STUDY RELATIONSHIP BETWEEN WATER RESOURCE AND CLIMATE CHANGE IN TERRITORY IN THE ARAL SEA REGION

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Abstract

The increase of irretrievable river water withdrawals and regulation of river flow has a negative effect on the natural regime of the Aral Sea. The Amu Darya River and the Syr Darya River Basins are the largest irrigated farming areas. This negatively transforms the natural environment and worsens socio-economic conditions in Aral Region as a whole, especially in the lower reaches of Amu Darya and Syr Darya, where natural conditions are largely determined by the sea's impact. At present, this causes desertification of the non-irrigated zone in the deltas, spreading to new areas as the Aral Sea dries out. This rapid drying out and destruction of the Aral Sea has led to a number of socio-economic, climatic and health related problems.

Keywords: Aral Sea, climate change, temperature, precipitation, water.

Introduction

The increase of irretrievable river water withdrawals and regulation of river flow has a negative effect on the natural regime of the Aral Sea (Oteniyazov, Xujakulov, Seytniyazov, & Atamuratov, 2020). The Amu Darya River and the Syr Darya River Basins are the largest irrigated farming areas. Their favorable soil and climatic conditions ensure guaranteed yields of various crops on irrigated lands (Aitekeyeva et al., 2020). Since 1961, for the drastic increase of irretrievable river water withdrawal, mainly for irrigation, the inflow of river water into the Aral Sea has started to decrease significantly, accordingly the sea's hydrological and hydrochemical regimes disrupted dramatically (Micklin, 2007). The sea level has continued to drop as evaporation exceeds inflow (Bohovic, Dobrovolny, & Klein, 2017; de Beurs, Henebry, Owsley, & Sokolik, 2015).

Until 1960, the Aral Sea was the fourth largest inland lake in the world. Located in the heart of the Central Asian deserts, at an altitude of 53 meters above sea level, the Aral Sea served as the giant evaporator (Begjanova, Karajonova, Nietullaeva, N Abdullaev, & Jarasov, 2021). As the Aral Sea is located on the route of a powerful jet airstream from west to east, this moist flow has moved along the whole Central Asian region, softening the climate of the region, to the Pamir mountain ranges (Nietullaeva, Fayzullaev, Karimova, & Shaudenbayev, 2021). There, part of the air currents surrounds the Pamir Mountains from the north and moves further to the east, and the other is retained by mountains and falls as precipitation. Further, the water would return to the Aral Sea through rivers Amu Darya and Syr Darya (Gafforov et al., 2020).

Earlier Aral acted as a kind of regulator mitigating cold winds coming in the autumn and winter from Siberia and reducing the heat effect in the summer months like a giant air conditioner. With tightening of the climate the summer in the region has become more dry and short, winters - long and cold (Timur T. Berdimbetov, Ma, Liang, & Ilyas, 2020). These changes are also reflected in the report of IPCC AR5. A characteristic feature of the Aral region climate is the high repeatability and long duration of dust storms. There often strong winds in the Aral Sea region. The maximum wind speed can reach 20-25 m/s (T. Berdimbetov, Ilyas, Ma, Bilal, & Nietullaeva, 2021). The drying up of the Aral Sea has brought about a process of double desertification (Karajonova, Begjanova, Berdimbetova, Juginisov, & Madreimov). One is due to the appearance of the dried bottom of the sea, the second-artificial waterlogging of irrigated lands (Elena Lioubimtseva, 2014). As a result, in the center of the belt of Karakum and Kyzylkum deserts formed another new desert "Aralkum" where the danger is represented by appearance of continuous saline lands consisting of fine marine sediments and residues of mineral deposits washed from irrigated fields (T. Berdimbetov, Ma, Shelton, Ilyas, & Nietullaeva, 2021). It marked a new stage of desertification impact to the process of ecosystem degradation of the Aral Sea area, regional and global climate (Song & Bai, 2016). The seabed that in the former natural state served as a kind of desalination factory, now acts as an artificial man-made volcano emits into the atmosphere a huge mass of salt and pathological dust (Elena Lioubimtseva, Kariyeva, & Henebry, 2012; Su et al., 2021). The effect of pollution is amplified by the fact that the Aral Sea is located on the route of a powerful jet airstream from west to east. This facilitates the rise of aerosols in the upper layers and the rapid dissemination in the Earth's atmosphere (T.T Berdimbetov, Zhu-Guo, Nietullaeva, & Yegizbayeva, 2021).

In the present paper, an attempt has been made to monitoring the influences change climate in water resources, analysis in climate data, change causes behind this ecological destruction.

