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Abdurazak Abilovich Taylakov
Jizzakh Polytechnic Institute
PhD, Jizzakh,Uzbekistan

Rashid Anorovich Kulmatov
National University of Uzbekistan
Professor of department "Ecology", Tashkent, Uzbekistan

Sayiddzakhon Zokirjon ugli Khasanov
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers
Lecturer of Center "ECOGIS", Tashkent, Uzbekistan

Gulzoda Khayrullaevna Khudoyberdieva
Jizzakh Polytechnic Institute
Lecturer department of "Ecology", Jizzakh,Uzbekistan

DEVELOPMENT OF A VISUAL PROGRAMMING ALGORITHM FOR BIM-MODELS USING A MODULE OF CONSTRUCTIONS USING A DYNAMO MODULE

Abstract: *The Aydar-Arnasay Lakes System (AALS) is located in the middle of the Syrdarya River, to the south of the Chardara reservoir, and in Jizzakh and Navoi provinces of the Republic of Uzbekistan, adjacent to the low plain of South Mirzachul. The largest lake of the AALS, Aidarkul, extends 130 km to the southeast at the foot of the Nurata ridge and adjoins the Tuzkon lake. From 70 km south-west of the Chardara reservoir, is the AALS connected to the East Arnasai chain of lakes.*

The AALS varies with the volume, area, and surface water resources of the Syrdarya River through the Chardara reservoir over the years.

Currently, the AALS has a significant impact on regional ecosystem and socio-economic conditions. Studying and evaluating the AALS hydrology, the volume, area, and variability of water levels altogether play an important role in the development of fisheries and ecotourism in the region. However, in the past studies, the dynamic changes in the volume, area and water levels of the AALS have not been investigated through up-to-the-date geo-information systems, requiring additional research.

This paper examines the changes in water volume, area, and levels of the AALS throughout 1993–2017 by considering availability of statistical data and field experiments.

Key words: *area, dynamics, GIS, hydrology, lake system, water volume, water level.*

Language: *English*

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Introduction

Aydar-Arnasay Lake System (AALS) - This is the largest artificial lake in the Aral Sea basin, located in the Arnasay lowland of Kyzylkum in southeastern Uzbekistan, in the Navoi and Jizzakh regions, and is formed by the confluence of three lakes (Arnasay, Aydarkol and Tuzkon) [1, 2, 4].

During the floods of 1969, about 60 percent (21 km) of the average annual flow of water into the Syrdarya was discharged into the Arnasai lowland in winter due to the limited capacity of the river from the Chardarya reservoir (on the Kazakh-Uzbek border) and the gradual filling of the natural abyss. Aidar-Arnasay lake system (Arnasay, Aydarkol, Tuzkon) appeared [3, 17, 18].

Since 1993, the Tokhtagul reservoir has been operating in an energy mode, and blocking the flow of water from the Chardarya reservoir to the Aydar-Arnasay reservoir has led to a complete change in the regime of the lake system due to a decrease in water capacity in the lower Syrdarya (especially during periods of freezing the river).

Change in the amount of water in the basin of the Aydar-Arnasay lake system. The work of the water system of the Syrdarya basin. The transition from irrigation to energy is inextricably linked with unregulated water flow from the reservoirs of Tokhtagul, Kairakum, Chardara into the Naryn-Syrdarya river [8, 9].

Today AALS is the second largest closed reservoir in the region after the Aral Sea. The size of the surface area of the lake system leads to strong evaporation and remains an important factor in climate change in the region [12].

In 1992-93 On average, 2.8 km^3 of water was discharged annually from the Chardarya reservoir into the Aydar-Arnasay reservoir, and in some years it increased to 9.2 km^3 [12, 13].

Drainage water from the collector flows of regional agriculture to Lake Tuzkan, which is part of the Aidar-Arnasay lakes system, Studied Kulmatov and others [4]. Four main ditches: Jizzakh Main Ditch (JMD), Kli, Akbulak and the boundary collector, on average 97.8% of the collector-drainage water flows annually into Lake Tuzkon. During 2000-2017 Lake Tuzkan received 14 971.51 million m^3 of collector-drainage water from regional collector-drainage networks, or an average of 831.75 million m^3 per year [4].

Water volume, area, water level, length and width of the Aydar-Arnasay lake system were studied on the basis of field expeditionary analysis [5]. It was concluded that the continuous continuation of water evaporation in the lake system led to a decrease in water level, which indicates an increase in water salinity during the summer and autumn seasons [5].

