The impact of the hydrological condition of Kashkadarya oasis on the formation of agrolandscapes

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Abstract. The article discusses the hydrological condition of Kashkadarya province, rational use of land resources and factors contributing to the degradation of agroirrigation landscapes due to soil erosion. It also highlights the impact of surface and groundwater on the socio-economic development of the region, as well as geographical and environmental issues of land use in the process of intercropping.

1 Introduction

The vast majority of lands transformed as a result of human activity are agricultural landscapes. The limit of expansion of agrolandscapes depends on the degree of water availability, geomorphological, soil and other conditions. Therefore, the study of the formation, development and change of agrolandscapes, as well as the functioning of irrigation systems in a particular region, the analysis of relief features, changes in hydrographic and hydrogeological conditions, and the study of soil conditions are of great importance.

In recent years, the expansion of irrigated areas, transformation of new lands, and issues related to water supply to the population have led to increased demand for the quantity and quality of river water resources. Therefore, the investigation of issues associated with the effective utilization of water resources and the exploration of distinctive solutions holds significant scientific and practical relevance.

Irrigated farming and rainfed farming are the cultivation methods used in agricultural production in rural areas. These are practiced in zones with insufficient supply of moisture, including arid, semi-arid, and dryland regions, during certain stages of the vegetation period where there is inadequate natural precipitation. Irrigated agriculture holds a crucial place among arable land reclamations. In dry and hot climates, agriculture relies on direct artificial irrigation to achieve high yields of agricultural crops. In such conditions, artificial

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irrigation is not only the most important and necessary method to enhance the productivity of irrigated land resources but is also an essential requirement for the effective management of agriculture.

2 Materials and methods

In the exploration of the subject, the foundation of significant scientific approaches and principles is established by ecological-landscape theory and systematic complex research, incorporating agrolandscape indication. Utilizing various methods such as aerospace, cartographic, paleogeographic, geographic comparison, statistical analysis, geoinformation modeling (GI modeling), and other approaches contributes to achieving the fundamental research outcomes. Due to the fundamental role of surface waters in irrigation, numerous scientific research has been carried out in this regard. Works by researchers such as Y. Gulomov (1959), V.V. Sinzerling (1927), S.X. Kondrashev (1931), M.I. Ivanin (1873), M.P. Danilevskiy (1934), E.I. Chembarisov, B.A. Bakhritdinov (1983), M.G. Nazarov (2020), F.M. Xushmurodov (2023), and others [16-20], have been dedicated to studying the historical influence of surface waters on traditional agriculture and the mineralization levels of these waters.

3 Results and Discussion

In Uzbekistan, there are ongoing systematic efforts to develop purposeful innovative programs and implement comprehensive measures for modernization based on scientific principles, utilizing irrigated lands and hilly landscapes. In this context, researching, evaluating, monitoring, and optimizing the influence of human economic activities on landscapes, as well as anthropogenic alterations in landscapes and their interconnection with climate and groundwater, hold significant importance.

Over the years, the agricultural networks have been steadily expanding, with the canals also relatively elongated. Moreover, smaller irrigation channels have been initiated to irrigate fields. In the I-IV centuries, during the Kushan Empire era, significant importance was attached to irrigation works. During this period, canals such as Zang and Bo'zsuv in the southern part of Uzbekistan, Eski Angor and Tuyatortar in the Samarkand region, Shoxrud and Romitanrud in the Bukhara region, Kirkkiz, and other channels in Khorezm were either dug or reconstructed [2].