Study area

A characteristic feature of the Aral Sea region's climate today, the (the term Aral Sea region, or another name Aral region stands for the geographic location of the Aral Sea and the surrounding area within a radius of 500km) - distinctly continental. This negatively transforms the natural environment and worsens socio-economic conditions in Aral Region as a whole, especially in the lower reaches of Amu Darya and Syr Darya, where natural conditions are largely determined by the sea's impact. At present, this causes desertification of the non-irrigated zone in the deltas, spreading to new areas as the Aral Sea dries out. This rapid drying out and destruction of the Aral Sea has led to a number of socio-economic, climatic and health related problems.

Method and dataset

In this paper, we used the Pearson correlation method to analyze the relationship between water change and climate parameters. We also use the Gaussian method to determine the average annual distribution of annaual river water.

we used climate factors such as, temperature, precipitation and evaporation. The climate variability (air temperature, precipitation and evaporation) received from 35 local meteorological station. Also runoff change calculated based on monthly observational data from 15 local hyrdological stations across the study area.

Results

Spatial climate change

Thus the main characteristics responsible for climate change in the Aral region are temperature increase and a decrease in precipitation. Located on the southern side of the Eurasian continent, the Aral Sea basin climatic regime formed by atmospheric air movements in the region. Climate is continental, with hot summers and dry winters with little snow and cold. Therefore, days, months, year's continental signs are notable. In summer, the temperature is not so much faltered. The average annual temperature is around 7–8^{0}C. The highest temperature + 26-27.6^0 C (July), the minimum temperature in January 11.3–13.4^{0}C. A very large annual variation in temperature is up to 78^{0}C, with less precipitation. In the summer months it is neither cloudy nor foggy, and open water surface evaporation level is very high. Sometimes in winter months there are very cold winds blown to the north of Aral from Kar Sea, so the temperature goes down to -30ºC. But that cold reaches only the middle regions, therefore it is rarely cold in the Southern part of Aral (Moynak). Sometimes low-pressure tropical air comes from the Northern India to Aral. Then the temperature rises up to + 35–40^{0}C. These are the characteristics of the climate of Aral. Aral Sea itself has a certain extent influence to the surrounding regions. Sea pressure rises during the summer months, and the wind often blows ashore from the sea. Because of the effects of the Aral Sea there is a slight increase of the temperature in the winter and a slight decrease (+ 2^{0}C) during the summer months in the wilderness surroundings. A wide range of new land has appeared on a place of the deserted sea, which has now become a hearth that spreads salt dust to the surrounding area. The climate of the new island is completely different from what it was before, because there are some increasing continental signs. The evidence of that is the strong wind which blows hard in recent years in the winter months. It cracks the soil without any vegetation. Such a phenomenon occurs in the summer months which show a new climate change regime.

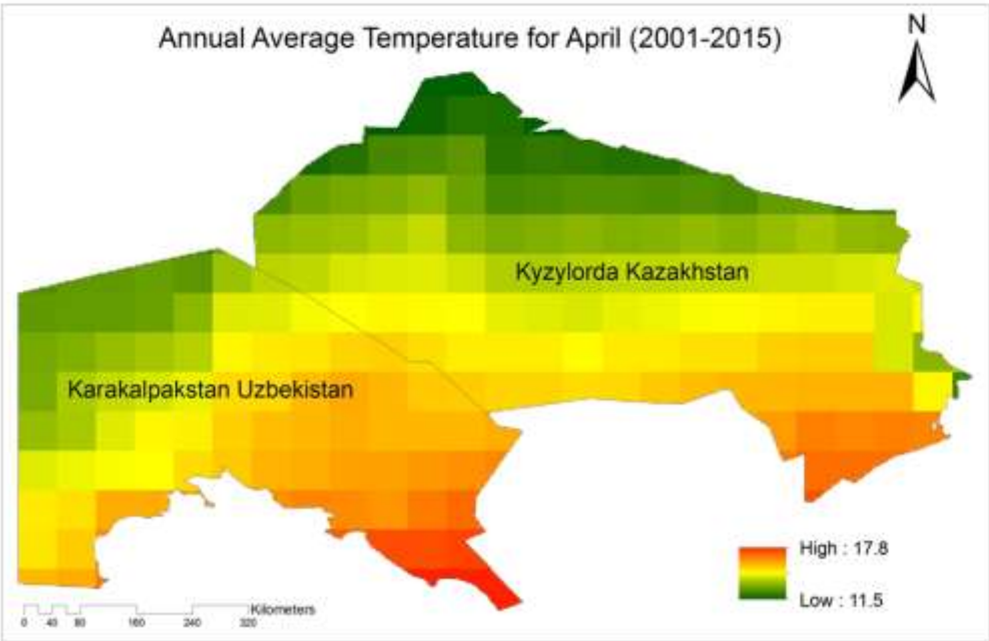

Fig 3. Change temperature in the Aral Region

Generally from the early times Aral region is lack of precipitation. According to the Aral and Kazaly hydrometeostation, the long-term average of annual precipitation in the region is about 90–110 mm. Of course, we cannot say this is the stable indicator. In some years there might be more and the next years less of precipitation expected. Therefore, long-term average amount of precipitation does not deviate much from the existing level. According to the fact that the amount of rainfall in the Aral region in 1998 was only 90mm, of that 34 mm fell in March and the rest 13 mm in August. In 2010, in only 8 months (January-August) the level of the rainfall has reached 134.4mm.

