Research Article

Received: 26 March 2023 / Accepted: 28 June 2023 / Published: 5 July 2023

Examination of the Amount of Atmospheric Precipitation: Case Study – Middle Zarafshan River Basin

Juraev Zuhriddin[1*]

Ziyaev Rahmat[2]

Khikmatov Fazliddin[2]

*[1]Chonnam National University,
Department of Geography,
Gwangju, Republic of Korea
[2]National University of Uzbekistan named after Mirzo Ulugbek,
Department of Land Hydrology,
Tashkent, Uzbekistan
Corresponding Author

DOI: https://doi.org/10.36941/mjss-2023-0022

Abstract

In this study, the fluctuating precipitation in Central Asia's Middle Zarafshan basin was examined. Investigating the seasonal variation and distribution of atmospheric precipitation in this area was the goal of this study. Changes in the amount of atmospheric precipitation seen over the primary and current climate periods were taken into consideration using data from 13 meteorological stations located in the basin's plains and mountainous regions. Calculations were made on changes in atmospheric precipitation by altitude zones throughout various climatic eras, and differences in annual fluctuations and distribution changes over time were displayed.

Keywords: *River basin; Precipitation; Climatic period, Quantitative changes; Regression equation*

1. Introduction

Precipitation, the most important component of the hydrologic cycle, is crucial to the process of water accumulation. Moreover, atmospheric precipitation is the main cause of river saturation. Atmospheric precipitation is crucial for the development of water resources of small rivers and streams, especially in arid regions (Ziyaev, 2021). Although it is beyond the scope of this study to examine how global warming affects precipitation controls, continued global warming is changing regional weather patterns. As a result, precipitation is increasing in some areas while decreasing dramatically in others. As a result of these changes, it became necessary to study precipitation variability in the central Zarafshan Valley in Central Asia (especially in the main part, which is located in Uzbekistan). For this reason, this issue is investigated in studies using the desert regions of Central Asia as an example.

The small rivers and streams in the middle Zarafshan basin in Uzbekistan have not yet been considered as a separate subject of atmospheric precipitation research, although the amount of precipitation in this area has a special impact on nature and living conditions in the region. This topic has been investigated in studies using the desert regions of Central Asia as examples (Kirsta, 1976). For example, such researchers as Babaev (1986), Voeikov (1900), Getker (1966), Kirsta (1976), Kunin (1980), Leshchinsky (1974), Nazarov (2005), Tukhtaeva (2008), Shver (1976), Hikmatov (2016), and Halimova (2021) have conducted studies. However, atmospheric precipitation falling on the catchments of small rivers and streams in the middle Zarafshan basin was not treated as a separate research topic. Therefore, the objective of this study was to investigate how the annual variations in the distribution of atmospheric precipitation in the Middle Zarafshan Basin are related to the local climate. The Middle Zarafshan Basin is first introduced before we come to the main part of the study, which is the area under investigation-particularly the Zarafshan Valley-as this study is presented in the field of global scientific research. Then, the practical part and the results of the work are presented. The work concludes with conclusions, remarks and relevant suggestions.

2. Geographical Approach

2.1 *Zarafshan Valley*

In Central Asia there is a valley called Zarafshan (Fig. 1). This valley is geographically located in the middle of the Zarafshan mountain range. The western foothills and the apartment sections of the valley are on Uzbek soil, so the total length of the Zarafshan valley there is about 480 kilometers. This part of the country includes Samarkand and Bukhara regions and Navoi region. Today, the eastern hilly part of the valley is part of the Republic of Tajikistan (Elmurodov, 2008).

The Zarafshan Valley begins at the 2775-meter-high "Zarafshan" glacier and extends for 781 kilometers to the "Sandiqli" desert in the western part (Babaev et al., 1986). The valley is mainly crossed by the Zarafshan River. Agriculture has been established here for a long time, and currently about 4 million people live here (Tukhtaeva, 2008). The valley plays an important role in the economy of Tajikistan and Uzbekistan. There is a large amount of land in the valley that can be irrigated (Muminova et al., 1995). Hay meadows and natural pastures are available for livestock breeding (Kunin, 1980).

Figure 1. Map of Zarafshan Valley
** Blue line illustrates the Zarafshan river.*

2.2 Zarafshan Basin

The Hisar and Zarafshan Mountains form the southern boundary of the Zarafshan Basin, which is more than 770 kilometers long and whose northern boundary is formed by the water line of the Turkestan Ridge (Kulmatov et al., 2014). More than one million hectares of irrigated agricultural land in Uzbekistan and 60 million hectares in Tajikistan are located in this area called the basin. Most of the water from the Zarafshan basin is used for irrigation of Uzbek soils (Haydarov, 2018).

The Zarafshan basin is divided into three sections based on relief features, the Upper Zarafshan, the Middle Zarafshan, and the Lower Zarafshan. The Middle Zarafshan Basin was selected for this study (Khikmatov et al. 2016). As mentioned earlier, there is an urgent need for scientific studies of atmospheric precipitation falling on the catchments of small rivers and streams in this basin (Ziyaev, 2021).

2.3 Middle Zarafshan Basin

The middle Zarafshan basin is not comparable in relief (Fig. 2). Its valley slopes from east to west and consists of a plain. In other words: While the altitude near Samarkand is 700-750 m, in Kattakurgan it is 450 m and drops to 347 m when entering the Navoi region. It rises in the middle of the basin both in the north and in the south. The Nurota Mountains, with an average elevation of 1500 meters, are located in the north (Khikmatov et al., 2005).

