately and heavily saline lands on the irrigated Myrzashol massif has grown by 25.2 thousand hectares.

Before the transformation of the Myrzashol zone into an irrigated one, the groundwater level was within 15-30 m. In 2020, the groundwater level on the irrigated area of 3622 ha was 0-1 m (in 1994 it was 105 ha), on 38,155 ha (in 1994 it was 7,792 ha) - 1-2 m.

The results of the study showed that the increase in the level of salinity of the soil cover is associated with an increase in the groundwater level due to the poor level of irrigation systems, as well as the weak filtration capacity of soils.

Keywords: irrigated soils, salinization, groundwater level, land reclamation, type of salinization

*e-mail: e-mail: tokbergen@mail.ru

Introduction

The world's agricultural land resources are 1,527 million hectares, including 1,212 (79.4%) million hectares of rain-fed land and 315 (20.6%) million hectares of irrigated land. To date, 139 million hectares (44.1 percent) of the world's irrigated land are susceptible to anthropogenic degradation, and the condition of land on an area of 57 million hectares (18.1 percent) is considered poor [1].

Salinization is the main factor limiting crop production in many regions of the world. It is estimated that approximately 20% of cultivated lands in the world and 33% of irrigated lands are subject to salinization and degradation [2].

Various environmental stresses, such as strong winds, extreme temperatures, soil salinization, drought, and floods, have impacted agricultural crop production and cultivation, with soil salinization being one of the most damaging environmental stresses, resulting in a significant reduction in cultivated land, yield, and crop quality [3].

Saline and soda soils cover roughly 11.737 million km^2 globally, mostly in dry and semi-arid areas [4, 5].

Salinization is a process that has mixed causes (natural and anthropogenic) throughout the planet, anthropogenic factors of which are associated with the use of irrigation and other human activities, such as changes in soil cover and land use [6].

The high absorption of groundwater by plant roots contributes to the accumulation of more salts than in meadows throughout the unsaturated soil profile (from the groundwater level to the surface) [7].

Agricultural land is degraded as a result of salinization processes. Land degradation affects agricultural production dramatically on a global, regional, and local scale [6, 8].

In Central Asia, on the border between Kazakhstan and Uzbekistan, the intensification of salinization due to the drying of the Aral Sea is widely known, mainly as a result of the expansion of arable land and irrigation more than five decades ago, which sharply reduced the runoff from the Syrdarya and Amudarya tributaries (and, consequently, increased salinization conditions) [9-11].

Land degradation as a result of this incorrect policy is still a serious problem in all Central Asian countries, with land salinization affecting approximately 15% of irrigated lands in Kazakhstan, 12% of total irrigated lands in Kyrgyzstan, 50-60% in Uzbekistan, and more than 90% in Turkmenistan [12, 13].

Combating desertification in Central Asia necessitates the development of novel, quick, and low-cost methods of observing spatial patterns of soil salinization [14].

Almost 60% of the population of Central Asia depends on agriculture as a source of food and income, and soil fertility guarantees food security and well-being to the entire population of the region.

Soil salinization is a serious challenge that requires coordination between countries that share water and land resources. The fight against soil salinization should be considered in combination with other measures aimed at sustainable intensification of agriculture as one of the foundations of food security.

The studies of Kovda V.A., Pankova E.I., Aidarov I.P. and others [15, 16]; have established that the natural cause of the relict and modern accumulation of salts in soils and waters in Central Asia are climate features, relief, geomorphology, geology of mountain formations and the history of the development of the Turan province itself.

Methods and models that allow assessing the condition of lands and, most importantly, predicting changes in the natural resource potential in conditions of anthropogenic impact are currently insufficiently developed. At the same time, it is known that the forecast of possible changes in the state of lands in the process of their use is the basis for the development of a system of measures for the conservation and effective use of natural resources.

Kazakhstan is one of the world's largest countries in terms of land resource occupied area and natural resource variety.

The soil cover of country varies from that of other countries in that it has low resistance to anthropogenic loads and is vulnerable to deterioration and desertification processes.

More than 75% of the total territory is subject to these processes to varying degrees. In this regard, there is a reduction in the area of agricultural land. The main reasons for the decrease in the area of farmland are the degradation of the soil cover in the desert and semi-desert zone, salinization of soils in the zone of irrigated agriculture [17].

In Kazakhstan, irrigated agriculture plays a leading role in agricultural production. Irrigated lands, in the total area of crops in the republic, as a percentage, occupy a relatively small part, and range from 10.7-11.7%, and used ones are even less than 6.8-7.7%.

At the same time, the share of agricultural production in value terms on irrigated lands is 28.7-32.3%. Crops such as cereals (10.3%), corn for grain (4.2%), rice (5.5%), cotton (12.9%), potatoes, vegetables and melons (8.8%), perennial herbs and others (58.2%) are cultivated on the irrigated lands of the republic [18].

Every year, significant areas of irrigated land (from 20 to 30%) remain unused in the irrigated agriculture zone of the republic for various reasons. The return of the irrigated hectare is still not high, one of the reasons is the low technical level of most irrigation systems and the deterioration of the reclamation condition of irrigated lands [19].

The goal of this study is to investigate the current state of soil reclamation of irrigated soils in the Kazakh part of the Myrazasholsky massif (the Hungry

Steppe), taking into account natural and anthropogenic factors, to identify the causes, patterns of formation, and geographical distribution of saline soils, to assess the change in the dynamics of water-salt regime on irrigated soils, to identify regional features of salt accumulation and secondary salinization, and to make recommendations. The new and reliable data on the depth of occurrence, mineralization and chemical composition of groundwater, the degree and types of soil salinization, the content and reserves of water-soluble salts, material analysis and generalization allowed for an assessment of the soil reclamation situation of the territory.

Materials and Methods

The object of the study was the irrigated soils of the Kazakh part of the Myrazashol massif (The Hungry Steppe).

To solve the set tasks, together with the South Kazakhstan hydrogeological and reclamation expedition, extensive field studies were conducted, i.e. salt survey of soils on a scale of 1:50000 on the entire territory of the region.

When using collector-drainage waters, the ecological and meliorative state of irrigated lands largely depends on their mineralization and the qualitative composition of surface water salts. Therefore, ecological and reclamation assessment of irrigated areas requires, first of all, the degree and chemistry of water salinity and comparing them with MPC (maximum permissible concentrations). Therefore, the suitability of collector-drainage waters for irrigation of agricultural crops was assessed by the following indicators: the dangers of soil salinization, the toxicity of individual ions. To characterize the quality of irrigation water, the following are determined: total salt content, quantitative indicators of anions, quantitative indicators of cations, different ion ratios, the presence of soda, toxic and non-toxic salts.

The chemistry of water salinity is determined by the ratio of ions among anions and can be supplemented by the same ratio of ions of the cationic part [20]. This is especially important for detecting soda salinization and predicting the possibility of soil salinization during irrigation and washing. The dominant position among sodium and magnesium cations during irrigation or washing leads to salinization of soils.

In total, 529 reference (key) and several dozen intermediate soil sections were laid on the studied territory, in 2020, 1729 soil samples and groundwater samples were selected for chemical analyses according to genetic horizons, and 15795 measurements of the groundwater level were carried out.

In 2002, 90 control wells and 3 piezometric control wells were created on the territory, in 2005 431 control wells and 5 piezometric control wells were put into operation. Since 2005, monitoring of the groundwater level in the territory has been carried out every 10 days, and determination of its salinity and chemical composition is carried out regularly three times a year.

The research uses genetic-geographical, profile-geochemical, comparative-geographical, natural-field and chemical-analytical methods.

In the cameral post-field period, processing of field, cartographic and laboratory analytical materials was carried out. A map of the reserves of water-soluble salts of the upper 0-1-meter soil layer of the districts has been compiled.

As a result of the conducted field and laboratory studies, maps of the groundwater level, salinity of groundwater and the degree of salinity of the soils of the Myrzashol irrigated massif on a scale of 1: 50,000 were compiled.

Field work was carried out jointly with scientists of the South Kazakhstan Hydrogeological and Reclamation expedition and soil samples taken during field work, and samples from underground and surface waters were examined in laboratories.

To evaluate the elements that influence the pace of decomposition processes in the root zone, exhaustive soil tests were conducted:

1) to determine the dynamics of moisture and salt migration during the growth season;

2) to determine the rate of ion exchange reactions between the soil solution and the soil-absorbing complex in the root zone in response to variations in salinity and groundwater levels. Soil and water samples were analyzed chemically in order to ascertain the degree of degradation processes.

Based on the chemical properties of soils, the cationic composition of the soil-absorbing complex, pH, and ionic composition were determined three times; during the chemical analysis of water (irrigation, ground, collector-drainage), the total content of salts, anions, cations, and pH were determined. Several indicators were utilized to evaluate the qualitative composition of irrigation, collector-drainage, and wastewater:

1) the magnesium cation content (Mg); 2) the irrigation coefficient and 3) the sodium adsorption coefficient (SAR) [21]. It is well known that the ecological and reclamation state of irrigated areas is contingent upon the technical condition of irrigation systems.

During field research, the dynamics of soil moisture, the rate of absorption, the filtration of water, changes in the cationic composition of the soil-absorbing complex, and the ion-salt composition of soils were observed. Using the balancing approach, the limits of changes in salt reserves and the cationic composition of the soil-absorbing complex in the root layer of the soil were determined for each variant upon completion of the research.

Results and Discussion

According to UNESCAP (2007), drought and desertification afflict all Central Asian countries. Desertification covers 66% of the area in Kazakhstan, and 80% in Turkmenistan and Uzbekistan. Erosion affects around 88% of arable land in Kyrgyzstan and 97% of agricultural land in Tajikistan. Despite the fact that the majority of these countries' populations live in rural areas, desertification and land degradation have a significant impact on their ability to survive [22].

This map is compiled by the Center for Environmental Remote Sensing (CEReS) of Chiba University, Japan. This study examines the following types of desertification: 1- degradation of vegetation cover, 2- wind erosion, 3-water erosion, 4- soil salinization, 5- soil salinization caused by a drop in sea level, 6 Waterlogging of natural pastures in Central Asia.