The average annual water consumption in our Republic amounts to 51-53 billion m^3, with 97.2% being sourced from rivers and lakes, 1.9% from collector-drainage systems, and 0.9% from groundwater. This utilization represents a reduction of up to 20% compared to the allocated water extraction limit. Kashkadarya river basin possesses unique characteristics in Uzbekistan's water management system, particularly in terms of its agroclimatic and hydrographic conditions. Kashkadarya region is characterized by arid climatic conditions. While it has significant land resources, the water resources, with a runoff modulus of 6.2 l/sec. km^2, are relatively limited.[1]

According to G.X. Yunusov (2022), the overall territory of the Kashkadarya region is divided into two distinct parts: 1) areas traditionally irrigated, and 2) newly reclaimed lands. Each section has its specific hydrological features, sources of water resources for irrigation, hydrogeological-meliorative conditions, meteorological characteristics, and other relevant factors taken into account [3].

The efficient use of water in irrigating agricultural landscapes requires careful consideration of irrigation points. Specialists in this field have conducted investigations and emphasized the following essential measures: 1) It is crucial to study the hydrochemical characteristics of river and canal waters before irrigation; 2) change in land reclamation and geochemical conditions; 3) ensuring the salt tolerance of crops in agricultural fields; 4) evaluating the compatibility of water with irrigation; 5) analyzing the composition of water; 6) the findings of studies conducted on irrigating with mineralized water; 7) Providing conclusions on the effectiveness of river or collector waters for irrigation (E.I.Chembarisov, B.A.Baxritdinov, 1983. 15 p.).

The longest river in the basin is the Kashkadarya, with a length of 332 km. It originates from the northern slope of the Obikhon Range in the western part of the Hissar Range in the Sughd Region of the Republic of Tajikistan, 1.5 km northeast of the Dovtosh pass at an elevation of 2960 m. The right tributary of the river, Sinchasoy Zarafshon, begins near the Dovtosh pass at an elevation of 3000 m on the southern slope of the western edge of the Hissar Range, not far from Dovtosh village. The Kashkadarya river flows through sandy terrain about 10 km north-west of Muborak city.

In the Kashkadarya basin, there are more than 120 rivers with lengths ranging from 10 km to 200 km. The total area where water is collected in the basin is 8,780 km², while the overall basin area is 12,000 km² (Table 1).

Table 1. The hydrological indicators of the Kashkadarya River and its major tributaries.

Rivers	length, km	The absolute elevation of the starting point, m	The elevation of the watershed where water is collected, m	Basin area, km^2		Observation area	Water consumption, m^3/s	Flow average modules, l/s·km^2
				Total ykjyky	Up to the Observation area			
Kashkadarya	332	3000	1823	12000	511	Varganza v.	5.2	12.0
Jinnidarya	57	2600-3000	1573	367	152	Jous v.	1.35	4.2
Aksu	62	4000-4300	2444	1280	845	Hazornov	12.3	14.6
Yakkabogdarya	99	4000	2702	1180	504	Tatar v.	6.2	13.4
Tankhozdarya	93	3500	2170	1910	435	Katagon v.	4.3	10.1
Katta Uradarya	113	3440		1410	1260	Bozortepa	4.6	
Kichik Uradarya	114			1670	1570	Gumbulok v.	1.6	
Guzordarya	86	2500-3400	1532	3400	3090	Yortepa v.	5.9	1.9

Source: Prepared by the author based on the geography of Kashkadarya region.

The largest irrigation system in the Kashkadarya basin is the Kalkamasoy (covering an area of 357 km^2, extending to the observation point near Kumdaryo-Chambil settlement where water is collected). It is formed as a result of the inclusion of Anzirat, Chunkaymish, Kuruksoy, Gorovli, Tolakol, Langar, Taragay, Kuruksoy, Govxona, and Xizalak channels. The waters of the Kalkama canal are collected in the Kalkama water reservoir and utilized for irrigation.

In the rivers of the Kashkadarya basin, the period of maximum flow occurs from March to June, while the low-flow period is from July to September, aligning with the specific characteristics of their drainage. In the upper part of the basin, the runoff modulus is 6.2 l/s per 1 km^2 of the area (Babushkin et al., 1985). The average annual runoff in the basin is 1345.1 million m^3, with more than half occurring in elevated areas above 2000 m.