The middle Zarafshan basin has a cold, although not very cold, winter. In January, temperatures usually range from -0.9 to 1.9 °C. When arctic air penetrates, the lowest temperature can occasionally range from -24 to 35 °C. Summertime brings hot, dry weather with little rain. Maximum summer temperatures are usually between +26 and +28 °C. However, maximum summer temperatures can reach +40 to +44 °C. A year without frost has 213-215 days in the middle Zarafshan basin. During the growing season, the total positive temperature ranges from 4300 to 5000 °C. In the Middle Zarafshan Basin, precipitation increases from west to east. At an altitude of 347 meters in Navoi region, 282 mm at 465 meters in Kattakurgan region and 328 mm at 695 meters in Samarkand region, the average annual precipitation is 177 mm. In the mountains there is a lot of precipitation every year; on the mountain "Omonquton" 881 mm of precipitation falls (Khalimova, et al., 2021). In spring 49% of the total annual precipitation falls, in winter 33%. Summer precipitation is only 4%. Snow accounts for part of the precipitation. However, it melts quickly due to the mild weather. Due to the cold climate in the highlands, it takes a while to melt (Ganiev, 2022).

It is important to focus on wind, a local natural phenomenon that affects precipitation, when understanding how precipitation is measured. The locations of the meteorological stations in the study area have different wind speeds. This means that the wind speed near the meteorological station Kogon (Bukhara) varies by 3 m/s. Another peculiarity in this area is the wind speed of 5.2 m/s in July. In the region of Jangeldi wind speeds of 5.4 m/s prevail. A similar feature of the wind in these two areas is that it blows stronger during the day, increasing its speed up to 6.3 m/s. However, compared to the areas where other meteorological stations are located, the wind blows stronger in the northern and northeastern parts of the middle Zarafshan basin. In other words: In the Jengeldi region in the north, the wind blows 24% (24% stronger) and 32% (245 m/s) stronger. In addition, the northeast of these two zones will experience winds blowing up to 40% faster than those mentioned, or 28–25 m/s quicker.

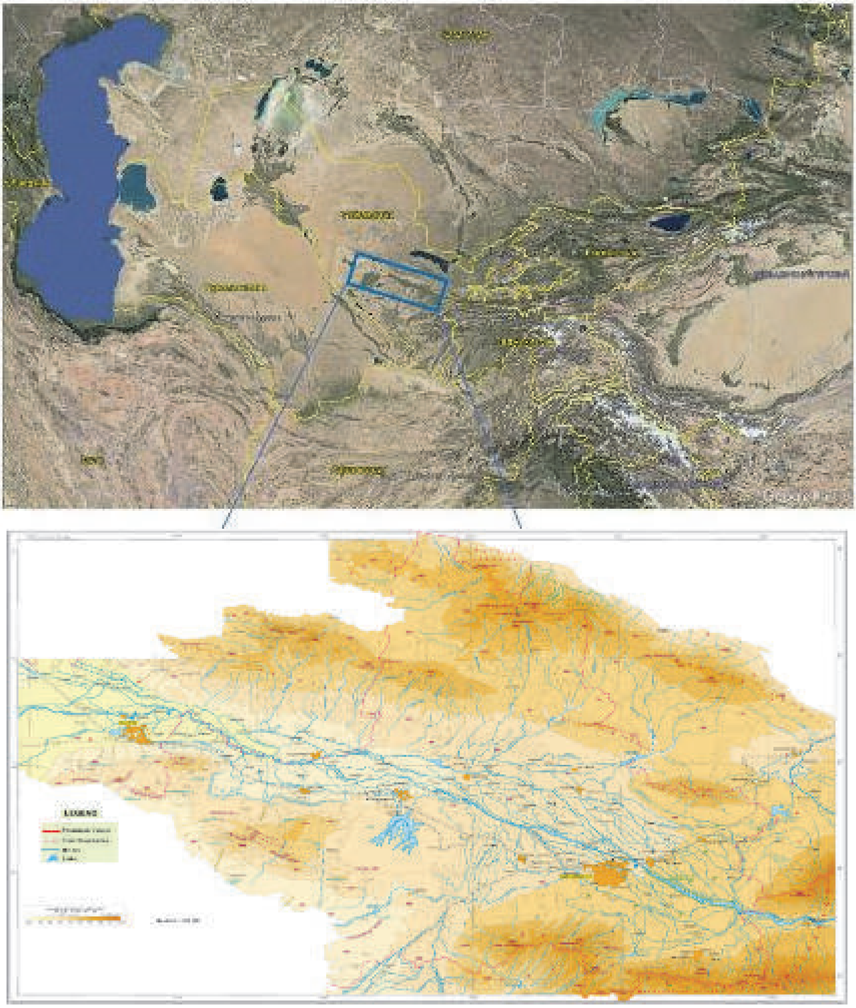

Figure 2. Natural map of the Middle Zarafshan basin

2.4 Zarafshan river

The key component for the study of atmospheric precipitation in this study is the Zarafshan River basin (Fig. 2). The Zarafshan is a small river with maximum and minimum water use of 930 cubic meters per second and 165 cubic meters per second annual average, respectively. The melting of ice and snow adds water to the Zarafshan. When it is time to irrigate crops, the river's water level rises in summer and discharges 61% of its annual water volume (Nazarov et al., 2005).

The Zarafshon has no permanent tributary in this area. The water of the river is mainly used for irrigation. In the Middle Zarafshan region, a reservoir called "Kattakurgan" with a capacity of one million cubic meters was built to use the water efficiently.

3. Method and Results

The following tasks were completed to achieve the goal of the study. The first step was to compile and synthesize information on atmospheric precipitation measurements taken at meteorological stations in the study region of the Zarafshan catchment. Second, it was determined how atmospheric precipitation in the basin changed over the years and across elevations. Finally, changes in the seasonal distribution of atmospheric precipitation by month were assessed using data from calculations for different climate periods.