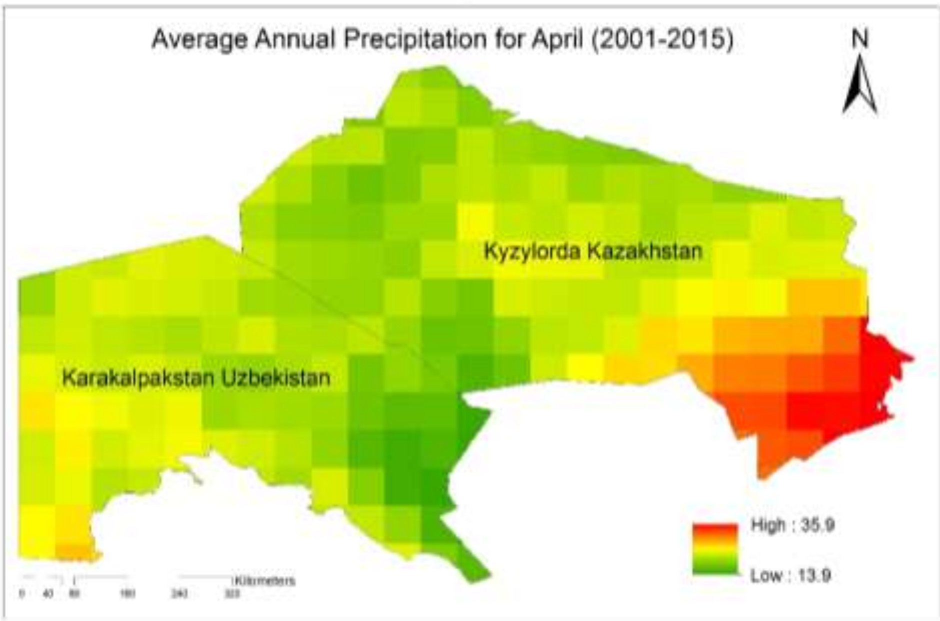

Fig 4. Change precipitation in the Aral Region

Desertification of the delta of the Amu Darya river in the Aral Sea zone

In general, as a result of the reduction in the flow of the Amu Darya water, an intensive process of desertification began, both in the area of the drained seabed and in the delta part of the river. The retreat of the sea and the associated formation of naked seabed areas, much of which consists of mobile solonchaks, sand, began from the south and south-east of the sea. The drained seabed is now becoming the focus of salt and dust transfer to the irrigated areas of this region.

As noted above prior to 1900, in addition to general information on the presence and location of the river and reservoirs, there were no materials on quantitative and qualitative indicators of water bodies (Elena Lioubimtseva & Cole, 2007). All information at that time was limited to a general description of the state of geographical objects located in this large region. For the first time in the literature sources, information on the water flow of the Amu Darya River within the delta of the Chatli hydro-power becomes available (E. Lioubimtseva, Cole, Adams, & Kapustin, 2005).

From 1913 to 1917 and further from 1931, there are data from systematic measurements of water discharge in the upper delta boundary. To highlight the characteristics of the flow of river flow into the delta of the Amu Darya, the hydrological data on the Chatli-Samanbay hydro-meteorology were used. The data cited indicate that water costs are decreasing from year to year. Reduction in the flow of river runoff into the delta is due to the loss of water for evaporation, filtration and for taking water for irrigation along the length of the river.

It is known that, since 1960-65 there was an intensive process of development of new lands (Bukhara, Karshi, Karakalpakstan, Turkmenistan), which led to a further decrease in the water content of the river, especially within the delta.