The Hungry Steppe (Myrzashol) is an area of historical desertification and salinization, covering about 10,000 km^2 in the territories of Uzbekistan, Southern Kazakhstan and Tajikistan (Fig. 1). It is a rolling plain totalling 1 million hectares at an altitude of 200-400 m above sea level [23].

Historically, irrigated arable lands occupied a smaller part of the territory located in the Syrdarya valley. In the 1960s, irrigation agriculture was significantly expanded and covered significant saline areas west of the Syrdarya River [14].

In the zone of the Hungry Steppe, in connection with the development of land, the implementation of water reclamation measures, the implementation of a complex of agrotechnical measures by I. Umbetaev and Zh.Y. Batkaev [24, 25]; 4 stages were allocated.

Stage I - the beginning of land development (1928- 1930) until the mid-50s. This period is characterized by a slow pace of development of new virgin lands with unlimited opportunities in water and land resources. During this period, mineralized groundwater lay deep (12-15 m) [26]; and soils had automorphic processes. Water was supplied to farms with an excess of 1.5-2.0 times the demand. The irrigation rate of cotton reached up to 12-20 thousand m^3/ha. As a result of such mismanagement of irrigation water, groundwater in the 50s rose to 3-4 m from the daily soil surface.

II stage from the 1950s-1960s to the 1970s. This period is characterized by a high rate of development of shifting lands [27].

Extensive development of new lands was not accompanied by the necessary construction of a collector-drainage network. Water intake began to be limited and the irrigation rate decreased from 12-20 thousand m^3/ha to 10-12 thousand m^3/ha. Salt intake exceeded losses by 2.4-2.5 t/ha. As a result, 50-55 % of the land is moderately and heavily saline. Therefore, in the period from 1955 to 1965 there was a decrease in the cotton harvest from 28-30 c/ha to 17-24 c/ha.

III stage from 1968-1970 to 1990-1992. This period is characterized by the development of the collector-drainage network, the fight against salinization based on vertical drainage, the irrigation washing regime, the implementation of a complex of water reclamation measures, as well as the introduction of intensive technology of agricultural practices, including mechanization, chemicalization, etc. By 1975-1980, the construction of 884 vertical drainage wells was completed in the former three districts of the southern cotton-growing zone of the region. [28].

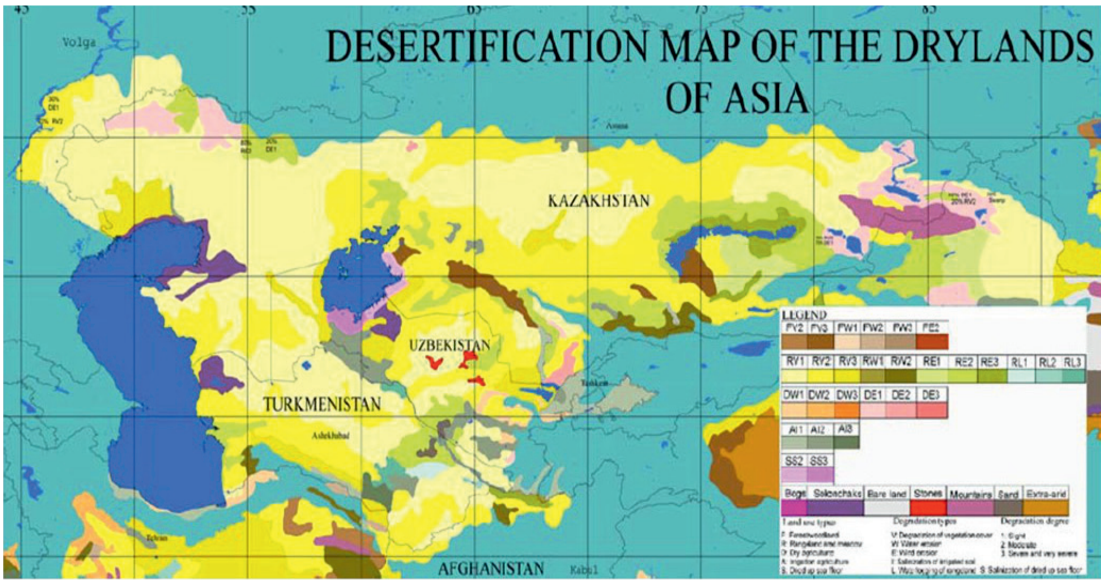

Fig. 1. A map of the desertification of the arid regions of Asia (the clipping shows only the Central Asian region). Resource: Khrain et al, 1999. Available on the website: http://lada.virtualcentre.org/eims/download.asp?pub_id=96960&app=0.

During this period, field planning (current and capital), anti-filtration measures of canals have been intensively carried out since the early 70 s. This made it possible to regulate the level of groundwater occurrence depending on the period of the year at a depth of 1.5 m in spring to 3.5 m in autumn.

The irrigation washing regime in 1970-1985 allowed to achieve a negative salt balance, salt removal increased from 9.7-14.5 t/ha to 20-25 t/ha. Thanks to all these measures in 1979- 1980, 80-85% of the lands were transferred to unsalted and slightly saline categories. Only 5-10% of the lands remained moderately saline, and heavily saline lands completely disappeared. For this reason, in 1976-1980, the yield of cotton in the southern zone of the region rose to 32-35 kg/ha.

IV stage from 1991 to the present. Collective farms and state farms were transformed into small peasant farms and cooperatives. Many farmers and peasant farms had no idea about the technology of cotton cultivation and allowed gross violations in carrying out agricultural techniques of sowing, pest control, water use, etc.

After the 1860s, when Central Asia was annexed to the Russian Empire, cotton became a key crop in the irrigated areas of the Syrdarya River in southern Kazakhstan [18].

Cotton becomes a monoculture, crop rotation is not observed by small farms, farmers sow crops at their discretion.

The fourth stage is characterized by the limitation of water use, a sharp deterioration in the operation of both irrigation and drainage systems, gross violations in intensive cultivation technology.

In 1991-1993, the utilization rate of vertical drainage wells decreased to 0.12-0.40 and in 1995-1996 practically stopped working. Since that time, there has been an increase in salinization of land, mineralization of groundwater and a decrease in the yield of all agricultural crops.

The volume of water for washing decreased by 34-52%, the water supply during the growing season also sharply decreased (from 35 to 65%), which contributes to the growth of salinization of land. Such a lack of water does not allow washing the soil with recommended water standards [29, 30].

The considered part of the Myrzashol irrigated zone belonging to Kazakhstan is characterized as the alluvial zone of the Syrdarya River and is a very complex area

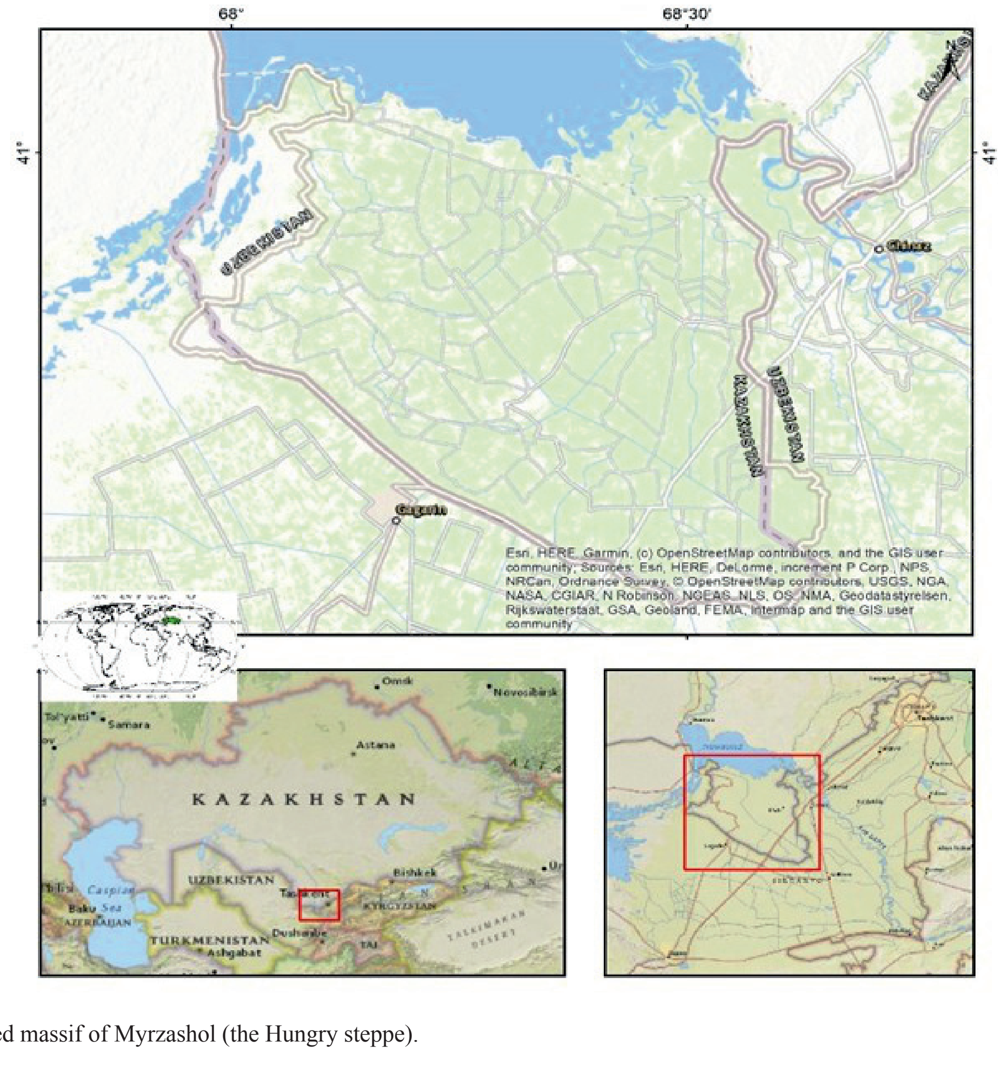

Fig. 2. Irrigated massif of Myrzashol (the Hungry steppe).

in its geological structure. From Quaternary sediments to Neogene sediments (i.e. to a water-resistant layer) consists of a conventional two-layer structure, i.e. a powerful layered alluvial sand with loamy interlayers in its layer, the surface of which consists of fine sandy loam and loamy soils.