13 meteorological stations located in the plains and mountainous regions of the middle Zarafshan basin were initially selected based on the objective of the work (see: Fig. 3 and Table 1). Special attention was paid to the issue of the distribution of meteorological observation sites among regions and the duration of observation years in each region. The total accounting period for all meteorological observation sites was set from 1961 to 2020. This general accounting period was divided into the basic climatic period and the current climatic period according to the responsibilities specified in the order. The World Meteorological Organization established the climatic base period, which covers the years 1961-1990. (Chub, 2007). The years 1991 to 2020 constitute the second calculation period or the current climatic period (Getker, 1966). For both calculation periods, characteristics such as the multi-year average, and the largest (maximum) and the smallest (minimum) precipitation amounts were determined. Based on a comparison of the outcomes of the executed calculations, quantitative variations in average and extreme values of atmospheric precipitation (**ΔX_{middle}, $\Delta X_{maximum}$, $\Delta X_{minimum}$**) were evaluated (Table 1).

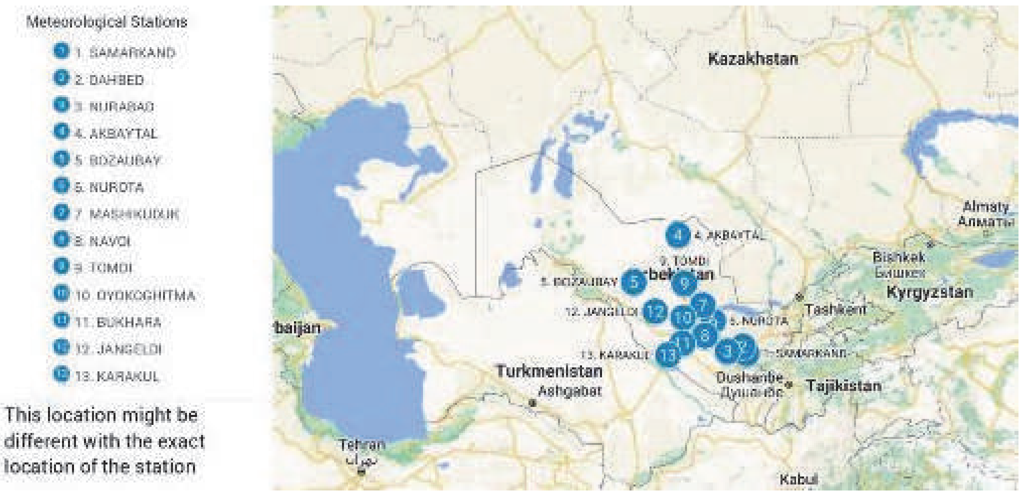

Figure 3. Approximately location of the meteorological stations.

Table 1. Variations of annual precipitation in the Middle Zarafshan Basin under climatic conditions

N	Meteorological station	Height (N,m)	Base climatic period X, mm			Current climatic period X, mm			Quantitative changes, mm		
			Mid	Max	Min	Mid	Max	Min	ΔX_{mid}	ΔX_{max}	ΔX_{min}
1	Samarkand	695	354	611	184	377	574	158	23	-37	-26
2	Dahbed	645	350	436	206	385	551	186	34	115	-20
3	Nurabad	530	382	702	196	362	538	162	-20	-164	-34
4	Aqbaytal	237	117	239	43,3	114	229	46,1	-3	-10	2,8
5	Bozauboy	297	87,6	165	35,3	93,3	204	27,4	6	39	-7,9

N	Meteorological station	Height (N,m)	Base climatic period X, mm			Current climatic period X, mm			Quantitative changes, mm		
			Mid	Max	Min	Mid	Max	Min	ΔX_{mid}	ΔX_{max}	ΔX_{min}
6	Nurota	499	241	419	129	253	374	148	11	-45	19
7	Mashikuduk	199	159	244	90	135	257	66,2	-24	13	-23,8
8	Navoi	346	206	385	110	195	298	109	-11	-87	-1
9	Tomdi	236	126	251	82,6	111	194	40,1	-15	-57	-42,5
10	Oyokoghitma	184	131	260	32	135	215	52,1	5	-45	20,1
11	Bukhara	225	143	245	77,5	130	203	56,9	-13	-42	-20,6
12	Jangeldi	209	100	170	61,6	92,8	180	30,5	-7	10	-31,1
13	Karakul	196	134	211	75,5	127	197	60,5	-7	-14	-15
Maximum		695	382	702	206	385	574	186	34	-164	-42,5
Minimum		184	87,6	165	32,0	92,8	180	27,4	-3	±10	-1

3.1 Interannual changes in atmospheric precipitation.

The following value ranges showed variations in typical (average, maximum, and minimum) precipitation levels: $\mathbf{\Delta X_{mid}=-24\div34}$ for average multi-year precipitation amounts; $\mathbf{\Delta X_{max}=-164\div115}$ in maximum precipitation values; and in the minimum values of precipitation, it was $\mathbf{\Delta X_{min}=-42{,}5\div20{,}1}$.

Analysis of the results shows that precipitation increased slightly in the current climate period compared to the baseline climate period at the meteorological stations in Samarkand, Dahbed, Bozaboy, Nurota and Oyokoghitma. Measured precipitation decreased somewhat at all other meteorological stations, which was the opposite of what was observed elsewhere (Tukhtaeva, 2008). In addition, for the baseline and current climate periods, we examined how the amount of precipitation measured at meteorological stations in the middle Zarafshan basin varied with altitude. To illustrate this (Fig. 5), a plot was made for both climate periods showing the relationship between the altitudes of the meteorological stations (N, m) and the multi-year averages of the precipitation amounts measured there (X, mm).