To supply water for irrigated agricultural fields in the Kashkadarya basin, with water from the Amudarya and Zarafshan rivers, large-scale irrigation infrastructures have been constructed. Among these, the prominent ones are the Eski Anhor and Karshi main canals.

The Eski Anhor canal draws water from the Darg‘om canal. Bearing the name "Manas," this ancient canal was originally dug in the 1st millennium. In its initial stages, the canal had a length exceeding 300 km. However, due to various pressures, the canal underwent alterations over time. In the mid-20th century, it underwent a comprehensive renovation and was put into operation in 1955. At its commencement, it starts at an elevation of 700 meters and gradually descends to 400 meters in the downstream section. With a length of 184 km, the water flow capacity of the canal ranges between 45-48 m^3/s. The water from the Eski Anhor canal is supplied to the Karshi reservoir through 25 pumping stations.

The canal's water conveyance capacity, averaging 60 m^3/s, is being effectively utilized to irrigate lands beyond the Chiroqchi district. A portion of the canal's water is directed towards the Chimkurgan water reservoir. Through the "Eski Anhor" irrigation system, approximately 17,380 hectares of land in the Chirokchi districts of the Kashkadarya region are allocated for irrigation.

The Karshi main canal, with a length of 290 km, played a crucial role in improving the Karshi desert. Its branches, the Ulyanov (now Mirishkor) canals (1965-73), and the Tallimarjon water reservoir became the main irrigation facilities. Constructed in a sequential "cascade" arrangement, six pumping stations, starting from the Amudaryo river, lift the water to an elevation of 132 m [7].

According to G.H. Yunusov, there is a probability that the capacity of the Amu Darya River will be reduced by 25-30 per cent. This, in turn, affects the amount of water that can be obtained through the Karshi Main Canal (KMC) for irrigation in Kashkadarya province and, as a result, requires the development of measures aimed at more efficient use of existing water resources [3].

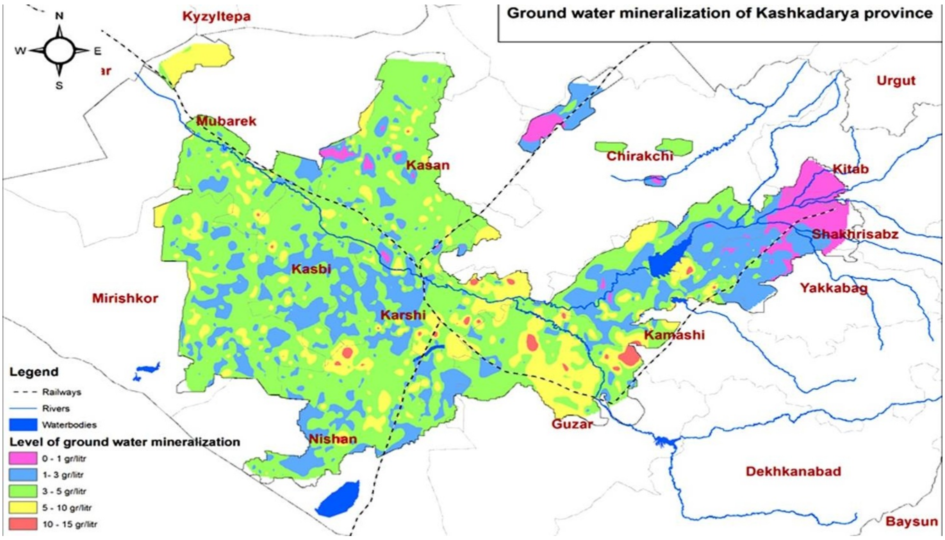
In addition to surface water, the Kashkadarya basin has distinct geological, tectonic, lithological, geomorphological and climatic characteristics that influence the regional distribution of groundwater. Depth and mineralisation of aquifers are important factors. Groundwater with significant yields is used to supply drinking water to the population of the region and partly for irrigation. The ameliorative condition of lands depends on the depth of groundwater and its mineralisation, as emphasised by V.A. Kovda (1972), M.M. Krylov (1952), F.M. Raksimboev (1967) and others..