Geomorphologically, Myrzashol district is located mainly at the mouth of the third channel of the Syrdarya River and a small part at the mouth of the second channel. Due to the fact that the plains are confined to the first mouth of the riverbed, with a height difference of 6-12 meters, the effect of natural filtration of groundwater is well observed in the vicinity. The level of irrigated land in Myrzashol district is at an altitude of 250-270 m above the Baltic Sea level [31].

The mouth of the third channel is a plain in the direction of the old Sardoba, Karai, Zhetysai channels in the lower reaches of the decaying western and north-western directions. In the west, the Kyzylkum desert borders with the Zhetysai, Arnasai and Tuzken basins. The Dostyk canal is located in the highest part of the district. In 1896, the Dostyk canal was constructed to provide water to the irrigated plains of the Syrdarya region in Uzbekistan and in the Kazakhstan part of Myrzashol [32].

The Myrzashol physical and geographical district is located between the Syrdarya River and lake Arnasay. In the north it borders Kazakhstan, in the southeast with Tajikistan, in the west with Kyzylkum (Fig. 2). In the south and southwest of the district are the Turkestan, Marguzor and Nuratin mountain ranges. Their northern slopes belong to Myrzashol and their southern slopes belong to the Middle Zarafshan district. The border of the districts runs along the watersheds of the ridges.

Approximately 90% of Central Asia receives less than 400 mm of precipitation per year: 191 mm in Turkmenistan, 264 mm in Uzbekistan, 344 mm in Kazakhstan, 533 mm in Kyrgyzstan, and up to 691 mm in Tajikistan's mountainous highlands. In the lowlands, yearly potential evapotranspiration surpasses annual rainfall, necessitating irrigation to develop agricultural crops [33].

The irrigated lands of the Syrdarya and Jizzakh regions of Uzbekistan (471.2 thousand ha), the Turkestan region of Kazakhstan (122.4 thousand ha) and the Khojent region of Tajikistan (14.2 thousand ha) are located here. Its territory is divided into lands of old and new development, confined to genetically heterogeneous parts – proluvial and alluvial. The proluvial part is called the Hungry Steppe foothill plain with a total area of about 600 thousand ha and is located in the southwestern part of the northern slope of the Turkestan ridge. The lands of the new development zone of the Hungry and Jizzakh steppes stand out here. In 1960-1980 irrigation and reclamation construction developed rapidly in the Hungry Steppe of the last century, which has large land reserves.

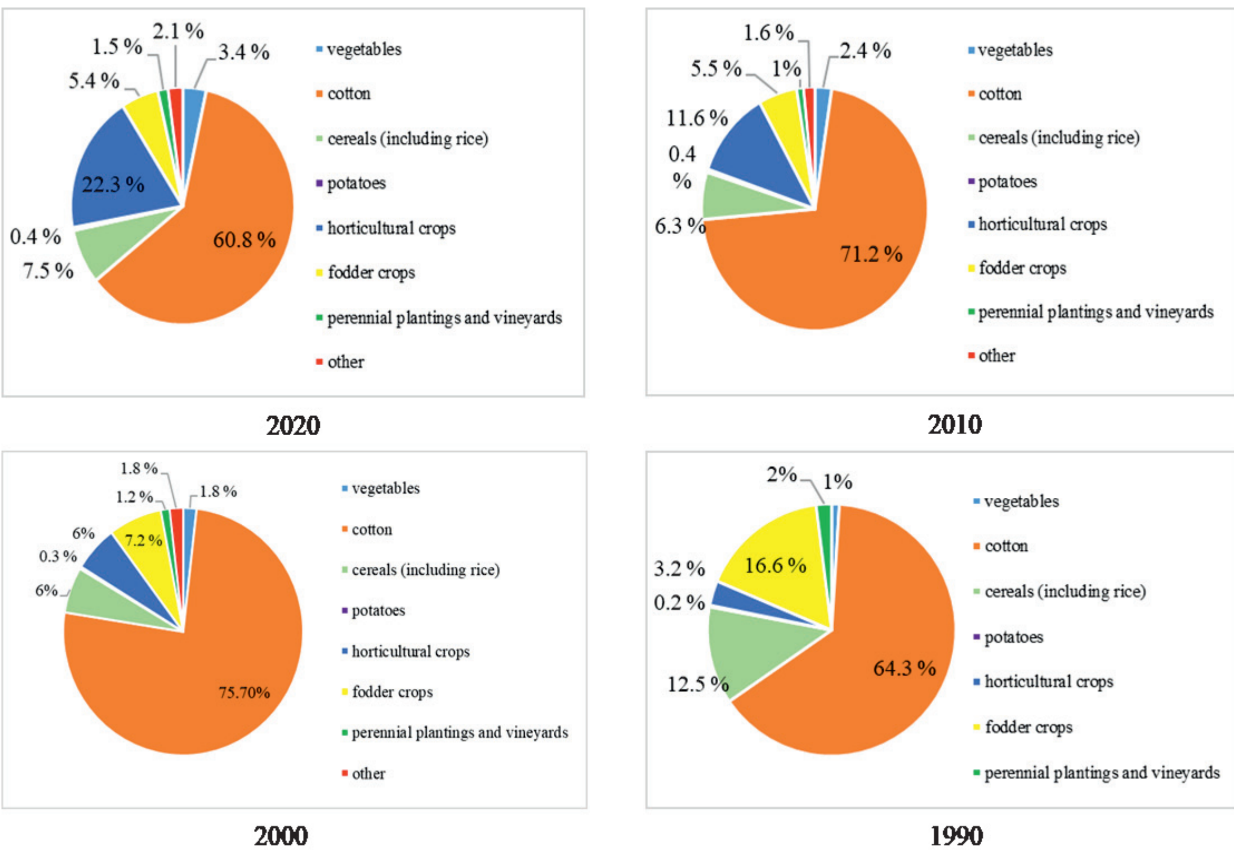

Fig. 3. The structure of arable lands in the Myrzashol irrigated massif for 1990-2020, % [34, 35].

Table 1. Dynamics of change of arable lands in the Myrzashol irrigated massif from 1985 to 2020, thousand ha [35].

Field type / years	1985	1990	1995	2000	2005	2010	2015	2020
Cotton	94.4	85.4	71.6	99.1	116.8	96.7	77	87
Cereals	20.5	16.6	13.5	7.8	8.1	8.5	15	10.8
Potatoes	0.3	0.3	0.3	0.4	0.5	0.6	0.6	0.6
Horticultural crops	3.9	4.3	5.2	7.8	7.9	15.8	28	27
Vegetables	1.4	1.4	1.7	2.4	2.5	3.3	4	4.9
Fodder crops	18.6	22	19.6	9.4	7.6	7.5	12.8	7.8
Perennial plantings and vineyards	2.6	2.7	2.8	1.6	1.2	1.3	1.0	2.1
Other	-	-	-	2.4	1.7	2.2	0,2	3.0
Total	141,7	132,7	114,8	130.9	146.3	135,9	138,1	143,2

Note: Based on the data of the Department of statistics of the Republic of Kazakhstan and the committee for land resources management.

Huge areas of virgin fallow lands were developed for irrigation, the irrigation zone was brought to more than 600 thousand ha [27].

The volume of agricultural products received increased every year. However, along with positive trends, negative consequences appeared and evolutionary transformations of irrigated soils took place. The soil-reclamation and ecological condition of irrigated lands has sharply deteriorated: the level of mineralized groundwater has risen above the «critical» level, the processes of secondary salinization and desertification have intensified.

Land Use

The total land area of the Myrzashol irrigated massif is 185,398 ha, of which 147,102 ha are irrigated agricultural land. In 2020, 143.2 thousand ha of irrigated land were used, including: cotton 87 thousand ha (60.8%), cereals (including rice) 10.8 thousand ha (7.5%), potatoes 0.6 thousand ha (0.4%), melons 27 thousand ha (18.9%), vegetables 4.9 thousand ha (3.4%), fodder crops 7.8 thousand ha (5.4%), perennial plantings and vineyards 2.1 thousand ha (1.5%) and other arable land amounted to 3 thousand ha (2.1%) (Table 1 and Fig. 3).

The main direction of agriculture in the region is cotton growing (Fig. 4). However, low cotton prices over the past decade have led to a reduction in acreage for cotton in the region due to non-reimbursement of the costs of its cultivation. In this regard, from 2000 to 2008, 100 thousand ha of cotton fields decreased by 30 thousand ha from 2015 to 2017 (Fig. 5a). In addition, the area under grain decreased from 16.6 thousand ha to 10.8 thousand ha in the period from 1990 to 2020, although the area of this arable land has increased over the past 10 years (Fig. 5b). On the contrary, the growing demand for melon crops sold at stable and reasonable prices from year to year encourages farmers in the region to sow it in large quantities. The area of melons in the irrigated area in the early 1990s was 4.3 thousand ha, in 2020 - 27 thousand ha, and the area of vegetables increased from 1.4 thousand ha to 4.9 thousand ha in 1990-2020 (Fig. 5 c, d). At the same time, the area under forage crops in the 1990s was 22 thousand ha, in 2020 - only 7.8 thousand ha and decreased to 14.2 thousand ha. The main reason for this is the fact that after the collapse of the USSR, state farms and collective farms engaged in large-scale animal husbandry were divided into small farms.

The Hungry steppe has large areas of fertile gray-earth soils, which are important for crop production and its accompanying economic development. The soils are fertile loams, but due to the aridity of the steppe, they need to be irrigated [36].

It is estimated that every year from 2 to 3% [37]; of the irrigated area of the Hungry Steppe (Myrzashol) – one of the largest irrigated regions of Central Asia – is withdrawn from crop production due to salinization. One of the largest cotton growing areas in Central Asia is the Hungry Steppe [38].

Currently, the processes of degradation and deterioration of soil-reclamation soils continue.

Solving this problem will necessitate innovative approaches to irrigation development in the region. To begin, an inventory of irrigated fields based on contemporary remote sensing and modeling of salinization-desalination processes for particular irrigation sites is required to determine the direction and intensity of the salt buildup process. These statistics alone can help identify the most promising irrigation lands. New irrigation systems that are now in use around the world should be adopted in these locations [39].