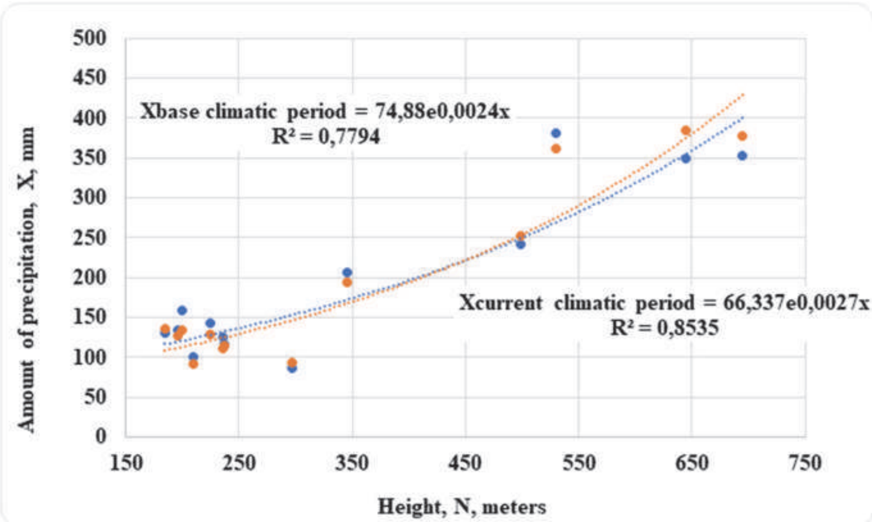

Figure 4. Variation of atmospheric precipitation in the middle Zarafshan basin in different calculation periods depending on height

Notes: The $X_{\text{Base climate period}}$ shows 1961-1990 while the $X_{\text{current climate period}}$ shows 1991-2018 years.

This graph shows that atmospheric precipitation in the study area at elevations of 400-500 meters has remained essentially unchanged over both climate periods. In contrast, their amount has increased above 500 meters. However, at meter points below 400 meters, atmospheric precipitation has slightly decreased in the current climate period compared to the baseline climate period. We can note that the values of the correlation coefficients showing the density of compounds in the form X=f(H) for the two climatic periods differ. In particular, it should be noted that the correlation coefficient of the pair representing the density of the association between atmospheric precipitation and the altitude of meteorological stations is r=0.882±0.019 in the baseline climatic period and r=0.923±0.011 in the current climatic period (Fig. 4).

These figures show the accuracy of the method used to calculate quantitative changes in air precipitation under climate change conditions (Budyko et al., 1987). In the study, interannual variations of atmospheric precipitation in the middle Zarafshan basin were considered. For this reason, diagrams depicting interannual changes in atmospheric precipitation measured at meteorological sites in the shallow part of the basin, Samarkand, Navoi, and Bukhara, for both accounting periods were prepared (Fig. 5).