Year	Month												Average year (m3/s)	Run-off mean year km3
	Jan	Fev	Mar	Apr	May	June	Jul	Avg	Sep	Oct	Nov	Dec		
1960	713	460	242	263	1470	2240	3690	2630	1780	930	594	705	1310	42.1
1965	453	413	24.3	319	959	1580	1500	1280	917	776	704	521	805	25.4
1970	711	458	9.28	270	979	1820	2110	1330	2270	952	730	664	1025	32.3
1975	33.4	0	0	0	64	928	1000	971	729	458	110	235	360	11.4
1980	135	123	0.4	482	687	407	429	188	542	435	104	0	294	9.3
1985	286	16,3	35,4	44,2	0	22,4	12,7	43,1	137	63	4,75	36	58	1.8
1990	66,9	33,4	29,3	29,3	109	297	393	352	364	413	246	283	218	6.9
1995	430	134	118	205	567	31	41	62	85	130	90	73	164	5.2
2000	296	105	35	26	24	18	5,53	5,5	4,57	4,51	4,08	2,85	44	1.4
2005	63,3	245	171	415	369	408	2090	580	420	152	48	142	425	13.4
2010	569.1	507.4	188.9	123.2	216.9	269.0	189.7	507.4	188.9	110.5	7.8	212.2	257.6	8.2
2015	34.1	42.6	256.2	118.9	184.6	323.5	173.1	461.8	223.9	73.1	0.0	227.9	176.6	5.6

Table 1. Average annual debit of the Amu Darya river water flow on the h/p Samanbay for 1990-2015.

Considering the possible changes in the flow of the river actually entering the lower reaches, it is necessary to take into account the rate of increase of water intake on the upper part of the river. Due to the above circumstances, the characteristics of the river runoff over the years are given in several variants. Periods of observations of the runoff of natural water, periods of river regime, altered by human economic activity and periods of river runoff by regulation of reservoirs, hydrounits, etc., so the observation periods are divided into three periods:

low-flow period: $Q_{min} \leq 0.15Q_{max}$

Medium-flow period: $Q_{min} < Q_{ave} \leq 0.5Q_{max}$

High-flow period: $Q_{ave} < Q_{max} > 0.5Q_{max}$

The nature of the change in water discharge and runoff in low-water years.

During the analysis, it was revealed that almost 56.2% of the period under study was in the low-water period, 29.8% in the middle-water period, and only 14% was in the high-water period.

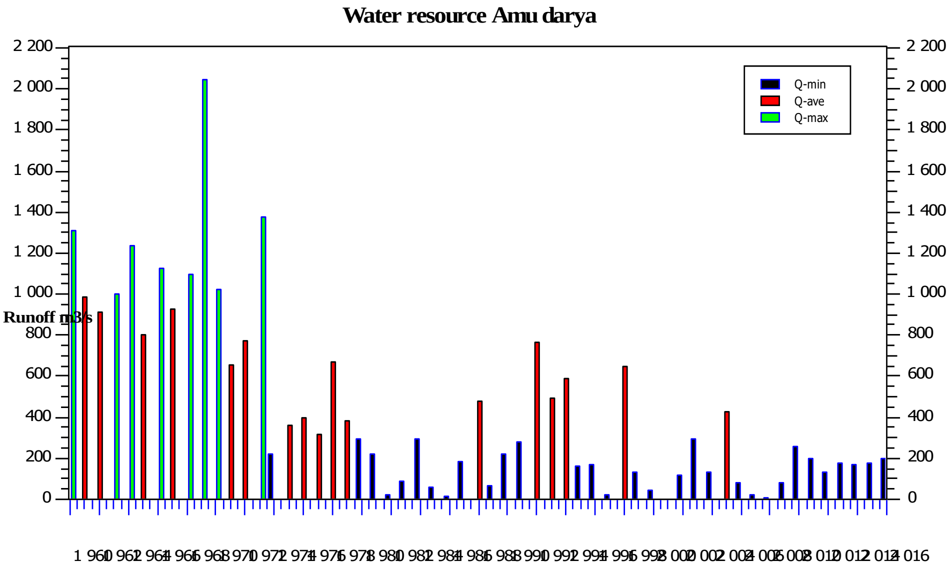

Fig 5. The oscillation of the water balance for each water period from 1960 to 2016.

The shallowest period was observed in 2001 and the annual water discharge was 3 m^3/s. During the general low-water periods, the annual volume of runoff ranged from 3 to 297 m^3/s (Fig. 5).

The average annual volume of water discharge was from 320 (1977) to 986 m^3/s (1961).The average long-term runoff during this period was 2042 m^3/s (1969), which is 6 times less than it was in the high water period. To the catastrophically low-water years for this period relate to 1986, 2001 and 2008.