In Kazakhstan, the Hungry Steppe is called the Myrzashol district. Billions of cubic meters of water in the region have been allocated for irrigation of cotton and rice fields as part of a large-scale infrastructure development program. While this diversion of water helped to increase the management area from 5 million

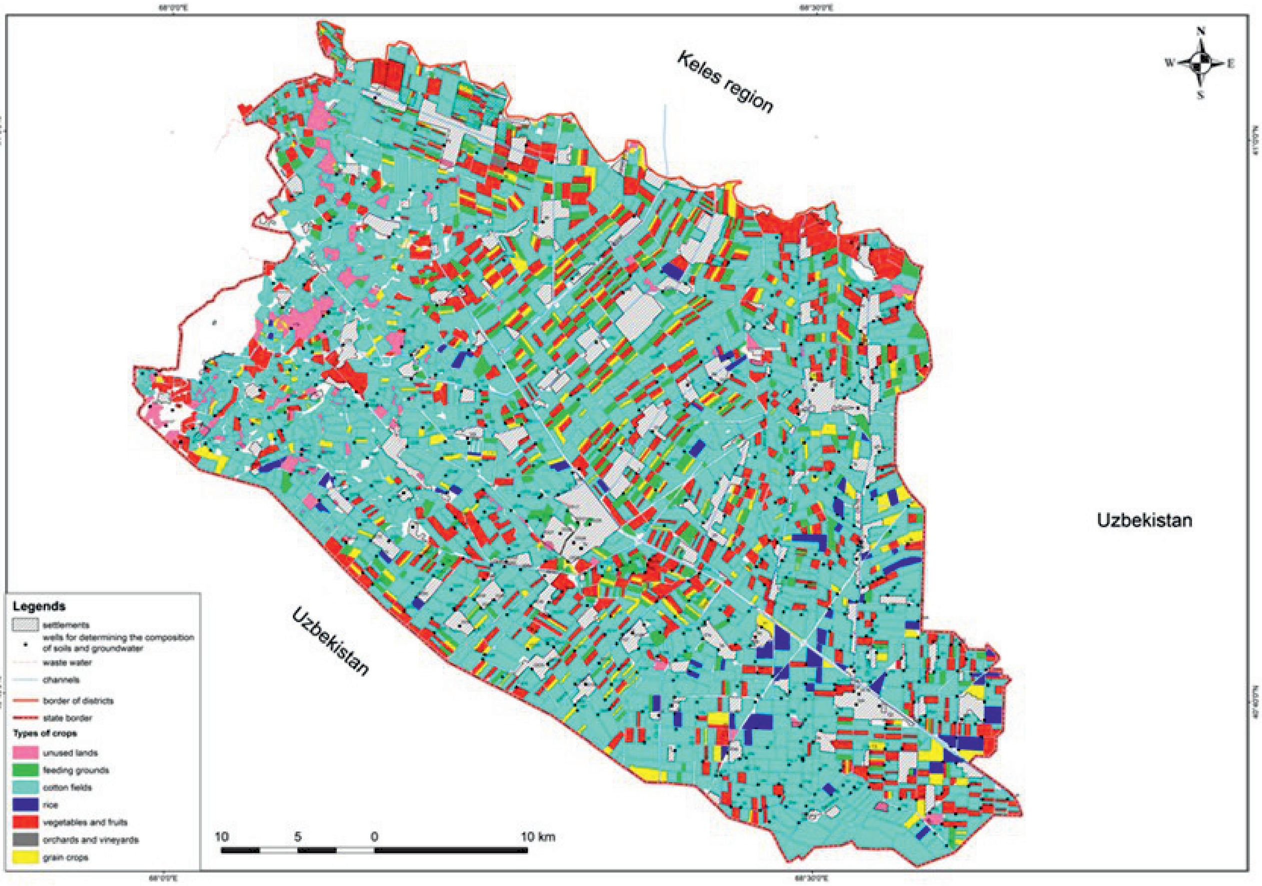

Fig. 4. Map of crops in the Myrzashol irrigated area.

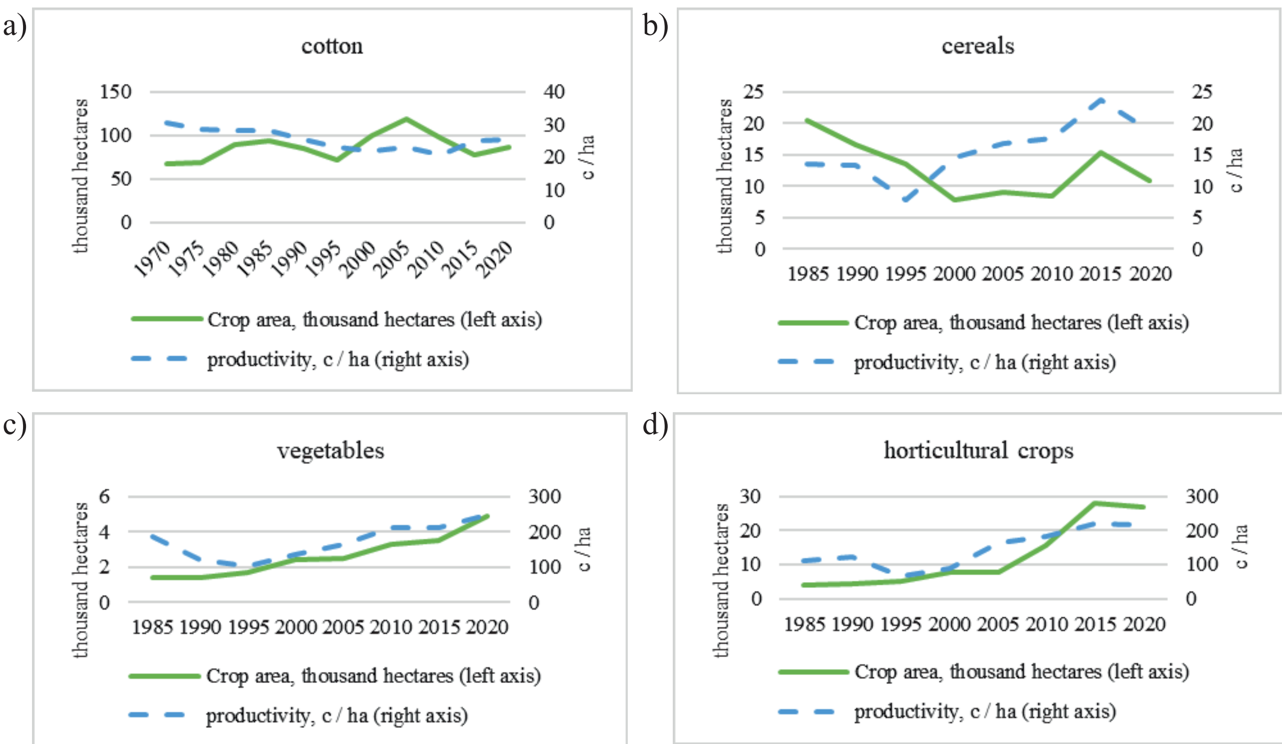

Fig. 5. Area and productivity of arable lands in the Myrzashol massif [34, 35].

Table 2. The distribution of irrigated land by depth of groundwater.

Years	Total area (ha)	Groundwater depth, m				
		0-1	1-2	2-3	3-5	More than 5
1994	125715	105	7792	72084	43441	2293
		0.1	6.2	57.3	34.6	1.8
2002	136842	378	22073	62584	49563	2244
		0.3	16.1	45.7	36.2	1.6
2014	147122	2591	32288	62461	48528	1254
		1.8	21.9	42.5	33.0	0.8
2020	146492	3622	38155	60800	39933	3982
		2.5	26	41.5	27.3	2.7

Note: The numerator - ha; denominator -% of total area.
1994-2014 according to Bekbayev's (2016) research, and 2015-2020 according to our research.

hectares (million ha) in (statistics; Kazakhstan) the 1950s to 8 million ha in the 1990s, it also led to a dramatic change in the natural flow regime and ecosystems in the area [40]. Large-scale irrigation of cotton fields inevitably leads to the processes of soil salinization.

Before the Myrzashol zone became an irrigated zone, the groundwater level was in the range of 15-30 m and was initially not considered due to the lack of their influence on irrigation. The transformation of the first general irrigated zone, due to the weak filtration capacity in soils, led to an increase in the groundwater level [31].

Currently, the groundwater level in the irrigated area is shown in Table 2 based on hydrogeological works carried out jointly by the Republican State Enterprise South Kazakhstan Hydrogeological and Reclamation Expedition» for 2015-2020. According to the results