The role of the Aidar-Arnasay lake system in the development of fisheries, the influence of the lake system on climate change and environmentally sustainable development in the region was studied [6]. AALS water resources fluctuated during the seasons depending on the amount of precipitation and the amount of water supplied to them [14, 15].

The influence of anthropogenic factors on the water regime of the Syrdarya water in the Chardarya reservoir and the release of AALS through the reservoir *B*. Amazed Isina and others [7]. In this study, changes in the water regime under the influence of anthropogenic activity were observed from 1980 to 2016 in the part of the Syrdarya river in Kazakhstan, where the Chardarya reservoir is a source of water. The results show that human activities, especially water use in agriculture and electricity production, were confirmed as key factors in changing the water regime of the Chardarya reservoir. The inflow and outflow of water to the Chardarya reservoir can often lead to severe flooding and socio-economic damage and losses in the underlying settlements of the Syrdarya [15, 16].

Quantitative and qualitative indicators of AALS of water resources *R*. Estimated by Kulmatov et al. [4, 6]. A study was made of the hydrology of the lake system, changes in the quantity and quality of water resources, its significance in the development of fisheries and ecotourism in the region.

It was found that the correlation between the change in the area of the AALS cable and the water level, an increase in the amount of water due to a rise in the water level is a factor in increasing the groundwater level and increasing salinity [8]. The study concluded that increasing water levels led to an increase in groundwater levels, which led to an increase in the salinity of the lake system [15].

Changes in the AALS after the 1990 y, changes in the regime of the lake system due to water discharged from the Tokhtagul reservoir in the Kyrgyz Republic, and an increase in groundwater levels due to an increase in water levels were studied on the basis of field expeditions [5].

Along with the increase in water volume, level and area of the lake system, the ecological condition of areas close to the lake system has deteriorated, and wetlands have appeared due to rising groundwater. As a result of the expedition, it was concluded that it is necessary to improve the monitoring system in AALS, to determine the current state of the lake system and future trends [5].

In 2008, AALS was included in the list of wetlands of *RAMSAR* of global importance. According to environmentalists, the inclusion of AALS in the *RAMSAR* list will draw the attention of the world community to the problem of maintaining and improving the environmental conditions of this unique lake ecosystem [19].

From the analysis of known studies in the literature, the following were revealed:

The above study does not analyze long-term hydrological changes in AALS. The dynamics of changes in the area of the lake system over many years, the correlation dependence of changes in water level, the amount of water resources of the lake system depends on the amount of water flowing from the Chardarya reservoir and collector drains, and climatic conditions. Changes in the area, water level and volume of the lake system for many years have not been evaluated using the Geographic Information System (GIS) software. The interdependence of changes in the quantity, area, water level, annual amplitude of AALS, the water of the Syrdarya river flowing into it through the Chardarya reservoir, collector-drainage water (CDW) and snow and rain water, changes in climatic conditions have not been studied enough.

In the future, AALS, which is important for the region, requires the development of scientific and practical recommendations for the protection and sustainable use of water resources.

The aim of this work is to integrate the GIS program in assessing the dynamics of changes in the volume, area, water level in 1993-2017 as a result of the discharge of water from the Syrdarya through the Chardarya reservoir and collector drainage water.

Materials And Methods

Experimental zone

Today, the Aydar-Arnasay lakes system is one of the largest water bodies in the country, one of the gray zones where the natural balance is disturbed, and the ecological environment is more serious.

AALS is located in the middle reaches of the Syrdarya River. To the south of the Chardarya reservoir there is a connection of the Kyzylkum desert and the Nurata mountains in the Jizzakh and Navoi regions of the Republic of Uzbekistan. The largest lake in the Aydarkol lakes system is located in the southeastern part of the lakes system at the foot of the Nurata Range and extends over 130 km and is connected with Lake Tuzkan. The lakes system is connected to the south-west of the Chardarya reservoir by the chain of eastern Arnasai lakes, which are almost 70 km long and which are a convenient zone for Mirzachul (Fig. 1).

Using modern GIS technologies to solve these problems ensures the high quality of the task in accordance with international standards, and also allows you to quickly analyze the situation and make the necessary management decisions in a short time [10].