Statistical analysis between water balance and climate change:

In our study, we will analyze the impact on the regional climate of fluctuations in the water balance of the Amu Darya River in the Aral Sea area over the past 57 years using correlation and linear regression methods. We divided the amount of used water from the Samanbay Hydropower Plant into three categories - low, medium and high water, and now we will be able to check the degree of coherence of changes in water volume in those years with climatic changes. In years of low water (Fig. 6), the cross-correlation between runoff and temperature averaged 0.223 (ρ-value <0.001), the correlation interval was between 0.126-0.316, during the second annual average period it was 0.633, and the interval was between 0.543-0.709, during the third, the shortest investigated high water period, the correlation was 0.723, the interval was between 0.612 and 0.807. For comparison, with each change in the water process, the mutual correlation between the runoff and the temperature also increases, for example, compared with the low water period, the cross-correlation in the mean water period is 64.7%, and compared to the high water period, we can observe that it reaches 69, 1%. Also, when analyzing the linear trend between runoff and air temperature or regression connection, we can see that together with the correlation, the mutual relationship was simultaneously increased, that is, when compared with three water periods, we can see that the regression coefficient interval increased by 92.3 % between R2 → 0.04-0.523.

Period water balance	Climate parameter	Observations	Correlation analysis				Regression analysis		
			r	p-value	95% Confidence Interval	Multiple R	R^2	Standardized R^2	Standard error
Q_min	Temp	384	0.223	<0,0001	0.126 to 0.316	0.223	0.050	0.047	11.828
	Precip	384	0.053	0.2985	-0.047 to 0.152	0.053	0.003	0.000	175.315
	Evapor	384	0.227	<0,0001	0.130 to 0.320	0.227	0.051	0.049	170.991
Q_med	Temp	204	0.633	<0,0001	0.543 to 0.709	0.633	0.401	0.398	447.114
	Precip	204	-0.277	<0,0001	-0.400 to -0.146	0.277	0.077	0.072	554.938
	Evapor	204	0.490	<0,0001	0.379 to 0.588	0.491	0.241	0.237	503.321
Q_max	Temp	96	0.723	<0,0001	0.612 to 0.807	0.723	0.523	0.518	786.048
	Precip	96	-0.229	0.0246	-0.411 to -0.030	0.229	0.053	0.043	1108.220
	Evapor	96	0.632	<0,0001	0.494 to 0.739	0.632	0.399	0.393	882.583

Table 2. Correlation between period water balance and climate parameters

Statistically significant trends between temperature and runoff for all months are positive (see table 2). On average, for the study area, they vary from 0.4 (R2 of p-value 0.001). The standard deviation for the whole sample ranges from 0.04 to 0.37. Negative trends are not recorded at all stations. The analysis of calculations on the verification array shows that this technique yields relatively stable results.