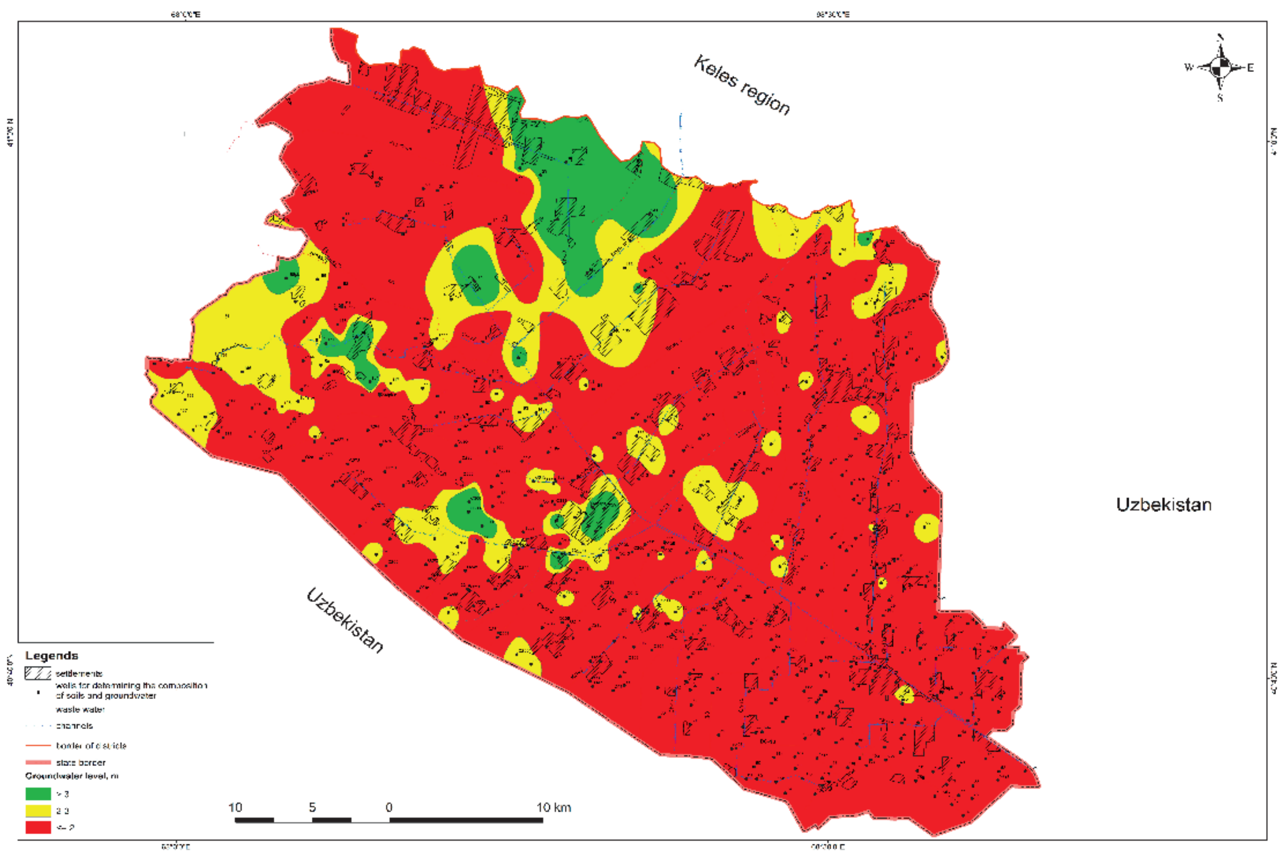

Fig. 6. Map of groundwater level of Myrzashol irrigated massif.

of the study, the groundwater level on irrigated lands in 2020 is: 2.5% (3622 ha) 0-1 meter, 26% (38155 ha) 1-2 meters, 41.5% (60800 ha) 2-3 meters, 27.3% (39933 ha) are located at a depth of 3-5 meters and 2.7% (3982 ha) at a depth of less than 5 meters (Table 2 and Fig. 6). In addition, based on the results of the conducted studies for 2020, maps of the groundwater level in the irrigated massif, salinity of groundwater and salinity of irrigated lands were compiled [31].

Considering the high air temperature, high evaporation rate and shallow depth (2-3 m) of saline groundwater, secondary salinization of the soil was inevitable; it developed in the area of the new irrigation zone of the Hungry Steppe [41]. The formation and replenishment of groundwater in insignificant volumes is associated with the influence of external parties (i.e. the Chirshyk, Angren rivers and their mouths, mainly with the impact of precipitation that falls in January-March (depending on weather conditions in the year), the most effective is the underground filtration of water from irrigation systems.

From the Dostyk canal to the Syrdarya River, the slope of the land's surface is between 0.007 and 0.0008, and between 0.0004 and 0.0008 to the Arnasai depression. The Myrzashol area, which encompasses the northwestern portion of Myrzashol, is separated lithologically into three hydrogeological divisions (according to the thickness of the surface layer, according to the filtration properties of water, according to good water permeability of the layers).

The first district occupies 52-53% of the land area between the lowlands of Sardoba and Arnasai, within 4-5 kilometers to the left of the central Myrzashol discharge and the Dostyk canal. The second hydrogeological region comprises between 40 and 44% area. The third hydrogeological region comprises 2 to 4% of the remaining land area. It mostly occupies narrow parts stretching along the left channel at the second outlet of the riverbed and almost reaches along the riverbed of the Syrdarya [31].

The thickness of the surface layer of the land changes during the transition from the first hydrogeological region to the second, from the second to the third hydrogeological region, and in the opposite direction the water permeability of powerful layers increases. To control and regulate water and salt behavior in the soil in the irrigated zone, a permanent monitoring system has been created, consisting of 529 units of control wells and piezometric wells. If the groundwater level is monitored every 10 days, then the determination of its salinity and chemical composition is carried out three times a year (Table 3 and Fig. 7).

The content of easily soluble salts in the hydromorphic soils of the Myrzashol massif varies very widely - from slightly saline with a salt content of 0.360-0.425% to highly saline (2.0-3.0%), often reaching the level of salt marshes (>3.0%). The presence of a fairly high magnesium content and a large amount of sodium in the composition of salts indicates the high toxicity of salts present in the irrigated hydromorphic soils of the Myrzashol basin.

In the research area, the groundwater level is at a depth of 0.8-2.5 m, which is much higher than the «critical» level. The mineralization of groundwater varies from slightly mineralized (3.86 g/l) to highly mineralized, with a salt content of 22-24 g/l. The reclamation well-being of the irrigated lands of the region as a whole is unstable, since on these lands groundwater remains medium (3-10 g/l) and highly mineralized (10-25 g/l). The productivity of gypsum-bearing soils depends on the use of special methods and technologies of reclamation (development), ensuring their radical reclamation in special irrigation and economic conditions [37].

Approximately 40% of arable land in the irrigated Myrzashol massif is now undergoing the salinization process: 3.7% (5473 ha) of the region is extremely salty, 7.8% (11453 ha), and 27.8% (40055 ha) are mediumly saline. (Table 4 and Fig. 8).

On lightly saline and saline-prone irrigated lands, where the salinity of groundwater, increased to 5 g/l, becomes unsuitable for plants; the problem of saving water should be solved mainly by improving the efficiency of irrigation networks and irrigation methods [21, 23, 24].

Table 3. The distribution of irrigated land by mineralization groundwater.

Years	Total irrigated land, ha	Mineralization, g/l							
		<1		1-3		3-5		>5	
		ha	%	ha	%	ha	%	ha	%
1994	125715	2718	2,2	66270	52.7	37491	29.8	19236	15.3
2001	136842	641	0.5	52229	38.2	34817	25.4	49155	35.9
2009	138767	40	0.03	34914	25.2	50849	36.6	52964	38.2
2014	147122	258	0.2	68473	46.5	45776	31.1	32615	22.2
2020	146492	139	0.1	87073	59.4	43631	29.8	15649	10.7

Note: 1994-2014 according to Bekbayev's (2016) research, and 2015-2020 according to our research

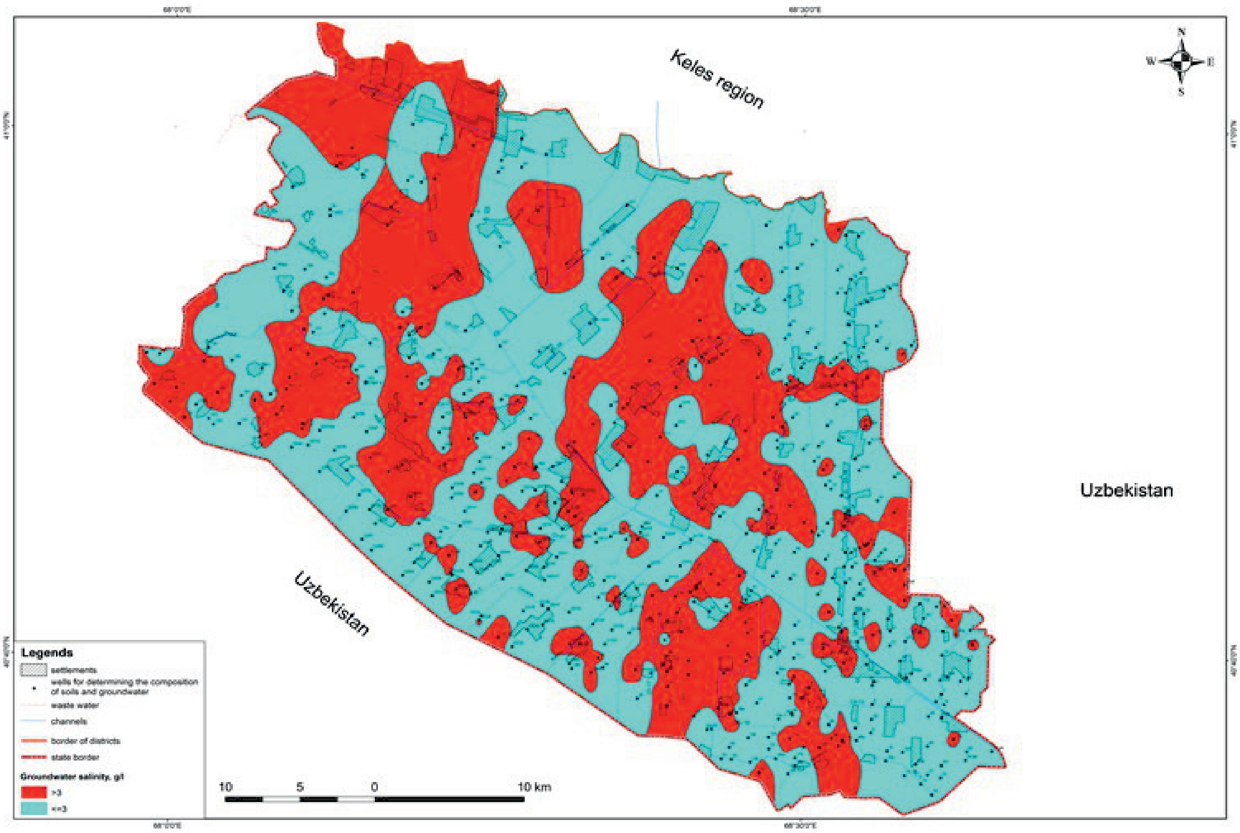

Fig. 7. Groundwater salinity map of Myrzashol irrigated massif.