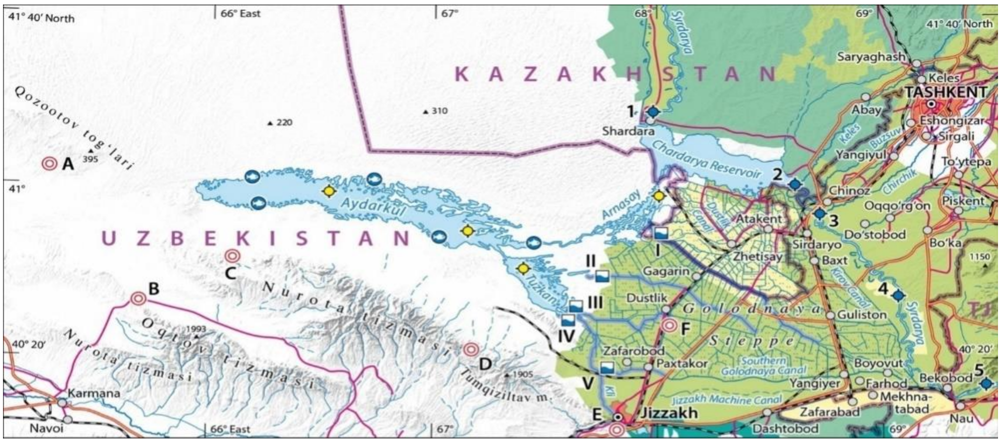

Figure 1. Study area and sampling points

Climate AALS

The climate of AALS is variable, with short average winter temperatures ranging from 13.2 °C (west) to 14.4 °C (south). The hottest climate is July-August, the temperature of which reaches 29.4-42.7 °C. The temperature of the AALS water in the summer rises to 28-30 °C. In the coldest months, the water temperature drops to 3.6 °C [11].

The climatic conditions of the Aidar-Arnasay lake system have changed over the years depending on the amount of long-term precipitation received from the Jizzakh and Dustlik meteorological stations.

Between 1993 and 2017, the lowest rainfall at the Jizzakh weather station was observed in 2000 (275.6 mm), and the highest in 2002 - 554.4 mm. At the Dustlik weather station, the lowest was in 2006 (207.1 mm), and the highest in 2009 (455.9 mm).

The Aydar-Arnasay lakes system is currently an indoor water basin with a water level of 244.8 m, a volume of 34.93 km^3 and an area of 3224 km^2. The total length of the lake system is 190 km and the width is 52 km.

Methods used

In addition to the field expedition data used in this article, satellite imagery was used to measure AALS area. The source of satellite images is Landsat (for more information about Landsat: *https://uz.eferrit.com/landsat/)* from the Earth Explorer database for the analysis of satellite images taken between 1993 and 2017 in accordance with the purpose of downloading. The downloaded images were shot in December 1993, 1997, 2003, 2007, 2013 and 2017, respectively, and were theoretically accepted as probable by the end of the annual change this month. The analyzed spatial images were used in addition to the primary data collected to assess the hydrological regime of AALS without using field practice.

To improve the accuracy of the research results, AALS had to download a lot of spatial images. The downloaded photos were combined using Erdas Imagine 2014. The COST model was used to improve the quality and filtering of images [21, 22] and geometrically corrected images to exactly match spatial coordinates. Using ArcGIS 10.6, AALS was extracted from the combined spatial data (*DN <20*) and analyzed in accordance with the reflective properties of the object [20].

Statistical analysis was performed to demonstrate the scientific importance of spatial data analysis in measuring AALS area. These statistical analyzes were performed using the open source *R-program.*

The analysis includes coefficients, analysis of variance and regression, showing the correlation of the expansion of the AALS region with the average annual temperature and annual total rainfall based on data from the Hydromet Center, as well as *P*-values indicating the statistical significance of the results. An additional correlation analysis of the AALS water volume was carried out taking into account the above climatic factors.

Results And Discussion

The water level, area and volume of AALS change over the years depending on the flow of water from the Syrdarya through the Chardarya reservoir and the flow of collector-drainage water (CDW) and the amount of annual rainfall.

The dynamics of changes in the AALS in recent years

Between 1993 and 2006, the water level and the area of AALS increased due to the influx of Syrdarya water into AALS through the Chardarya reservoir and the discharge of KDW water. Figure-2 shows the results of a study conducted in GIS programs to assess the dynamics of changes in the area of the Aydar-Arnasay lake system in recent years.