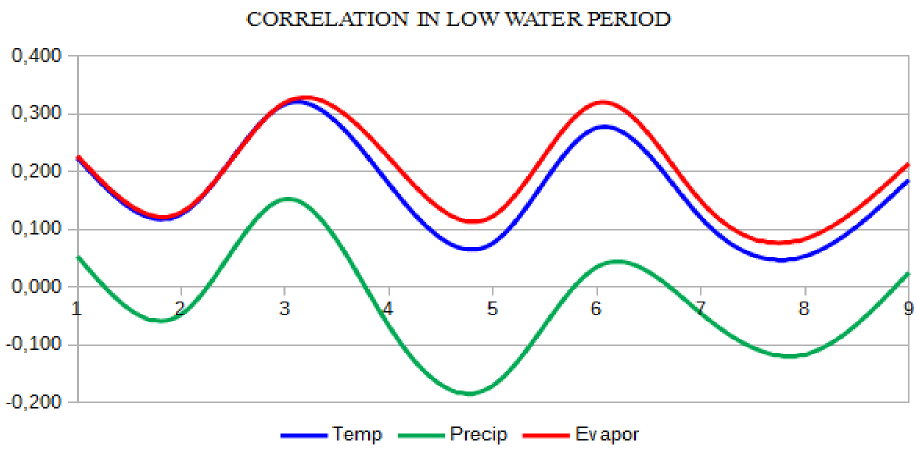

Fig 6. Correlation between runoff and climate parapetrs in low-water period

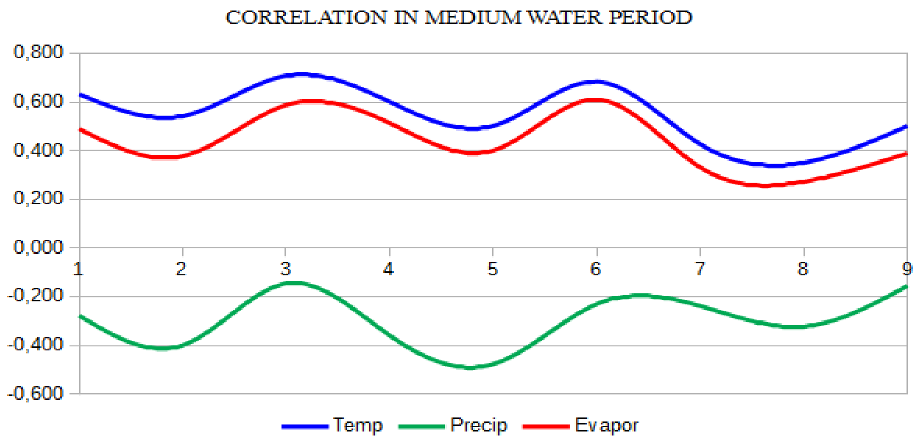

Fig 7. Correlation between runoff and climate parapetrs in medium-water period

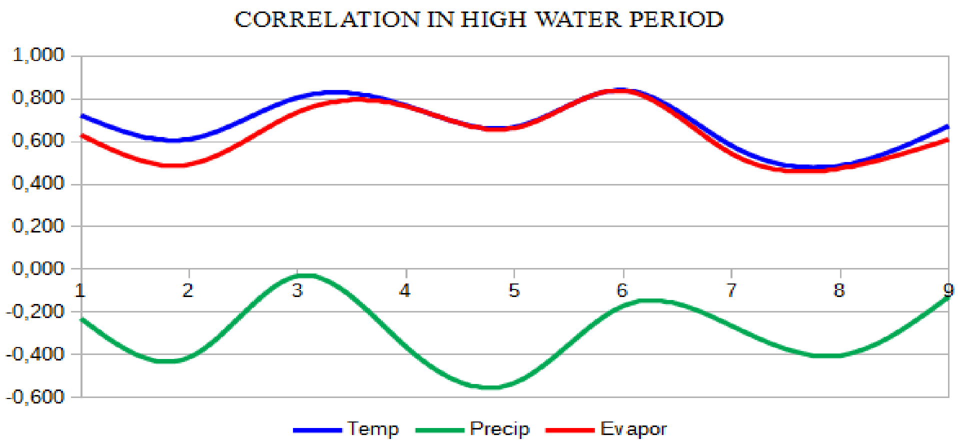

Fig 8. Correlation between runoff and climate parapetrs in high-water period

During the low-water period, the lowest water balance was observed (2001-3.2

m/s2), the air temperature averaged 12.8°C. In the period of 1961-2016, a water deficit was repeated, or a hydrological drought occurred 13 times in a row, and these processes mainly occurred after 1995. During the drought process, the average annual air temperature increased by 20.5%, that is, up to 2.840 ° C, the interval oscillation was (11.01-13.85 ° C). During the medium-water period (Fig. 7), the linear trend between temperature and runoff was positive. This period was mainly observed in 1970-1990, and at that time the annual air temperature changed by 28.9% and the temperature fluctuation interval was 9.8-13.8 ^{0}C.

The high water period (Fig. 8) in the last 57 years is a very little studied period, and it was only 8 years, that is, between 1960-1970. When comparing the relationship between water balance and air temperature with two other periods, a relatively stable temperature was observed. In accordance with the results obtained, we offer several theoretical factors. On the continents, large lakes reduce the annual amplitude of air temperature and thus the climate mash. For example, the annual amplitude of the temperature in the middle of Lake Baikal is 30-31^{0}C, on its banks it is about 36^{0}C, and at this latitude of the Yenisei River the temperature is 42^{0}C. Other lakes such as Issik-kul, Ladoga and others in this way affect the temperature of the air. With the help of the notions of the marine and continental climate, a relatively small annual amplitude of sea-climate air temperature and sea air masses is described. The continental climate is formed in parts of the ocean, which are characterized by a high frequency of air masses in the interior parts of the continent.

Here the annual amplitude of the air temperature is usually very high. In tropical latitudes, the high values of annual amplitudes on land are due not to the cold winter climate, but to the higher summer temperature. Therefore, with the continental climate, the average annual temperature is much higher than the temperature in the marine climate. Due to the sharp decline in the Aral Sea area, the former positive climate impact has decreased, which can be described by high summer temperatures and very low winter temperatures, which affect the regional climate with great amplitude.Therefore, the continental climate of Aral seqa zone is characterized by humidity, precipitations regime and other factors.

In continuation of this analysis, we will consider the correlation between runoff and precipitation. When comparing the results obtained from here with the temperature, we get a reverse picture, that is, a negative relationship between the linear trend and the correlation. When compared by water balance, the runoff and precipitation have a low correlation coefficient relative to each other, and only during the low water period have a positive coefficient of 0.053 (R2 of p-value 0.2985), the coefficient of the interval is (-0.047 to 0.152). During the remaining two medium-water and high-water periods, their mutual relationship from -0.277 to -0.229 (R2 of p-value 0.001-0.046). The linear trend is positive, but very low (0.002-0.07). We will try to justify the obtained correlation coefficient and regression trend using meteorological statistical data. For example, during the period of the hydrological drought (2001, 2008), the average annual volume of runoff in the water balance was 4.57 m^3/s and the amount of precipitation (77-110 mm), the mean water fluctuation period was in the range 320-913, and the precipitation was 71-168 mm. During the high water period, the water balance was 913-1378 m^3/s, and the precipitation remained stable unchanged as in the previous period, only in 1969 when the scale of water resources increased by 50%, we can see that the precipitation level rose by 36% and there was a mutual connection between them.