In the current ecological and meliorative situation of the Hungry Steppe massif, the irrigation problem of sustainable development of irrigated agriculture can be solved by: technical re-equipment of irrigation networks and structures; improvement of physical and chemical properties of soil (desalination, decolonization, application of organic and mineral fertilizers); improvement and introduction of water-energy-saving irrigation technologies (drip, sprinkler); increased drainability of irrigated lands; use of groundwater for irrigation and additional irrigation. An increase in the water supply of irrigated lands can be achieved by matching the drainage regime (vertical, horizontal) with the irrigation regime.

Unfortunately, the methods of integrated management of surface and groundwater have been neglected [21, 42, 43].

A growing lack of water resources and a rise in the level of mineralized groundwater above the critical depth are two important things that make the degradation process in the root layer worse. The reason for the rise in these factors is that water is lost on the way from the source of irrigation to the field that needs watering. It was found that when crops are watered in the Hungry Steppe massif, about 30% of the water used to water the crops is lost through discharge, evaporation, and infiltration [43].

Table 4. The structure of the salinization degree of irrigated soils .

Years of observations	Area of irrigation (thousand ha)	Including by salinization			
		Not saline and slightly saline.		Medium and strongly saline	
		ha	%	ha	%
1995	125,4	93.6	74.6	31.8	25.4
2005	138,8	92.2	66.4	46.6	33.6
2014	147,1	91.0	61.8	56.1	38.2
2020	146,5	89,5	61,3	57	38,7

Note: 1995-2014 according to Bekbayev’s (2016) research, and 2015-2020 according to our research

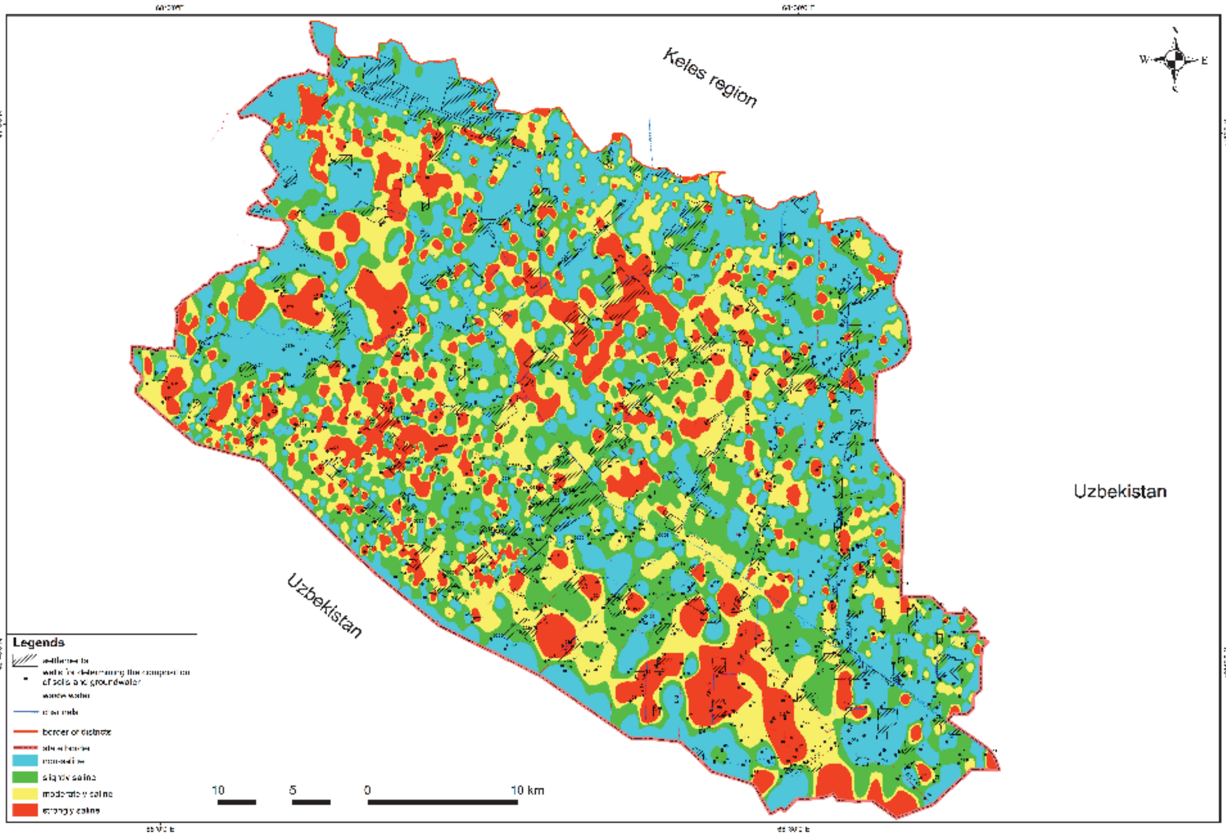

Fig. 8. Soil salinity map of Myrzashol irrigated massif.

In December, January, and February, control wells are measured once per month; for the remaining 9 months they are measured three times; tables are calculated accordingly; for instance, in Zhambyl rural district, 5 wells for 3 months have 15 measurements once and for the remaining 9 months, 5 wells have 135 measurements of 15 measurements, for a total of 150 measurements. In addition, the Maktaaral Department monitored three stationary ecological sites in the monitoring territory to determine the effect of vertical tubular discharges on the condition of irrigated land reclamation (taking soil samples for analysis during observations, monitoring the progress of agrotechnical measures, sampling water from water systems and discharges, measuring control wells).

The heat of the sun, low water, and the absence of woody vegetation had an impact on the structure of the soil cover of the region. The soil cover is formed by loose and meadow soils. Due to the small amount of woody vegetation, the humus content in these soils is low, the thickness of the humus layer will also not be obvious. Therefore, it is unproductive for agricultural crops on the basis of loose soils. According to the granular composition, various clay soils are found in the area. The predominance of medium clay soils. Table 5 shows the structure of the soil cover in the area. The table below depicts how the areas of reclamation type soils have evolved during the last five years. It should be highlighted that large-scale changes occurred in the meadow and meadow gray soils areas in 2016,

Table 5. The structure of the soil cover of the Maktaaral district.

Reclamation types of serozems	2015	2016	2017	2018	2019	2020
Light sierozem	591 0,4	1783 1,2	2010 1,37	2586 1,8	2501 1,70	3982 2,7
Meadow sierozem soil	42207 28	46358 31,5	107627 73,1	107486 73	93932 63,9	100733 68,8
Meadow	108150 71,6	98961 67,3	37464 25,5	37030 25,2	50669 34,4	41777 28,5
Total	150948	147102	147101	147102	147102	146492

Note: The numerator - ha; denominator -% of total area.

2017, and 2018. This, in turn, was caused by protracted or persistent waterlogging of the soil.

Irrigated meadow soils are formed in conditions when the groundwater level is at a depth of 1.5-2.5 m. They are mainly widespread in the II-I terraces of the Syrdarya, in hollows and depressions, on deluvial-proluvial, loess and lake-alluvial deposits of the Central Myrzashol, and are found mainly in territories where gray-meadow and meadow-gray-earth soils are common.

These soils were formed under conditions of constant moistening of the soil profile, as a result, automorphic gray-earth soils, continuously changing, transformed into intermediate-meadow-gray-earth and gray-earth-meadow, and at the final stage into hydromorphic meadow soils. After the lapse of time, the external signs of meadow soils were formed in them, and the flora inherent in these soils was formed. In addition, under conditions of constant hydromorphism and waterlogging, anaerobic conditions were formed and oxide compounds of iron, aluminum, and manganese were formed. The lower horizons of the soils have a dull brown-brownish hue, the high level of groundwater has led to secondary salinization. Therefore, when using meadow soils, it is necessary to establish a full-fledged operation of the collector-drainage network. [44, 45].

According to Table 5, in 2020 there were some changes in the structure of the soil cover of the district compared to last year. Due to frequent salinization processes, the volume of meadow soils developing in the most unfavorable hydromorphic regime for crops has decreased by 6% this year. The fertility of irrigated lands in the Myrzashol massif is lower than in other areas. The amount of humus in the humus layer of the soil before watering ranges from 0.5 to 1.4%.

The absorption capacity is in the range of 8-11 mg/eq per 100 g of soil. The mechanical composition of the soil is light and medium loamy, many fractions are large pollen, the number of which reaches 50%. The total nitrogen content is 0.035-0.04%. The volume of cation exchange per 100 g of soil is 8-9 mg /eq, the reaction of the soil solution is slightly alkaline, pH (6,9-7,8). Cotton, alfalfa, wheat, sugar beet and legumes grow well in such areas. Alluvial-proluvial deposits are present as the parent rock. According to field experiments: volumetric masses range from 1.16 to 1.82 g/cm^3 (1.16 injection layer). The general trend of all the described soils is that in almost all experiments the maximum volume mass corresponds to the level below the arable layer, which is explained by the long-term practice of plowing to the same depth without applying organic fertilizers, and sowing only one crop of cotton.

The degree of soil salinity is the primary measure of the rehabilitation of irrigated land in the district. Saline soils are less productive, resulting in a significant decrease in crop production. For instance, moderately salty soils diminish crop yields by 35%.

The severity of salt accumulation depends on the water regime of the land, particularly the groundwater level and their mineralization, which influences the status of reclamation. In the district's salty parts, an irrigation and exudative water regime is implemented. Together, mineral groundwater and wastewater elevate and evaporate salts to the surface, leaving salts in the soil's root zone. When groundwater level is less than 2.5 meters, salt deposition in the arable layer is minimal. On 41 percent of the district's irrigated area this year, the groundwater level was close to 2 m above the earth.

The analysis of the data in Table 2 shows that the overall unsatisfactory situation in the area of salinization, since only 39% of all irrigated lands are high-yielding unsalted lands. According to salinity, 35% of irrigated lands are poorly, medium and highly saline.

For the improvement of soil quality and management of irrigated light grey soil in southern Kazakhstan, as well as the maintenance of a higher cotton yield, it is necessary to implement not only ameliorative and agro-technical measures, but also additional investments for the restoration of vertical drainage wells and the systematic cleaning of farm and off-farm drainage networks [46].