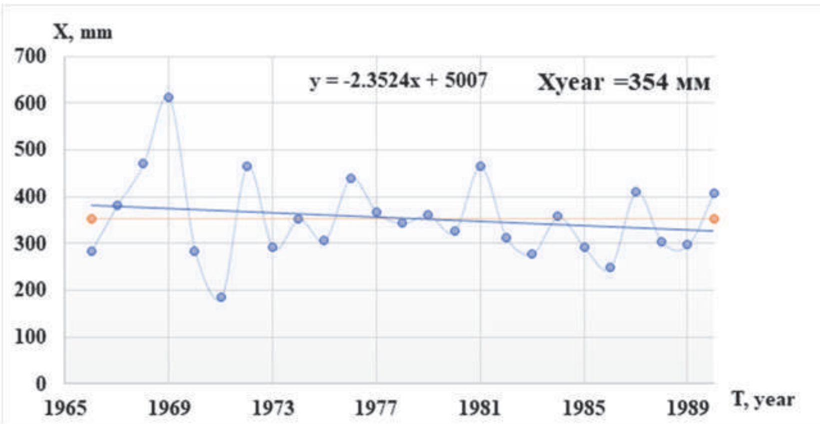

Figure 5. Base climatic period

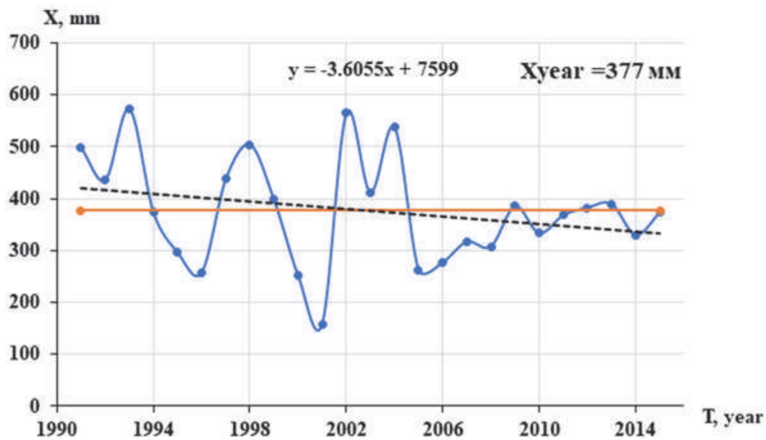

Figure 6. Current climatic period

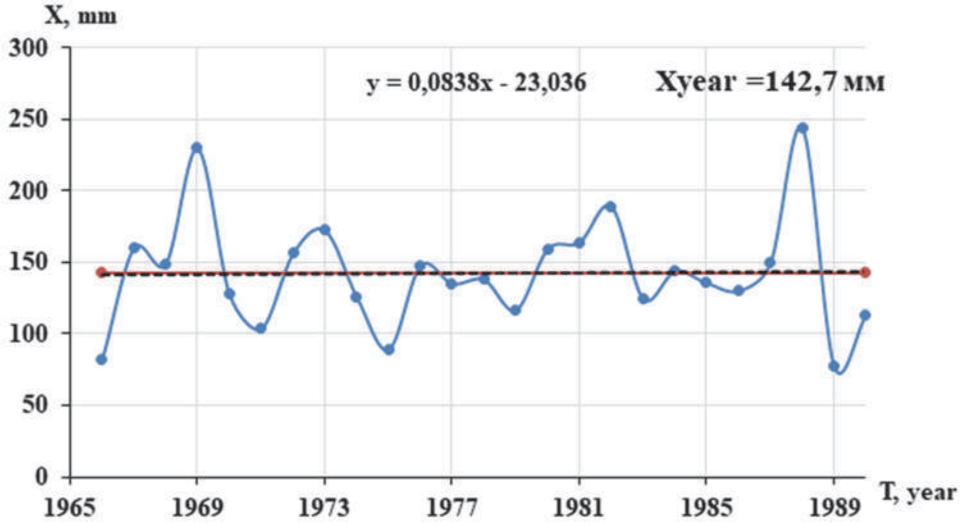

Figure 7. Samarkand region meteorological station
Base climatic period

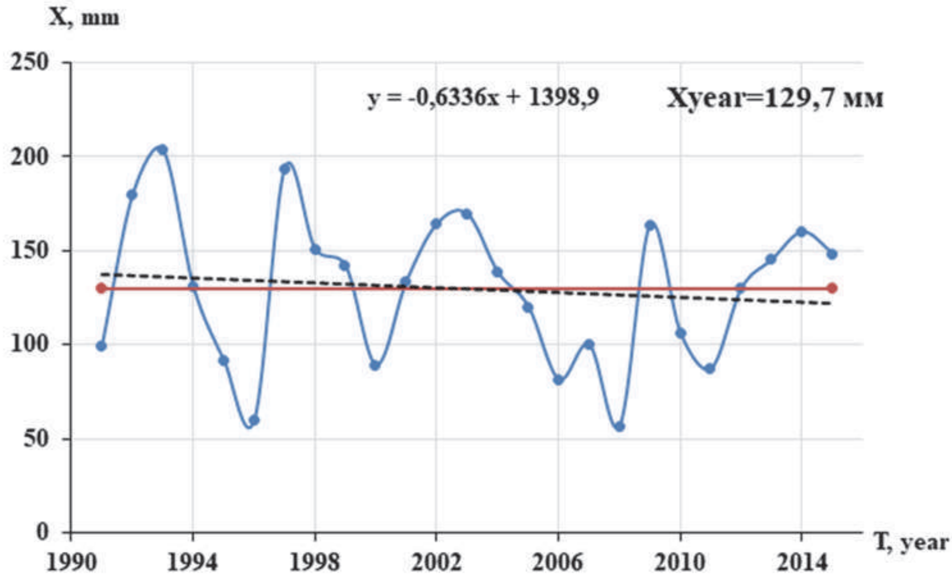

Figure 8. B. Bukhara region meteorological station
Current climatic period

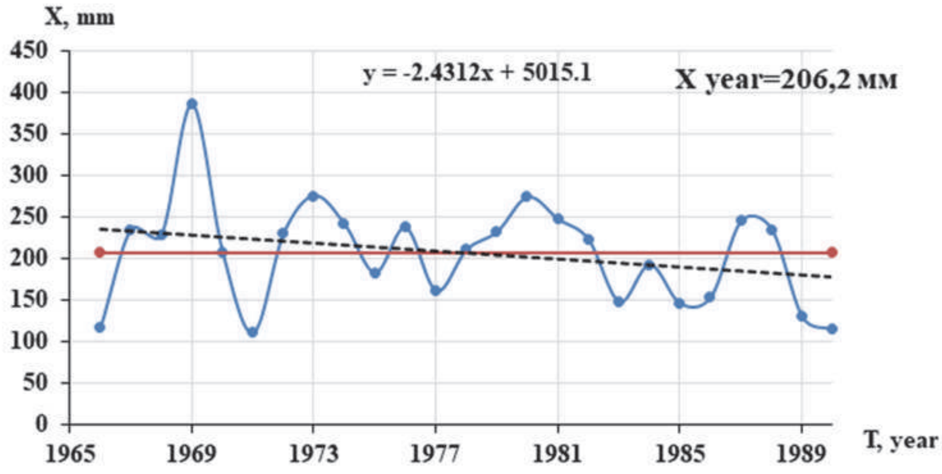

Figure 8. Base climatic period

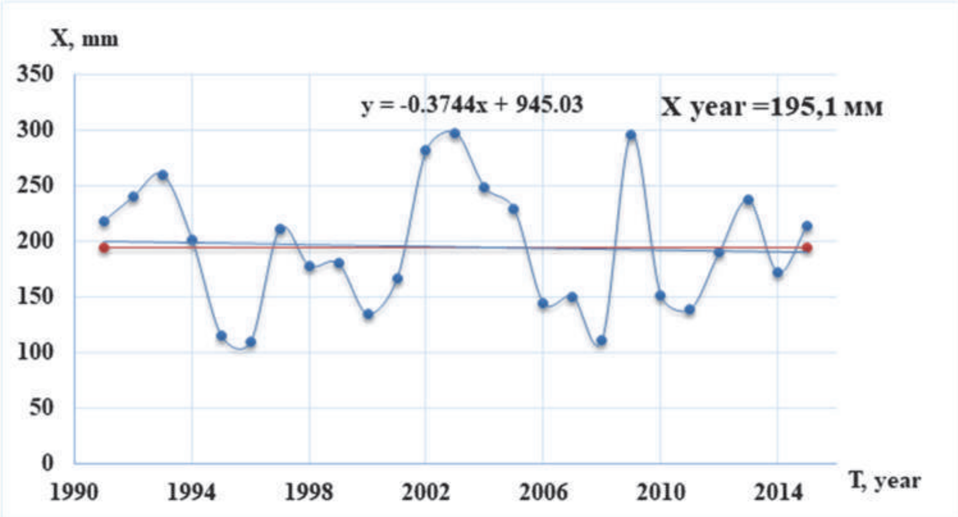

Figure 9. Interannual changes of atmospheric precipitation in different climatic periods.
Current climatic period

From the above graph, it can be seen that the trend lines showing the interannual variations of atmospheric precipitation at the Samarkand meteorological station are decreasing in both climatic epochs. The trend lines of atmospheric precipitation essentially did not change during the basic climatic period, as shown by the diagrams prepared using data from the Bukhara meteorological station; the horizontality of the trend line is an unmistakable sign of this. Also, the change in the trend line during the current climatic period has a negative sign, which means that it has decreased. The trend line of the studied meteorological station Navoi showed a decrease of large values during the basic climatic period, while the current climatic period approached this comparatively positive sign (Fig. 5).