The strong salinity of groundwater is the main cause of soil salinization in the region. In the Kashkadarya hydrogeological zone, groundwater use is 9.8 cubic meters per second [15]. Groundwater concentration in the Kashkadarya basin varies from 0.5 g/l to 2.0 g/l, gradually increasing from west to east along the river flow. This is manifested through an accumulation of salts in depressions, for example, in the bottom of depressions in the mountain valleys, as well as through infiltration of irrigation water in irrigated areas.

Recently, such problems as climate aridity, decreasing precipitation, increasing evaporation and high efficiency of irrigation have arisen. In the studies of G. Yunusov in 2022, evapotranspiration (Eo) was measured using the Y.N. Ivanov Method. Monthly evaporation coefficients were calculated based on average monthly air temperatures and absolute humidity data of meteorological stations Kitob and Shakhrisabz.

In Kashkadarya province, two-thirds of irrigated areas have groundwater with mineralization of more than 3 g/l, and one-third - with lower mineralization in the range of 1-3 g/l [7].

Consequently, the general rise of the groundwater surface in the region leads to an increase in the salt content of groundwater. Climatic factors also contribute to salt accumulation in groundwater. This can be clearly seen in the diagram of depth and salinity of seepage water irrigated in these Kashkadarya oases (Figure 1). In this regard, irrigated groundwater during hot summer months under the influence of intense sunlight favors the accumulation of various salts in groundwater composition.



The analysis of studies conducted by the above-mentioned specialists indicates that a significant part of irrigated areas of Kashkadarya oasis is closely located in saline groundwater. Such neighborhood is influenced by natural processes and anthropogenic activities in landscapes, which leads to unfavorable conditions affecting soil salinization.

As noted earlier, the arid climatic conditions prevailing in Kashkadarya province, combined with the high natural groundwater table, favor rapid accumulation of salts in the soil due to intensive groundwater infiltration. In this context, ensuring sustainable land reclamation of territories, especially those used for double cropping, becomes a critical task. Therefore, the solution to unique geo-ecological problems affecting the reclamation state of irrigated areas of Kashkadarya province requires practical research based on scientific studies.

The term "oasis" is used to designate the territories created by irrigation in desert landscapes. The first chapter shows that oases are landscape systems formed as a result of anthropogenic activity. Landscape scientists have approached the designation of these landscapes in different ways. N.A. Gvozdetsky (1977) called them "oasis landscapes", and L.N. Babushkin and N.A. Kogay (1964) called them "irrigated landscapes". Other researchers such as L.I. Kurakova, Y.R. Milanova, A.M. Ryabchikov, and others (1971-1992) described them as "agro-irrigation landscapes", and F.N. Chalidze (1980) introduced the term "irrigation landscapes". At present, such landscapes are mostly called agroirrigation landscapes. According to L. Alibekov (2013), these landscapes are manifested as a result of changes in landscape components in irrigated areas, including irrigation erosion, soil accumulation in the agro irrigation anthropogenic layer, double salinization of soil and groundwater, soil and soil compaction, leaching of surface and underground water, channelization of watercourses and changes in local relief with features that retain some common features compared to natural landscapes, but exhibit new anthropogenic features based on changes in landscape components.

A. Abdulkosimov (1966) gives the following definition of oasis landscapes: a unique landscape complex that has developed over several centuries as a result of human activity, characterized by the cultivation of trees, shrubs, and plants in desert territories specifically associated with the widespread development of sugarcane farming [5]. In the Kashkadarya basin, anthropogenic landscapes associated with agriculture can be divided into the following categories: agro-landscapes of traditional farming; agro-landscapes of irrigated farming, or agro-irrigation landscapes.