Furthermore, for the region's future sustainable development, it is crucial that every drop of water given to agriculture is used efficiently. Analysis of water productivity is gaining importance on a global scale due to population expansion and rising demands on water resources [38].

Currently, there are problems in the region that can be attributed to old and new problems. The development of secondary salinization in the region can be attributed to the old problems that arose as a result of the widespread development of irrigation in the twentieth century, which determined the transfer of automorphic soils to hydromorphic ones.

The first major irrigation object of the early twentieth century was the Hungry Steppe. The widespread development of irrigation has led to the rise of groundwater in most irrigation systems and the development of secondary salinization of soils. At the same time, on secondary-hydromorphic and secondary-saline soils, the fight against salinization in the early twentieth century was carried out by means of the simplest anti-filtration measures using alfalfa and other crops, with the help of which for a number of years they unsuccessfully tried to combat secondary salinization.

The new problems of the study include social and economic problems that arose with difficult socio-economic situations in the late twentieth and early twenty-first centuries in connection with the independence of the republic. The solution of old and new problems is interrelated: it is impossible to solve social and economic problems without improving the reclamation condition of irrigated lands in the region. Solving this issue requires the development of new approaches to the development of irrigation in the region. First of all, it is necessary to conduct an inventory of irrigated lands based on modern methods of remote sensing and modeling of salinization-salinization processes for individual irrigation arrays in order to establish the direction and intensity of the salt accumulation process. Already on the basis of these data to identify the most promising lands for irrigation. Most importantly, it is necessary to abandon the template when designing reclamation measures and take into account the specifics of the natural features of each irrigation array when regulating the water-salt regime of irrigated lands. It would probably be advisable to exclude the most saline and difficult-to-reclaim lands from irrigation, but this issue should be economically justified for each specific object. [47].

One of the main tasks for the further development of irrigated agriculture is to increase the productivity of irrigated lands, to maximize crop production from irrigated lands at the lowest cost of water and energy resources.

The solution to this problem at the present stage is seen in the use of water- and energy-saving technologies and irrigation techniques for agricultural crops.

The effective use of irrigated lands of the Myrzashol massif affects the development of agriculture in the region and food security, as a result of which it is possible to reduce the poverty of the rural population. According to the UN Sustainable Development Goal 2, agriculture is the largest source of income and jobs for poor rural households. [48].

The timely solution of these problems should solve the socio-economic problems of the region.

Conclusion

Due to the varying conditions of soil reclamation in the Hungry Steppe, a diversified approach to implementing reclamation measures is required. Vertical drainage is highly successful, and the availability of natural runoff and meteorological conditions of a given year are not generally considered while justifying its regime.

The structure of the Hungry Steppe's water balance changed dramatically as a result of technological processes. The incoming part of the groundwater balance before irrigation (under natural conditions) was made up of underground inflow from the feeding areas in the foothills of the Turkestan ridge, Chirchik-Angren basin, and a small amount of atmospheric precipitation infiltration; the expenditure part was made up of underground runoff (outside the region, in the zone of natural discharge in the valley Syrdarya River), as well as an insignificant amount of atmospheric precipitation infiltration.

Due to the irrigation of more than 600 thousand ha of agriculture, the Hungry Steppe is a significant consumer of mixed river and return flow. Simultaneously, most of the river flow is generated outside the territory under consideration, while the return flow is formed entirely within it.

For the development of irrigated agriculture in the region of the Hungry Steppe, a system of irrigation channels has been constructed and is in operation. During the growing season, up to 400 millimeters per second (m/s) of surface water is provided, with losses of up to 40%.

For the effective use of irrigated lands, it is necessary to take into account the following basic conditions of the Myrzashol massif:

- compliance with the method of applying mineral and organic fertilizers to the soil by regional agricultural machinery. In addition to enriching the soil with small elements, fertilizers reduce its salinity. They, especially mineral fertilizers, cover the ground and do not evaporate the water supplied to the crops. When the water evaporates, its salts remain in the upper layer of the soil. In addition, in order to avoid evaporation of water, it is necessary to sow seeds of crops in the spring. Plants growing close to each other do not evaporate water from the soil.

As a result, the salts are carried to the lower layers by the water. Plants in Alfalfa do not evaporate water. Alfalfa should be introduced using an alternating sowing strategy in regions where cotton is grown. Cotton is planted five times, while alfalfa is planted three times.

The best manure is those produced by fertilizers. A deposit of 15-20 tons per ha of land is required. 20 kg of superphosphate or 10 kg of phosphorous flour should be applied to each ton of manure to adequately feed the soil with nitrogen and phosphorus. Irrigated fields should be fertilized with ammonium sulfate or ammonium nitrate from nitrogen fertilizers, superphosphate, phosphorous, or bone meal from phosphorus fertilizers, and potassium chloride or potassium sulfate from potassium fertilizers, depending on the pH of the soil.

– compliance with the procedure for the operation of solid household waste placed on the irrigated lands of the district,
– improvement of the technical condition of water supply and drainage systems,
– implementation of recommendations on the saline distribution of saline lands.

In order to disperse the salts, it is necessary to rinse. Their effectiveness depends on the maintenance and timely application of equipment, the number of washings, the quality of land preparation and the operation of drainage systems. In modern irrigation and reclamation conditions of the area, salt washing can be recommended to reduce salinization of weak and medium-saline soils, empty (open) volume with a groundwater level >3 m and a washing water norm of 4-4.5 thousand/m^3 ha, otherwise wastewater and groundwater will mix and re-salinization will begin.

Utilize salinity maps to identify the specific salt water leaching rates. Flushing is only effective if the sewer system does its job and removes mineralized wastewater from the irrigation area, increasing the potential for re-salinization. Despite annual recommendations, surveillance of salt washings in several steppe regions has shown violations of salt washing technology. First, virtually everywhere, washing standards do not exceed 2,000 to 3,000 m^3 ha; it is assumed that this quantity is only adequate for desalination of slightly salty fields. On the irrigated lands of the Maktaaral district, salt washing and humidification are typically combined. This is only achievable on somewhat salty soils.

According to our calculations, the average saline washing rate should be at least 3-4 thousand m^3/ha. In addition, improper preparation of irrigated lands for flushing (deep plowing, lack of comprehensive planning) prevents the uniform distribution of water over the soil surface. In order to save land, farmers have created an area of irrigation ditches (volumes) of 0.5-1 ha instead of the normal 0.1-0.2 ha, which also prevents the uniform distribution of water.

The intensity of salt removal in areas with a groundwater level of more than 3 m is shown in Table 2. In order to avoid compaction under the arable layer, which complicates rooting, absorption and reduces the water permeability of the roots to a minimum of 0.05 m/day, it is necessary to treat the entire area by plowing or planting. According to Kazakh scientists, to increase the salt resistance of agricultural crops, their seeds should be soaked in 0.2% $MgSO_4$ solution before sowing per day. Then they will be resistant to sulfate salts. If the soil is rich in chloride salts, the seeds should be kept in a 3% NaCl solution for an hour, and then rinsed with plain water for 1.5 hours. The predominance of sulfate salts in Maktaaral soils.

Consequently, the following procedures can be implemented for successful utilization of salty soils:

The exclusive use of unsalted or slightly saline terrain for agricultural purposes.

In the absence of such areas, these fields may be converted from irrigated to non-irrigated pastures. On these fields, halophytes were subsequently planted for the growth of animal husbandry.

Restoring drainage systems and cleansing salinized soils

4. Development of water management systems (concreting of aqueducts, cleaning and deepening of shallow ditches, installation and commissioning of vertical drainage wells, and other measures) to prevent the mineral groundwater level from approaching the surface.

5. To prevent mineral water from evaporating from the surface, produce crops that provide ample shade and cover the surface with mineral fertilizers (manure).

Deep tilling and the use of mineral fertilizers to prevent evaporation and enhance absorption.

7. Implementation of water-saving irrigation techniques for agricultural crops (sprinkling, drip irrigation and other methods). More frequently, little amounts of water should be delivered to the field. Then, the wastewater does not mix with the mineral groundwater and does not bring the groundwater's salts to the surface.

Use of salt-resistant crops (sugar beet, wheat, barley, rice,sunflower, safflower, etc.), seed hardening prior to planting (soaking seeds in a solution of salt and bitter salt).

Acknowledgments

The authors express their gratitude and appreciation to the specialists of the South Kazakhstan Hydrogeological and Meliorative expedition of the Ministry of Agriculture of the Republic of Kazakhstan for their cooperation and responsible approach in preparing the results of scientific research for publication.

Conflict of Interest

The authors declare no conflict of interest.

References

1. FAO. The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point (SOLAW 2021). The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point (SOLAW 2021). **2021**.
2. BOURAS H., BOUAZIZ A., CHOUKR-ALLAH R., HIRICH A., DEVKOTA K.P., BOUAZZAMA B. Phosphorus fertilization enhances productivity of forage corn (*Zea mays* L.) irrigated with saline water. Plants, **10** (12), **2021**.
3. SHRIVASTAVA P., KUMAR R. Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi Journal of Biological Sciences, **22** (2), **2015**.
4. HASSANI A., AZAPAGIC A., SHOKRI N. Predicting long-term dynamics of soil salinity and sodicity on a global scale. Proceedings of the National Academy of Sciences of the United States of America, **117** (52), **2020**.
5. YIN X., FENG Q., LI Y., LIU W., ZHU M., XU G., SINDIKUBWABO C. Induced soil degradation risks and plant responses by salinity and sodicity in intensive irrigated agro-ecosystems of seasonally-frozen arid regions. Journal of Hydrology, 603, **2021**.
6. PRĂVĂLIE R. Exploring the multiple land degradation pathways across the planet. Earth-Science Reviews, 220, **2021**.
7. NOSETTO M.D., ACOSTA A.M., JAYAWICKREME D.H., BALLESTEROS S.I., JACKSON R.B., JOBBÁGY E.G. Land-use and topography shape soil and groundwater salinity in central argentina. Agricultural Water Management, 129, **2013**.
8. FENTA A.A., TSUNEKAWA A., HAREGEWEYN N., POESEN J., TSUBO M., BORRELLI P., KUROSAKI Y. Land susceptibility to water and wind erosion risks in the East Africa region. Science of the Total Environment, 703, **2020**.