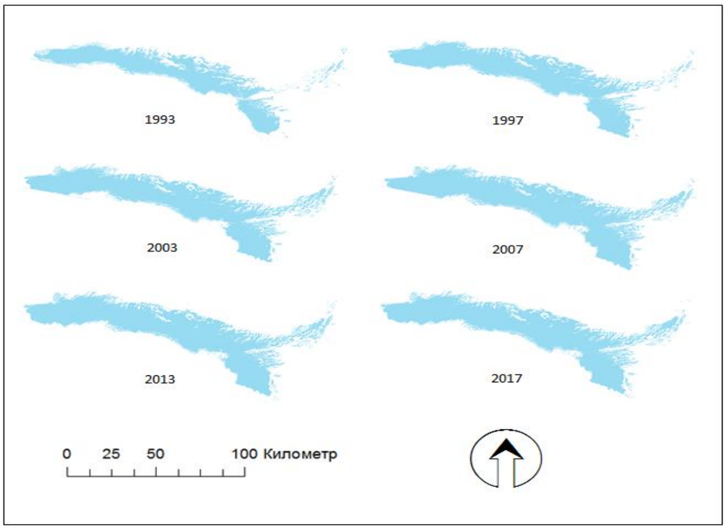

Figure 2. Dynamics of changes in the area of the Aydar-Arnasay lake system over the years.

As can be seen from the data in Figure-2, from 1993 to 2017, the expansion of the AALS zone was observed. To make the resulting map look more perfect, the map created for each year was placed on top of each other (Figure-3).

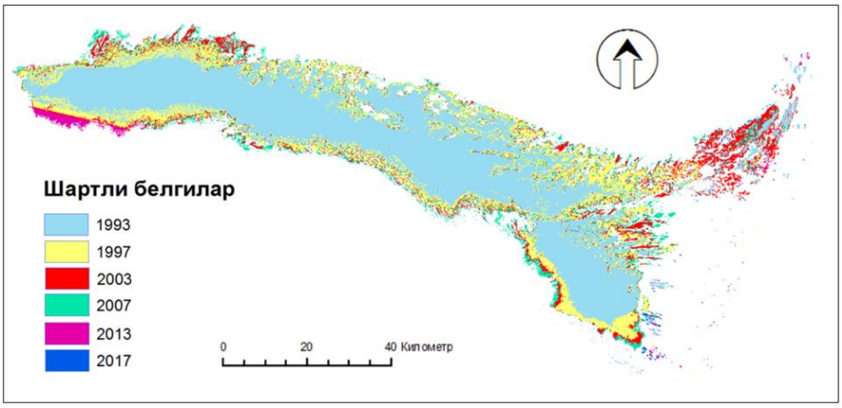

Figure 3. Dynamics of changes in the area of the Aydar-Arnasay lake system over the years

From the data of the GIS, we can only see the growth of the AALS area, but they cannot provide quantitative data. (Figure-3). With this in mind, the numerical values of the area of the AALS map created for each year were obtained on the basis of the data in Figure-3 (table-1).

Table 1. The numerical change in the area of the Aydar-Arnasay lake system discovered by the GIS programs in the years of research

YEARS	AALS Area (km^2)
1993	3,898.35
1997	4,593.40
2003	5,259.91
2007	5,451.25
2013	5,564.31
2017	5,696.56

It should be noted that it is not possible to completely reduce errors obtained from GIS data. As mentioned in the section on the methods used, the COST model used to improve the quality of the resulting GIS cards significantly reduced the error in the AALS reflection values. In the analysis performed in the GIS program, it was assumed that the error was 5%, and the numbers of the AALS field indicated in the GIS were plotted taking into account the error (Figure-4).

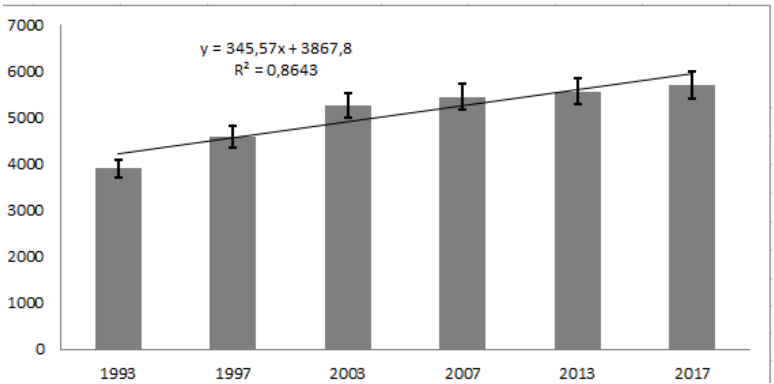

Figure 4. Dynamics of increasing the area of the Aydar-Arnasay lake system based on a 5% error

After detecting changes in the AALS zone using GIS technologies, a statistical analysis was carried out to check the degree of compliance of the result. At the same time, first of all, we used data on climatic factors from the Jizzakh and Dustlik weather stations located around AALS from Uzhydromet, taking into account the years selected in accordance with satellite images (Table-2).