The emergence and development of agroirrigation landscapes have unique features. In irrigated areas, anthropogenic changes in landscape components undergo specific transformations: first, biotic components (fauna and flora) change according to a certain pattern, and then abiotic components (soils, hydrological regime, climate, relief). Thus, in irrigated areas, human activity changes all landscape components beyond the geological bases.

Thus, the essential feature of natural environment transformation for rational land and water resources use in areas of irrigated agriculture is the organic connection of natural landscapes (landscapes) with human economic activity. Irrigation, which involves supplying water to areas with water scarcity, plays a crucial role in improving soil fertility in arid climates.

Irrigation is the main hydraulic engineering technique in arid climates. It provides plants with moisture and nutrients, regulates air temperature above the soil surface, and increases soil moisture. In arid regions, natural precipitation alone is often insufficient, as dry winds can lead to excessive evaporation, resulting in insufficient moisture for plants. Irrigation helps to overcome these limitations by providing a controlled supply of water to the soil.

In agro-irrigation landscapes within the Kashkadarya basin, changes in natural hydrological conditions are also observed due to the expansion of irrigation. In particular, the increase in irrigation water supply, expansion of water surface, and increase in mineral content are noticeable. According to M. A. Pankov (1974), in the Karshi district, the increase in surface water (associated with the intensification of mineralization processes) occurs at an annual rate of 30-40 cm in traditionally irrigated areas and up to 1 m in newly irrigated areas. Hydrogeologically, in areas with significant salt deposits in soil and groundwater layers, the mineralization level of irrigation water can reach 1-3 g/l in areas with limited relief and up to 5-25 g/l in flat areas (Hasanov, 1981).

Irrigation has a particularly large effect on the stormwater regime, causing a change in the hydrogeological situation embodied in nature (see Table 2). This effect is manifested first of all in the disturbance of the natural hydrogeological situation of the territory. Due to irrigation, there is an increase in the saturation of filtration water, an increase in its level, and an increase in the level of mineralization. Soil salinization and overwatering occur when crops are insufficient and agrotechnical rules are violated.

In agro-irrigated landscapes, the above-described factors (relief, hydrogeological, hydrological, and other) conditions are changed as a result of changes in soil formation processes and soils. In agro-irrigated landscapes the physical properties of soils, the rate of chemical and microbiological processes, decomposition, and accumulation of organic matter change. The application of mineral fertilizers, especially in agricultural fields, accelerates this process. Soil cover change under such conditions occurs in 3 main directions: 1) anthropogenic evolution of indigenous soils; 2) emergence of new anthropogenic soil types; 3) end of soil formation process.

Depending on changes in the natural direction of soil formation in agro-irrigated landscapes, the soil also changes and acquires new properties and characteristics. Especially on ancient irrigated lands, as a result of long-term irrigation, soils change radically, and agro-irrigated sediments are formed in the upper part, i.e. new types of soils - cultural oases - are formed in place of native soils. For example, in the Kitab-Shakhrisabz bog, a thicker humus layer, uniform distribution of humus and total nitrogen in the soil profile are observed for cultural oasis soils.

Changes in soil formation in agro-irrigated landscapes, formation of new micro-relief, and changes in the lithogenic basis of new landscapes lead to fundamental changes in the ecological state of plants, i.e. the natural vegetation cover is strongly modified. In agro-irrigated landscapes, natural biocenoses are replaced by agro-biocenoses, riparian vegetation, hedgerows, and other vegetated soils.

As the area of agro-irrigation landscapes in the Kashkadarya basin expands, the ameliorative condition of lands also deteriorates. After all, the use of agro-irrigation landscapes does not take into account the susceptibility of lands to some unpleasant processes, and the area of lands subject to such processes as re-salinization, irrigation erosion, deflation, suffusion, which negatively affects them, is increasing from year to year. This situation requires several measures to optimize the use of agro-irrigation landscapes.