9. JIANG L., JIAPAER G., BAO A., LI Y., GUO H., ZHENG G., DE MAEYER P. Assessing land degradation and quantifying its drivers in the Amudarya River delta. Ecological Indicators, 107, **2019**.
10. YU Y., PI Y., YU X., TA Z., SUN L., DISSE M., YU R. Climate change, water resources and sustainable development in the arid and semi-arid lands of Central Asia in the past 30 years. Journal of Arid Land, **11** (1), **2019**.
11. ZHOU Y., ZHANG L., XIAO J., WILLIAMS C.A., VITKOVSKAYA I., BAO A. Spatiotemporal transition of institutional and socioeconomic impacts on vegetation productivity in Central Asia over last three decades. Science of the Total Environment, 658, **2019**.
12. BUCKNALL J., KLYTCHNIKOVA I., LAMPIETTI J., LUNDELL M., SCATASTA M., THURMAN M. Irrigation in Central Asia. Social, economic and environmental considerations. Europe and Central Asia Region, (**February**), **2003**.
13. BOBOJONOV I., AW-HASSAN A. Impacts of climate change on farm income security in Central Asia: An integrated modeling approach. Agriculture, Ecosystems and Environment, 188, **2014**.
14. VASENEV V., VERETELNIKOVA I., BRIANSKAIA I., DEMINA S., ROMZAYKINA O., PULATOV B., PULATOV A. Soil Electroconductivity as a Proxy to Monitor the Desertification in the Hungry Steppe (Uzbekistan). B Springer Geography. **2020**.
15. KOVDA V.A. Soils of the arid zone as an object of irrigation (1968). Nauka, Moscow. Retrieved from http://www.cawater-info.net/library/rus/hist/pochvy1968/index.htm **1968** [In Russian].
16. PANKOVA E., AIDAROV I., YAMNOVA I., NOVIKOVA A.F., BLAGOVOLIN N.S. Natural and human-induced salinization of soils in the Aral Sea basin (geography, genesis, evolution) (T. 194). **1996** [In Russian].
17. FAO. Guidelines for the management of saline soils (FAO, 2017). Food and Agriculture Organization of the United Nations and Lomonosov Moscow State University. Retrieved from https://ecfs.msu.ru/resources/publications/rukovodstvo-po-upravleniyu-zasolennyimi-pochvami **2017** [In Russian].
18. TOKBERGENOVA A., KIYASSOVA L., KAIROVA S. Sustainable development agriculture in the republic of Kazakhstan. Polish Journal of Environmental Studies, **27** (5), **2018**.
19. MINISTRY OF ENERGY OF THE REPUBLIC OF KAZAKHSTAN. National report on the transition of the Republic of Kazakhstan to «Green Economy» for 2013 -2016. (pp. 20–21). **2017** [In Russian].
20. YAKUBOV H.I. USMANOV A.U. BEKMURATOV T.U., M. SH. SH., HEINZ R.A. Recommendations on the assessment and possibility of using collector-drainage water for irrigation of agricultural crops in the Fergana region. Scientific Research Institute of Irrigation and Water Problems of Uzbekistan. Retrieved 6 august 2022, from http://www.cawater-info.net/books/ruk-cdw-fergana/pages/003.htm **1989** [In Russian].
21. BEKBAYEV R.K. Factors Influencing on the Degradation of Water and Land Resources of Mahtaaral Irrigation Massif. Academia Journal of Agricultural Research, **4** (3), 118, **2016**.
22. JI K.Y. Degradation of land resources in Central Asia. FAO. **2008** [In Russian].
23. BICHSEL C. The Drought Does Not Cause Fear. Revue d'études comparatives Est-Ouest, **43** (01–02), **2012**.
24. UMBETAEV I., BATKAEV ZH.Y. The system of cotton cultivation in the south of the Republic of Kazakhstan. (Umbetaev I., Red.). Almaty: Kus Zholy. **2000** [In Russian].
25. UMBETAEV I., BIGARAEV O., BAIMAKHANOV K. Effect of soil salinity on the yield of cotton in Kazakhstan. Russian Agricultural Sciences, **41** (4), **2015**.
26. RAFIKOV A. Natural reclamation assessment of the lands of the Hungry Steppe. Publishing House of the Uzbek SSR «FAN». Retrieved 6 august 2022, from http://www.cawater-info.net/library/rus/hist/rafikov/index.htm **1976** [In Russian].
27. AKHMEDOV A.U., GAFUROVA L.A. Assessment of the current soil-reclamation state of the soils of the Hungry Steppe. Vladimirsky farmer, **4**, 7, **2019** [In Russian].
28. DUKHOVNY V., UMAROV P., YAKUBOV H., MADRAMOOTOO C.A. Drainage in the Aral sea basin. Irrigation and Drainage, **56** (SUPPL. 1), **2007**.
29. SAPAROV A., JALANKUZOV T., SULEIMENOV B.U. The influence of irrigation and fertilizers on the chemical properties of irrigated light gray soils of Southern Kazakhstan. Soil science and agrochemistry, **1**, 56, **2009**.
30. SULEIMENOV B., SAPAROV A., TANIRBERGENOV S. State and prospects of use of irrigated serozems of southern Kazakhstan. Soil science and agrochemistry, 1, 19. Retrieved from https://cyberleninka.ru/article/n/sostoyanie-i-perspektivy-ispolzovaniya-oroshaemyh-serozemov-yuzhnogo-kazahstana **2013**.
31. REPUBLICAN STATE INSTITUTION SOUTH KAZAKHSTAN HYDROGEOLOGICAL AND RECLAMATION EXPEDITION. Scientific research work for 2015-2020 (pp. 1–103). Shymkent: Republican state institution «South Kazakhstan hydrogeological and reclamation expedition». **2020** [In Russian].
32. ABDURAIMOVA D., IBRAGIMOVA Z., OTAKHONOV M., KHUSANOVA D. Deformation processes in open drainages. B E3S Web of Conferences (T. 264). **2021**.
33. HAMIDOV A., HELMING K., BALLA D. Impact of agricultural land use in Central Asia: a review. Agronomy for Sustainable Development, **36** (1), **2016**.
34. LAND RESOURCES MANAGEMENT COMMITTEE OF THE MINISTRY OF AGRICULTURE OF THE REPUBLIC OF KAZAKHSTAN. Information on land resources. Nur-Sultan: Land Resources Management Committee. Retrieved from https://www.gov.kz/memleket/entities/land?lang=ru **2020** [In Russian].
35. AGENCY FOR STRATEGIC PLANNING AND REFORMS OF THE REPUBLIC OF KAZAKHSTAN. Annual report for 1975-2020. Nur-Sultan: Bureau of National statistics. Retrieved https://stat.gov.kz/ **2020** [In Russian].
36. JALANKUZOV T., SULEIMENOV B., BUSSCHER W. J., STONE K.C., BAUER P.J. Irrigated Cotton Grown on Sierozem Soils in South Kazakhstan. Communications in Soil Science and Plant Analysis, **44** (22), **2013**.
37. KUSHIEV H., NOBLE A.D., ABDULLAEV I., TOSHBEKOV U. Remediation of abandoned saline soils using glycyrrhiza glabra: A study from the hungry steppes of central Asia. International Journal of Agricultural Sustainability, **3** (2), **2005**.
38. KAMILOV O.K., AKHMEDOV A.U., RUZMETOV M.I. Actual problems of reclamation of saline soils of the arid zone. The problem of genesis, fertility, land reclamation, soil ecology, assessment of land resources, 138, **2002**.
39. TANIRBERGENOV S.I., SULEIMENOV B.U., CAKMAK D., SALJNIKOV E., SMANOV Z.

The ameliorative condition of the irrigated light serozem of the turkestan region. Periodico Tche Quimica, **17** (36), **2020**.

40. ABDULLAEV I., MOLDEN D. Spatial and temporal variability of water productivity in the Syr Darya Basin, central Asia. Water Resources Research, **40** (8), **2004**.
41. RUKHOVICH D.I., PANKOVA E.I., CHERNOUSENKO G.I., KOROLEVA P.V. Long-term salinization dynamics in irrigated soils of the Golodnaya Steppe and methods of their assessment on the basis of remote sensing data. Eurasian Soil Science, **43** (6), **2010**.
42. BEKBAYEV R.K., BALGABAYEV N.N., ZHAPARKULOVA Y.D., BEKBAYEV N.R. Dynamics of condition of groundwater and using if for sub-irrigation on irrigated lands of the Golodnostepsky massif. Oriental Journal of Chemistry, 31, **2015**.
43. BEKBAYEV R., BALGABAYEV N., ZHAPARKULOVA Y., KARLIHANOV O., MUSIN Z. Factors that intensify soil degradation in the Kazakhstan part of the Golodnostepsky irrigation massif. Life Science Journal, **12** (1s), 1, **2015**.
44. SOBITOV U.T., ABDURAKHMANOV N.YU. Characteristics and fertility degree of irrigated soils of the Hungry steppe oasis. Scientific review. Biological sciences. Retrieved from https://science-biology.ru/en/article/view?id=1092 **2018** [In Russian].
45. KUZIEV R.K., SOBITOV U.T., ABDURAKHMONOV N.YU., & MIRSODIKOV M.M. Change of soil properties in irrigated agriculture. (Scientific Review. Biological Sciences), **3**, **2020** [In Russian].
46. TANIRBERGENOV S.I., SULEIMENOV B.U., SAPAROV A.S., SOLTANAYEVA A.M., KABYLBEKOVA B.Z. The fertilizer system increasing the salt tolerance and productivity of cotton in the conditions of saline soils in southern Kazakhstan. Research Journal of Pharmaceutical, Biological and Chemical Sciences, **7** (6), **2016**.
47. PANKOVA E.I. Salinization of irrigated soils of the Central Asian region: old and new problems. Retrieved from https://cyberleninka.ru/article/n/zasolenie-oroshaemyh-pochv-sredneaziatskogo-regiona-starye-i-novye-problemy/viewer **2016** [In Russian].
48. FAO. SDG 2. Zero hunger | Sustainable Development Goals | Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org/sustainable-development-goals/goals/goal-2/en/ **2015**.