Table 2. Climate change data around AALS in research years.

Years	Average annual temperature (Jizzakh weather station), ˚C		Average annual temperature (Meteorological station Dustlik),˚C		Rainfall (November-May), mm (Jizzakh ms.)	Rainfall (November-May), mm (for example, Dustlik)
	Summer	Winter	Summer	Winter		
1993	27.6	4.1	27.9	5.0	361.7	267.0
1997	27.5	3.7	27.6	4.2	358.4	289.3
2003	27.3	3.8	27.8	4.3	402.6	378.5
2007	27.2	2.5	27.4	3.5	392.2	336.8
2013	26.2	1.1	26.9	0.9	416.4	350.1
2017	27.2	2.1	27.3	2.5	407.0	345.2
Long-term average	27.2	2.9	27.5	3.4	389.7	327.8

Based on the meteorological data presented in Table-2, a correlation analysis was carried out to assess the impact of local climatic factors on the change in the AALS zone (Table-3).

Table 3. Correlation of local climatic factors with changes in the area of the Aydar-Arnasay lake system

	Average annual temperature (Jizzakh weather station)		Average annual temperature (Friendship Weather Station)		Precipitation, November-May (Jizzakh weather station)	Precipitation, November-May (weather station Dustlik)
	Summer	Winter	Summer	Winter		
Correlation	-0.62	-0.75	-0.74	-0.74	0.87	0.88

The results of the above correlation show that the AALS area increased simultaneously, as the average temperature recorded during the annual seasons decreased over the years, and the rainfall in *November-May* increased over the years (Table-3). It is logical that a drop in air temperature reduces the potential evaporation (evaporation) of the process. Therefore, the area of the lake at the research site, where a drop in air temperature was observed, increased.

Precipitation was previously thought to play a role in increasing the AALS area. According to the results of table-3, the change in area with precipitation positively correlates with each other. This, in turn, means that the total rainfall during the annual rainy season has a large and significant effect on the change in the area of AALS. The following statistical analyzes were performed to take a deeper approach to the problem. Based on the results of the regression statistics, we see that the selected area values and climatic factors (variables) strongly correlate (table-4).

Table 4. The results of regression analysis

Multiple R	0.853
R^2	0.728
Normalized R^2	0.669
Standard error	315.080
Accounting	6

Based on the results of Table-4, the coefficient (R^2), indicating the total statistical correlation of variables with each other, was 0.728. This showed that the results of the GIS analysis strongly correlated (R^2> 0.70) with the primary climatic data.

According to the results of analysis of variance, the total interdependence of variables (significance level-*F*) was considered scientifically significant (table-5).

The *F* value (45.635) of the dependence of the GIS analysis of satellite images taken over 6 different years from the 6 observation records analyzed in the regression in Table-5 differs from the critical *F* value shown in the general *F* test (45.635). 8.003) is much larger, and the significance level *F* is very low (<0.05), which confirms the above results from a scientific point of view.

Table 5. The results of analysis of variance

	df	***F*- value**	***F*- significance level**
Regression	6	45.635	0.000787

In general, we can say that the integration of GIS technologies is scientifically and statistically useful for assessing the dynamics of changes in the field of AALS over the year.

The results of the regression analysis, which statistically confirms the degree of dependence of the change in the AALS field for each variable found using the GIS programs, are presented in Table-6.

According to the results of the correlation analysis, the values of the change in the AALS area during the year determined using the GIS program depend on the amount of precipitation and the average annual temperature (tables 3-6). Regardless of how high the scientific significance of this correlation is, the results of the regression analysis in Table-6 also confirm the statistical significance of the results of the above correlation analysis (p <0.05 - for temperature and precipitation).

Preliminary data show that in 1993 the water level was 237.58 m, an area of 2045 km^2, in 1996 - 242.48 m, an area of 2682 km^2, in 2000 - 244.26 m, an area of 3140 km^2.

The highest level, volume and area of AALS water were noted in 2006. The water level is 246.82 m, volume 42.15 km^3, area 3599 km^2. In subsequent years, due to a decrease in the amount of water discharged through the Chardarya Reservoir, AALS led to a decrease in water level and a decrease in area. In 2010, the water level was 245.78 m, area - 3412 km^2, in 2014 - 245.56 m, area - 3373 km^2, in 2017 - 244.73m, area - 3224 km^2. The correlation between water level and area was close (R^2 = 0.935).