The diagrams show that the highest value of annual atmospheric precipitation during the basic climatic period was 611 mm in 1969 at the Samarkand meteorological station, located in the flat area of the Zarafshan river basin. The average amount of long-term atmospheric precipitation at this meteorological station during the base climatic period was 354 mm. Compared to the baseline climatic period at the Samarkand meteorological station, the amount of atmospheric precipitation increased somewhat (Chub, 2007). The year 1993 was the year with the highest precipitation in the whole accounting period with a total of 574 mm.

3.2 *Changes in the distribution of precipitation*

The difference between the base climatic period and the multi-year average atmospheric precipitation in the present climatic period was 23 mm at the Samarkand meteorological station. The year 1988 was the one with the highest precipitation in the basic climatic period (244 mm) at Bukhara meteorological station. The amount of atmospheric precipitation was also greater in 1969, 1973, and 1982 than in other years. In the current climatic period, the highest atmospheric precipitation amounts at this meteorological station were in 1992, 1993 and 1997, and the lowest in 1996 and 2008. The amount of atmospheric precipitation at Navoi meteorological station in the current climatic period was 11 mm lower than in the base climatic period. The year 1969 was the year with the highest precipitation (385 mm precipitation) at this station in the base climate period. Apart from 1969, the amount of atmospheric precipitation at this meteorological station was not near 300 mm. As a result, the trend line dropped dramatically. The amount of atmospheric precipitation during the present climatic period shows various characteristic values at the Navoi meteorological station. For example, the amount of precipitation was high in 1992, 2002, 2003 and 2009, while it was below average in 1995, 1996, 2000 and 2008.

One of the main objectives of the study was to investigate the changes in the seasonal distribution of atmospheric precipitation by month. Therefore, the characteristics of annual precipitation distribution in the baseline and current climatic periods for the lowland and mountainous regions of the Zarafshan River Basin were analyzed using meteorological data on atmospheric precipitation (Fig. 6).

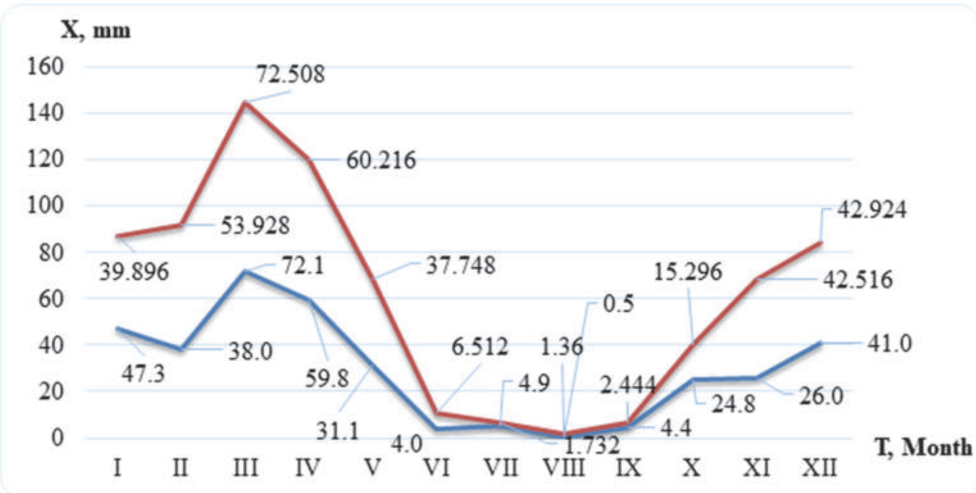

Figure 10. Samarkand Meteorological Station
Notes: In this figure, the Base climate period – in X year is 354 mm, Current climate period – in X year is 377 mm.

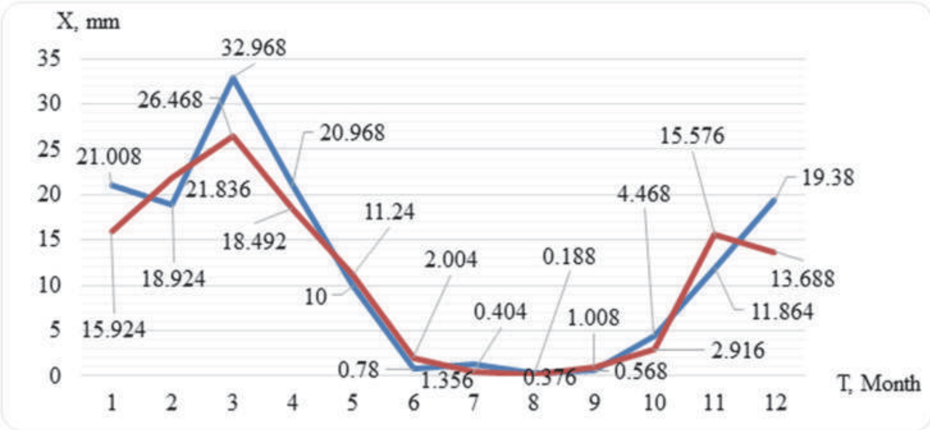

Figure 11. Bukhara Meteorological Station
Notes: In this figure, the Base climate period – in X year is 143 mm, Current climate period – in X year is 130 mm