As the area of irrigated land in the Kashkadarya basin expanded, the area of re-saline lands also increased. For example, in 1965 the area of irrigated lands in Kashkadarya province was 154.9 thousand hectares, of which 21.5 thousand hectares had different degrees of salinisation.

Irrigation is a powerful factor in agricultural intensification and transformation of natural landscapes, which includes a number of complex economic activities: construction of irrigation systems (canals, reservoirs, etc.), land preparation, agricultural irrigation of fields and residential areas, cultivation of crops, etc. As a result, natural components (relief, fauna and flora, soil, groundwater, microclimate, etc.) are significantly changed on irrigated lands. As a result of the irrigation of the Karshi desert of Kashkadarya province with an arid climate, there is over-salinization, waterlogging (overwatering), irrigation erosion, subsidence, and other negative consequences.

The Kashkadarya basin has long been irrigated and irrigated agriculture is developed. The most negative impact on agriculture in the irrigated farming zones of the basin is caused by such natural geographical processes as water erosion, wind erosion, gravitational processes, flooding, siltation, waterlogging, salinization, and siltation.

Currently, in the oases of the basin, given the development of agriculture by modern intensive methods, closely linking agriculture with industrial production, foreign investors are attracted and clusters are functioning. Utilizing the available opportunities, greenhouse farms have even been established across the city. This has resulted in providing the population with jobs and food all year round.

The impact of irrigation erosion on the degradation of agro-irrigated landscapes is also increasing. Irrigation erosion leads to changes or rather deterioration of water-physical and agronomic-chemical properties of agro-irrigated landscapes. Due to these processes, the amount of waste, nitrogen, and other nutrients in the soil is also reduced. The reduction of organic matter in the soil requires the application of mineral fertilizers in large quantities. The use of chemicals - mineral fertilizers and pesticides, herbicides, defoliators, and other toxic chemicals in crop cultivation - causes pollution of soils, waters, and the whole environment, which leads to the deterioration of living conditions in villages. Degradation of soil structure, reduction of humus content, and environmental pollution on irrigated lands are caused by excessive use of mineral fertilizers and other pesticides in the recent past.

The increasing development of natural and anthropogenic processes that cause a decrease in the productivity of agro-irrigated landscapes requires the creation of a set of measures effective both from the ecological and economic points of view for the rational organization of the use of such lands in agricultural production on a scientific basis and for the protection of landscapes.

In the organization of rational use of irrigated lands created by agro-irrigation landscapes, it is important to organize landscape monitoring and development of geo-ecological forecasts based on the study of natural features of landscapes and their changing conditions under the influence of anthropogenic factors. Ground and surface water pollution is a serious environmental problem of irrigated agriculture. This process results from the use of water for crop irrigation and the leaching of salt from the soil. The mineralization (salinity) of water used for irrigation in most rivers is 0.2-0.5 g/l. However, at present their mineralization has increased, which leads to over-salinization. At the moment the level of soil and water salinisation is increasing due to the use of mineral fertilisers.

In general, it is important for agriculture in Kashkadarya province to first create irrigation and then reclamation systems. For efficient use of land and water and achieving economic efficiency, it is best to radically improve reclamation conditions, introduce water use technology at the normative level, and then proceed to the application of agrotechnical and agro-reclamation measures.

Irrigation, related to hydro melioration, consists of many measures aimed at long-term improvement of the soil water regime to increase its productivity. Irrigation is carried out utilizing engineering hydraulic structures in order to change or regulate the water regime of the territory.

4 Conclusion

Degraded lands formed in the Kashkadarya basin cause great damage to agricultural fields, pastures, and ecosystems. Also, the intensity of anthropogenic impact on the nature of the territory causes landscape-ecological problems and disturbances of metabolism and energy and balance of ecosystems.

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