Table 6. The results of the regression analysis of the values of the variation of the area of AALS relative to the variables found using the GIS program

	Standard error	**t-statistic**	**p-value**
The average annual summer temperature (Jizzakh weather station)	385.32	0.71	0.00084
The average annual winter temperature (Jizzakh weather station)	390.68	0.39	0.00076
The average annual summer temperature (weather station Dustlik)	505.08	0.64	0.00081
The average annual winter temperature (weather station Dustlik)	188.34	0.21	0.00087
Precipitation (Jizzakh weather station)	15.41	1.09	0.00004
Precipitation (Weather Station Dustlik)	9.00	0.63	0.00006

The dynamics of changes in water volume in AALS

In 1993, 16.70 km^3, in 1994 - 18.62 km^3, in 1995 - 25.72 km^3, i.e., the volume of the AALS water body increased from year to year. In 1999, it was 31.73 km^3, in 2004 - 38.32 km^3, and in 2006 the maximum was 42.15 km^3. in 2008, it was 40.36 km3, in 2010 - 38.50 km^3, in 2014 - 37.70 km^3, and in 2017 - 34.93 km^3 (Figure-5).

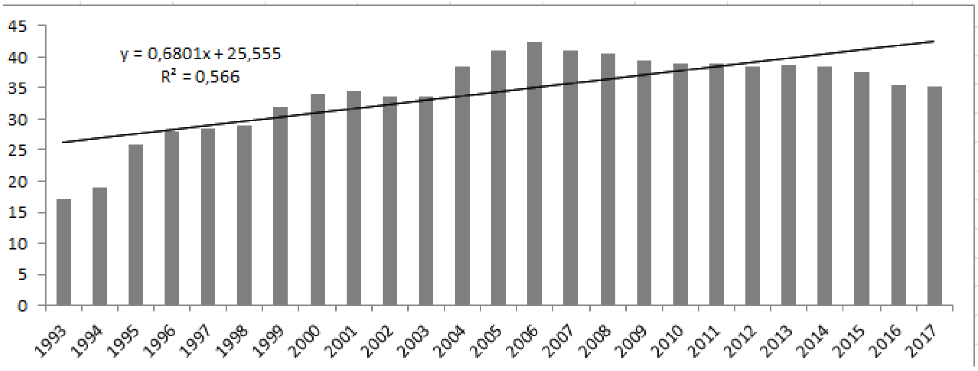

Figure 5. Dynamics of changes in water volume over the years of the lake system. Aydar Arnasay

A correlation was established between the dynamics of changes in the volume of AALS water and the climatic variables indicated above (Table-7).

Table 7. Coefficients of dependence of the change in water volume of AALS over the years on climatic factors

	Average annual temperature (Jizzakh weather station)		The average annual temperature (weather station Dustlik)		Precipitation, November-May (Jizzakh weather station)	Precipitation, November-May (Dostlik weather station)
	Summer	Winter	Summer	Winter		
Correlation	-0.63	-0.72	-0.73	-0.71	0.74	0.78

The correlation analysis shows that the increase in AALS water volume was significantly related to the average annual temperature measured at a weather station located next to both research facilities. This analysis gave the expected result, that is, a negative correlation (increase with evaporation with increasing temperature to reduce the volume of water). AALS showed that the increase in water volume is also highly dependent on precipitation (table-7).

The results of the study showed that the maximum amount of water discharged from the Chardarya reservoir was 9,286 km^3, while the minimum amount of water discharged in 1994 (0.025 km^3) was observed in 2016.

In 2013, 2017 and 2018, wastewater was not discharged into the lake system at all. A detailed graph of discharge waters over the years can be seen in Figure-6.