We will try, on a theoretical basis, to explain why the level of interconnection between precipitation and runoff is low and negative. Despite the extreme complexity of daily changes in precipitation, there are two main types of daily variation in precipitation on land - continental and river bank. However, due to local conditions, there is a deviation from these species and their complication. The maximum peak of continental precipitation is observed in the daytime and a weak second maximum is observed in the morning. The minimum level of precipitation is observed after midnight, and the second minimum is before noon. The main maximum is associated with the enhancement of daytime convection, and the second - with the development of night layer clouds. In summer the main maximum is sharply expressed in comparison with winter, and this is explained by the annual change in convection. Taking into account the fact that the Aral zone is a region of the tropical desert, the continental type of precipitation change is typical for tropical zones, because in this zone the daytime convection develops more strongly, the frequency of frontal clouds (without prominent daily changes) is at a very low level. In the Aral Sea region, there is a difference (sometimes sharp) between rainy and dry seasons. The season of precipitation falls neither in the summer, but in the spring (1969, 1981, March-April, 70-84.2 mm) fall (1969, 1993 November 41-51.2 mm) and winter (1987, 1992 gg. December, February 38-67.2 mm). Dry summer is associated with the influence of subtropical anticyclones characterizing low-cloud weather. In winter, anticyclones move toward low latitudes and cyclonic activity at mid-latitudes extends to the subtropics.

The rainy and dry seasons last about half a year. This type of annual change in precipitation is especially characteristic for precipitation in the desert zones of Central Asia, where one can see similar conditions of atmospheric circulation. It can be concluded from this, that the only source of water resources in the Aral Sea region is the water supply of the Amu Darya River, which is not sustainable, and when comparing the extent of the influence of the river basin on the latitude of this region, it is very small and this in turn proves that it can not be the main factor for the formation of rainy seasons in the region. Conversely, the small level of precipitations observed in this region is mainly due to cyclones that arise due to strong winds (in spring and winter 25-50 m/s).

Evaporation is the main element of the hydrological cycle. During the appearance of surface runoff, these losses are very small, and they can be neglected. Basically, evaporation takes place in the period between the phenomena of runoff, which is usually prolonged. The air temperature has a constant tendency to diurnal changes. When daily maximum - the temperature of daytime air temperature reaches the highest values, the minimum - is observed before sunrise. This type provides a constant evaporation process. The reason for the daily change in air humidity is the development of convection on land in the daytime. With the rising of the sun, the soil starts to warm up, along with it the process of evaporation increases and elastic evaporation develops on the surface of the earth's crust. Apparently, due to the fact that evaporation and temperature are directly proportional and parallel to each other, the temperature observed in certain years in the Aral region simultaneously changed. When analyzing the correlation relationship between evaporation and runoff, it is sufficient to draw a conclusion on the basis of the results given in Figure No., where the temperature and evaporation have almost the same positive coefficient.

Average annual distribution of runoff to the Amu Darya rivers: The analysis was carried out based on data on average monthly and average annual water discharge of the Amu Darya, data on average monthly and mean annual air temperatures, monthly and annual precipitation. Methods of statistical analysis are used in the work. Trends were calculated by the method of least squares, cyclicity was estimated by constructing integral difference curves. The tightness of the connection between the analyzed series was estimated using correlation analysis. The reliability of linear trends and correlation coefficients was estimated at 95% significance level.

The duration and boundaries of hydrological seasons are as follows: spring (March-May), summer-autumn (June-November), winter (December-February). The limiting period of the year and season are chosen based on the prevailing type of water consumption and the relative water content of the season. For the limiting period, a low water season (both low-water seasons: summer-autumn and winter) is taken, and winter is the limiting season. The obtained results show that the main part of the river flow takes place in the spring season, and the smallest in the winter season. The results of the calculations are given in Tab.3.