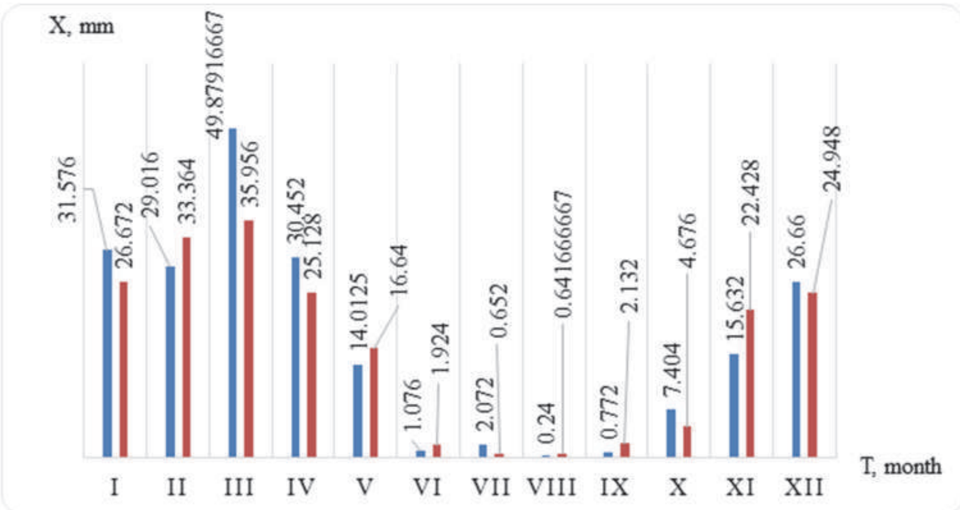

Figure 12. Changes in the distribution of rainfall in the Middle Zarafshan basin by month during the year.
Notes: In this figure, the Base climate period – in X year is 209 mm, Current climate period – in X year is 195 mm

Figure 6 (A, B, C) shows that March is the month with the highest average monthly atmospheric precipitation observed at all meteorological stations for the basic and current climate periods. For example, the average monthly precipitation in March at Samarkand meteorological station was 71 mm during the basic climate period and slightly increased to 73 mm during the current climate period. At Samarkand meteorological station, the average annual precipitation increased by 23 mm from 354 mm during the basic climatic period to 377 mm during the current climatic period. In Dahbed meteorological station, the precipitation amount in the current climatic period was also significantly higher (37 mm) than in the baseline period.

At Bozaboy and Nurota meteorological stations, 6 mm and 11 mm of precipitation fell in the current climatic period, respectively, slightly more than in the base period. More atmospheric precipitation fell during the baseline climate period at Nurabad, Oyokoghitma, Bukhara, Jangeldi, Karakol, Okbaytal, Nurota, Moshikuduq, Navoi, and Tomdi meteorological stations located in the middle Zarafshan basin. Their annual values have slightly decreased in the current climatic period. Precipitation totals in the summer months of both biennia have been unusually low, and in some years there has been virtually no precipitation. In addition, precipitation has increased dramatically at all meteorological stations since September.

4. The Influence of Precipitation

As a result of global industrial development, more hydrocarbon gasses are now released into the atmosphere each year. This increases the "greenhouse effect" on our planet and causes climate change. As a result, natural disasters of hydrometeorological origin are increasing. For example, in some parts of the world precipitation is much higher than normal, while in other regions drought is increasing. More than 80 percent of the water resources used in our country are formed by snow and glaciers in Kyrgyzstan and Tajikistan. Certain works are carried out in our republic for the effective use of these existing water resources. Special programs are adopted for this purpose and their implementation is ensured. In particular, the Action Strategy for the Development of the Republic of Uzbekistan identified important tasks related to "...taking systematic measures to mitigate the negative impacts of global climate change and the drying up of the Aral Sea on agricultural development and the lives of the population" (www.strategy.uz). In fulfilling these tasks, studies to improve the methods of calculating the main hydrological indicators of the hydrological regime of the rivers formed on the territory of Uzbekistan and its neighboring countries and the phases of the water regime they form are of urgent importance.

In the organization of water management works, for the rational use of the river during the recharge period, it is first necessary to determine the water management year for each river. It is known that the beginning of the water management year coincides with the beginning of the replenishment period of the river. The replenishment period starts at different times in different rivers depending on the saturation sources. For example, in the Zarafshan, a river fed by glaciers and a permanent snowpack, the replenishment period begins in May and lasts until September. In the rivers of the basin that are saturated with snow and glaciers, the replenishment period is between April and July. In contrast, in the rivers that collect water from the underlying catchments or are saturated with snow and rainwater, the replenishment period may start in March and last until the first month of summer, i.e., June.

As a result of climate change in the Zarafshan Basin, the demand for water resources will increase in the future. This, in turn, makes agriculture in the basin more difficult. As the productivity of agricultural production decreases, the demand for imports from abroad increases. It can be inferred that the scarcity of water resources due to climate change will affect various sectors of the economy.

5. Conclusion

To conclude, the following can be said about the results of the study: first of all, the meteorological stations of Samarkand, Dahbed, Bozaboy, Nurota and Oyokoghitma in the lowland and mountainous regions of the Zarafshan River basin have recorded a modest increase in the amount of precipitation during the present climatic period compared to the baseline climatic period. At all other meteorological stations, precipitation decreased between 3.0 and 24.0 mm (3.0÷24.0 mm), which was exactly the opposite of what was observed elsewhere. The pair correlation coefficient representing the density of the relationship between the atmospheric precipitation and the altitude of the location of the meteorological stations in the basic climatic period in the studied part of the Zarafshan River basin was r=0.882, and its error was σ_r=±0,019. The value of this statistical quantity corresponded to r=0.923 during the present climatic period, and its error corresponded to σ_r=±0,011.