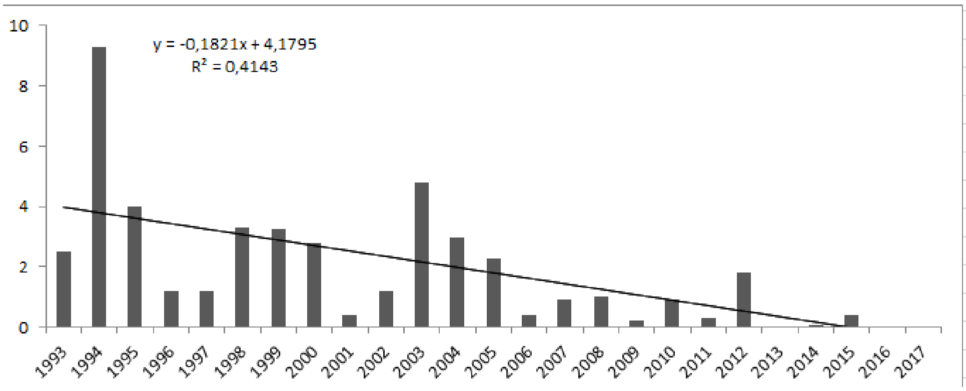

Figure 6. Dynamics of changes in the amount of water discharged from the Chardarya reservoir into the Aydar-Arnasay lakes system

By 2000, due to changes in the amount of water discharged from the irrigated lands of the Jizzakh region - Kli, Akbulak, Jizzakh main ditch, Pogranichny, Central Mirzachulsky ditches, the water volume amounted to 33.48 km^3, the area - 3140 km^2.

According to preliminary data, the volume of water discharged from the Chardarya reservoir in 2006 amounted to 2793 km^3, while the largest area, water volume and water level in AALS, i.e. 42.15 km^3, increased by 3599 km^2, water level 246, 82. meters.

Due to the fact that the annual volume of water discharged from the Syrdarya, i.e. Chardarya reservoir, decreased in 2010 compared to previous years and amounted to ***8.40 km^3*** (Figure-6), the volume amounted to 38.50 km^3, an area of 3412 km^2, annual water level is 245.78 meters.

The annual volume of water discharged into the system of lakes from the Chardarya reservoir has changed over the years: 0.250 km^3 in 2011, 1,623 km^3 in 2012, 0 in 2013, 0.124 km^3 in 2014, 0.343 km^3 in 2015 and 0.025 km^3 in 2016 year. due to the small amount of precipitation during the next two years of 2017-2018. the water level in the Syrdarya river was low, and water from the Chardarya reservoir did not enter the AALS (Figure 6).

The highest and lowest values of AALS water level during the year, that is, the annual amplitude, varied as follows.

In 1993, the maximum annual water level was 239.52 m, the lowest annual level was 237.15 m, the annual amplitude was 2.37 m, in 1994 the highest annual level was 242.10 m, the lowest annual level was 238 , 89 m. The annual amplitude index was 3.21 m, the highest annual level in 2000 was 245.51 m, the lowest level during the year was 244.25 m, the annual amplitude index was 1.26 m, the highest annual level in 2003 it was 246.28 m, the highest level during the year was the lowest level of 244.21 m, the annual amplitude index was 2.07 m, the annual soky level of 247.15 m in 2006, the lowest level for the year 246.42 m, the annual index of amplitude of 0.73 m (Fig.7).

In AALS, the correlation between the amplitude of the annual maximum and minimum water levels for the period 1993-2017 was close (R^2 = 0.534).

Water levels rose and fell between 1993 and 2017. It grew to 1.12 m in 1994, 2.90 m in 1995, 0.88 m in 1996 and only 0.02 m in 1997 (Figure-8).

The water level in the lake system rose to 1.06 meters by 1999, 0.57 meters in 2000 and 0.19 meters in 2001. In 2002, the water level dropped to -0.34 meters. By 2004, the water level rose to 1.65 meters, but in the next 2007-2017 it fell to minus (Figure-8).

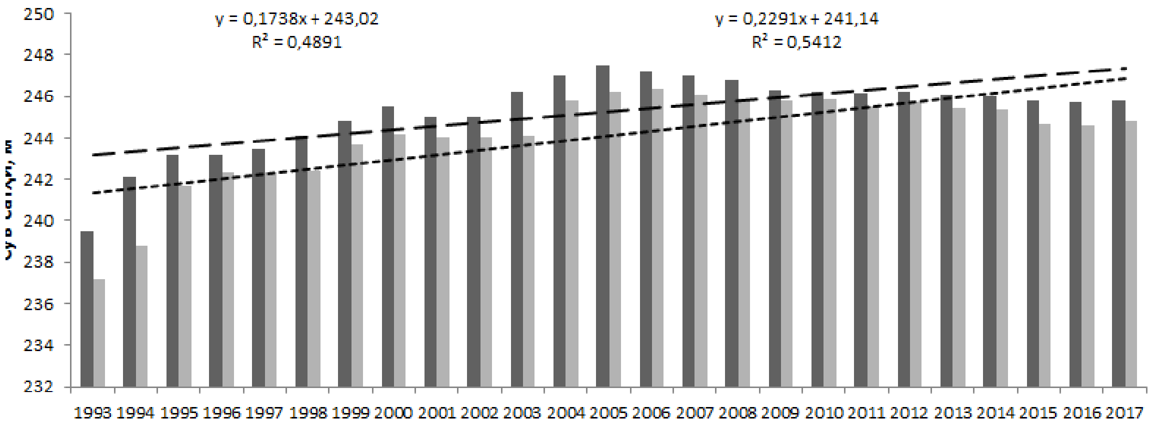

Figure 7. Changes in the amplitude of the maximum and minimum annual water levels in AALS for 1993-2017