Provision of the year, %	Spring				Summer-autumn							Winter				Amount for the year, %
	III	IV	V	Sum %	VI	VII	VIII	IX	X	XI	Sum %	XII	I	II	Sum %	
25	4.0	4.7	10.8	19.5	13.0	15.1	11.1	12.6	9.2	4.4	65.5	5.5	5.2	4.3	15.0	100
50	2.6	2.8	10.9	16.3	16.1	19.5	14.2	10.8	7.4	5.3	73.2	3.6	4.0	2.9	10.5	100
75	1.4	4.8	10.3	16.5	17.2	21.1	15.3	10.4	6.3	4.2	74.5	3.8	2.9	2.3	9.0	100

Table 3. The annual distribution of the Amu Darya river flow in the last 57 years (part of the territory of Aral region) for years of different provision (as a percentage of annual runoff)

According to the distribution of the Amu Darya, the share of spring flow for the high water group is 19.5%, medium-water - 16.3%, low-water - 16.5% of the annual runoff, and for winter runoff - 15% for the high-water group, 10.5% for Medium water and 9% for low-water. In the summer-autumn season, a large water group accounts for 65.5%, for the middle-water group - 73.2%, for the shallow water group - 74.5% of the annual runoff.

The distribution of runoff by months within different seasons is not the same. The results of in-season distribution of runoff are given in Table 4.

Season water resource group, %	Spring			Summer-autumn						Winter		
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II
25	20.8	23.1	56.1	19.6	23.0	17.1	18.8	14.6	7.0	36.4	34.7	28.8
50	15.9	17.3	66.9	22.0	26.5	19.3	15.0	10.0	7.2	34.4	38.2	27.4
75	8.3	29.2	62.5	23.1	28.2	20.4	14.0	8.2	6.1	41.9	32.8	25.3
Average	15.0	23.2	61.8	21.6	25.9	18.9	15.9	11.0	6.8	37.6	35.2	27.2

Table 4. In-season distribution of runoff for different seasonal water groups (As a percentage of seasonal runoff)

The most uneven intra-seasonal distribution is characteristic for the spring period. The largest monthly runoff on the river. Amu Darya is observed in May and is 61.8%, and the smallest in March and equal to 15% of the spring. This is explained by intensive snowmelt in late March and early April. In the summer-autumn season, the distribution of the flow is more evenly distributed. The lowest monthly flow for the distribution of the Amu Darya is observed in November and is 11.1% of the seasonal one. The distribution of runoff within the summer-autumn season is characterized by a regular decrease in the monthly runoff from the beginning of the season to July-September and then by a gradual change at the end of the season. During this period, the rivers feed mostly underground waters, which are gradually depleted by July-September, and precipitation, which falls in large numbers during this season, does not participate in the feeding of rivers, as they are used for evaporation, soil wetting and infiltration. Then, by reducing evaporation and falling autumn rain, the monthly run-off increases by the end of the season.

In the winter season, the distribution of the flow of the rivers in question is different. For the distribution of the Amu-Darya typical flow distribution within the winter season is typical. The largest runoff is in December and is 37.6% of the winter runoff, and then the run-off is decreasing by February. The smallest average monthly flow in February is 27.2% of the seasonal. This pattern of distribution of runoff within the season is due to the gradual depletion of groundwater during the winter season. This type of distribution of flow is not typical for the rivers of the given region and is caused by planned discharges of the reservoir in winter.

As a result of studies of the intra-annual distribution of the flow of right-bank tributaries of the Amu Darya River (within the Republic of Karakalpakstan), updated data on the distribution of river runoff were obtained in comparison with the data presented. The revealed changes in the intra-annual distribution of runoff are due to the lengthening of the series of actual observations and the resulting changes in runoff under the influence of climatic and anthropogenic factors.

Conclusion

In this article, the disaster of the Aral Sea and its influence to regional climate were studied, with the help of statistic data. In addition,meteorological and hydrological data were checked and compared. Based on the forecast models, the forecast of the future water balance of the Amu Darya was compiled, and the influence of the river water balance on the climate in the region was studied. During the process of analyzing the meteorological and hydrological data for 2005-2010 (the amount of precipitation is 101.4 mm, the average annual run-off was 145.26 m^3/s) and when comparing the annual precipitation in the Aral Sea region and the given water volumes in the 2011- 2016 (the amount of precipitation is 136.8 mm, the average annual flow was 173.9 m^3/s), they were very low, and over the past five years, the amount of precipitation and water indicators have significantly increased. This in its turn, indicates a change in the better economy and climate of the Aral region. Presently, organizations such as the International Fund of the Aral Sea, the United Nations and a number of donor positive work is carried out to improve the environmental situation in the Aral Sea region by countries. In particular, the World Bank for Development, the People's Republic of China, through dedicated loans, planted saxaul (haloxylon) at the bottom of the dried bottom of the Aral Sea, and also organized several artificial lakes around the Aral Sea, which in turn contributed to improving the ecological situation, and this process is still going on.

Acknowledgements

We are grateful to the Nukus branch of Tashkent University of Information Technologies named after Muhammad Al-Khwarizmi and Nukus branch of Navoi State Mining Institute for providing the opportunity to work on this study.

Conflicts of Interest: The authors declare no conflicts of interest.

Author’s contributions

All authors have read and agreed to the published version of the manuscript.

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