At most meteorological stations in the Zarafshan basin, including 611 mm at the Samarkand meteorological station, the highest value of annual atmospheric precipitation was measured in 1969 during the Basic climatic period. It should be mentioned that Samarkand meteorological station recorded a difference of 23 mm between the average multi-year atmospheric precipitation during the current climate period and the Basic climate period. Thus, the maximum values of monthly atmospheric precipitation reported in both climatic periods correspond to Marchand April in all studied meteorological stations of the basin. The summers of both periods were very low to no precipitation, especially during the months of July and August. In addition, future research should focus on quantitative changes in expected river flows during climate change in the Zarafshan basin, as well as water resources assessment.

References

Babaev, A.G., et al. 1986: Deserts, nature of the World, Moscow (in Russian: Pustyny. Priroda Mira), p.318.

Budyko, M.I. et al. 1987: Anthropogenic climate change (Ed.) L.: Gidrometeoizdat, (in Russian: Antropogennie izmeneniya klimata), p.405.

Chub, V.E. 2007: Climate change and its influence on hydrometeorological processes, agroclimatic and water resources of Uzbekistan, Monograph, “VORIS” publishing house, (in Russian: Izmenenie klimata i yego vlijanie na gidrometeorologičeskie processy, agroklimatičeskie i vodnye resursy Uzbekistana), p.133.

Elmurodov, N. 2008: Ethnic groups of the Zarafshan oasis of the Uzbek people, Monograph, (in Uzbek: Zarafshon vohasi ozbek xalqi etnik guruhlari), p.41-49.

Ganiev, S.R. 2022: The hydrological regime of the rivers of the Middle Zarafshan basin, water resources, and their effective use. Dissertation, (in Uzbek: O‘rta Zarafshon havzasi daryolarining gidrologik rejimi, suv resurslari va ulardan samarali foydalanish), p.48.

Getker, M.I. 1966: Issues of calculations and distribution of some physiological phenomena in the territory of Central Asia, Monograph, (in Russian: Voprosi raschetov i raspredeleniya nekotorix xarakteristik osadkov na territorii Sredney Azii), p.24.

Haydarov, S.A. 2018: Assessment of the influence of climatic factors on the formation of water resources of rivers of the Zarafshan basin. Dissertation, (in Uzbek: Zarafshon havzasi daryolari suv resurslarining shakllanishiga iqlimiy omillarning ta'sirini baholash), p.48.

Karimov, B.K. et al. 2022: Impact of agricultural development on water quality in Zarafshan River, Uzbekistan, Central Asia: Trends since the 1960s, Current Directions in Water Scarcity Research, 5:411-436 https://doi.org/10.1016/B978-0-323-85378-1.00021-0

Khalimova, G.S. et al. 2021: Sources of water resources of the low mountains of Uzbekistan and issues of their effective use, Monograph, (in Uzbek: O‘zbekiston past tog‘lar suv resurslarining manbalari va ulardan samarali foydalanish masalalari), p.160.

Khikmatov F.H. et al. 2016: Hydrometeorological conditions and water resources of the Zarafshan river basin. Monograph, (in Uzbek: Zarafshon daryosi havzasining gidrometeorologik sharoiti va suv resurslari), p. 276.

Khikmatov, F.H. et al. 2005: Climate change. NIGMI, (in Russian: Izmenenie klimata), p.40.

Kirsta, B.T. 1976: Hydrological features of the western regions of Central Asia (on the example of Turkmenistan), Ilim, (in Russian: Gidrologicheskie osobennosti zapadnix rayonov Sredney Azii – Turkmenii), p.294.

Kulmatov, R.A. et al. 2014: Modern environmental issues in the transboundary Zarafshan River, Geoloekologiya 2, (in Russian: Sovremennye jekologicheskie problemy transgranichnoj reki Zarafshan), pp.38-49.

Kunin, V.N. 1980: Desert Waters and the Environment, Nauka, (in Russian: Vodi pustini I okrujayushaya sreda), p.287.

Leshchinsky, G.T. 1974: Resources of temporary surface runoff of the deserts of Central Asia and Western Kazakhstan. Ilim, (in Russian: Resursi vremennogo poverxnostnogo stoka pustin Sredney Azii i Zapadnogo Kazaxstana), p.187.

Muminova, F.A. et al. 1995: Climate Variability in Central Asia (Ed.) SANIGMI, (in Russian: Izmenchivost' klimata Sredney Azii), p.215.

National encyclopedia of Uzbekistan, 2000: Volume 1, pp. 40-44. www.ziyo.uz (in Uzbek).

Nazarov, I. et al. 2005: On the regional distribution of atmospheric precipitation and their effective use in the Bukhara region, Innovation, (in Uzbek: Buxoro viloyatida atmosfera yog'inlarining hududiy taqsimlanishi va ulardan samarali foydalanish), pp.265-266.

Shver, C.A. 1976: Atmospheric precipitation on the territory of the USSR. Gidrometeoizdat, (in Russian: Atmosfernie osadki na territorii SSSR), p.302.

Tukhtaeva, H.T. 2008: Fight against desertification based on the rational use of local water sources (in the case of Central Kyzylkum). Monograph, (in Uzbek: Mahalliy suv manbalaridan rasional foydalanish asosida cho'llanishga qarshi kurash), p.38.

Ziyaev, R.R. 2021: Shifts of water regime phases of Zarafshan basin rivers under climate change conditions, Monograph, (in Uzbek: Zarafshon havzasi daryolari suv rejimi fazalarining iqlim o'zgarishi sharoitidagi siljishlari), p.48.