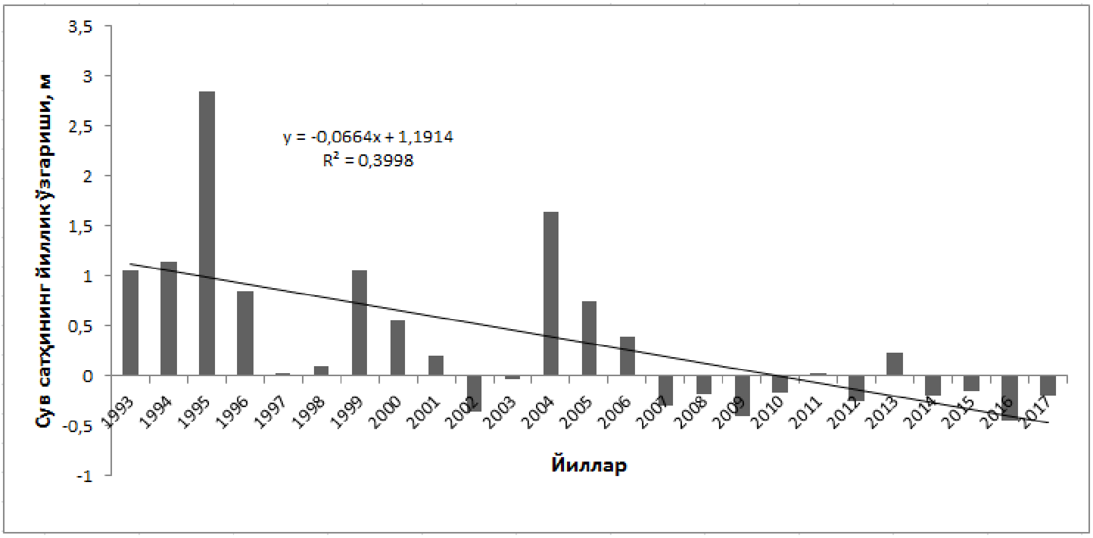

Figure 8. Dynamics of annual changes in water level in AALS

This decrease in water level was caused by the fact that the amount of water flowing from the Chordara reservoir decreased from year to year from 2008 (in 2013 there was no water at all) due to the large surface area of the lake system.

Conclusion

Hydrology, water volume, area and dynamics of changes in water level in different years vary mainly depending on the amount of Syrdarya water discharged into the ash system through the Chardarya reservoir and the amount of collector-drainage water discharged into it.

Over the years of research (1993-2017), the volume of AALS water ranged from 16.70 to 34.93 km^3, the area from 2045 to 3224 km^2, and the water level - from 237.58 to 244.73 m. 15 km^3, the area increased at 3599 km^2, the water level was 246.82 meters.

GIS technologies were first used to determine the AALS domain based on the results of statistical analysis. Using GIS technology, you can track the dynamics of changes in the area of the studied reservoir in online mode, without going directly to the object of study.

It has not been substantiated that the hydrological characteristics of AALS depend on temperature, but not on precipitation.

Monitoring the dynamics of changes in water volume, area, water level and annual level of AALS plays an important role in the development of fisheries, ecotourism, and the protection of flora and fauna in the lake system.

To improve and develop the monitoring system in the AALS, it is necessary:

• Regular field observations at the AALS site;

• Assessment of the dynamics of changes in the AALS water resources based on the GIS program and development of scientific and practical recommendations;

• Assess and justify the need for water resources in order to maintain the environmental status of AALS at an acceptable level, to introduce a system of integrated use and effective management of water resources in the middle reaches of the Syrdarya.

Using modern GIS technologies, the Aydar-Arnasay lakes system is able to detect and evaluate the dynamics of changes in water levels, emergency situations during floods, forecast areas affected by floods, and minimize the negative consequences of floods in case of emergency.

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