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EVALUATION OF THE TIME-SPACE DISTRIBUTION OF ATMOSPHERIC PRECIPITATION IN THE KUR-ARAS PLAIN IN THE AZERBAIJAN REPUBLIC

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Characteristics of the space and time changes in the amount of precipitation in the Kura-Aras lowland were studied in the research paper. The precipitation data of the hydrometeorological station covering a decade from 1992 to 2022 was utilized in the analyses. To conduct research, the mathematical-statistical and cartographic methods were used. According to the conducted research, the amount of precipitation in the Kura-Aras lowland is 310 mm. 40% of the total amount of precipitation rains during the warm semi-period, while 60% falls in the cold semi-period in the lowland. The amount of precipitation decreases from the coastal areas to the plains during the cold, while in the warm period, this process occurs oppositely. It was determined that atmospheric precipitation decreased in January, March, April, May, June, August, October, November and December, and this indicator increased in February, July and September. The annual indicator of the amount of precipitation in the plain decreased by 10% during the years 1991-2022 compared to the base quantity (1961-1990). 18% of the total precipitation was in the range of 10-19 mm, and 16% was in the range of 20-29 mm. Compared to the norm, in the period 1991-2022, in the Kura-Aras lowland, a 19% decrease was recorded in monthly recurrences of precipitation above 50 and 60 mm, and a 15% decrease in precipitation above 70 mm. The research results can be used in the establishment of novel economic areas in the lowland, in the development of maps, economic assessment and mitigation measures against climate change.

Keywords: amount of precipitation, climate change, precipitation limits, oscillation, trend curve, variation integral

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INTRODUCTION

Atmospheric precipitation, which is considered one of the main climate-forming factors on Earth, is the main link of the water cycle in nature (Pierrehumbert, 2007). Falling of precipitation in case of solid and liquid directly depends on air temperature (Mammadov, 2015). In the territory of Azerbaijan, precipitation decreases from the plains to the highlands, but on the northeastern slopes of the Great Caucasus Mountains, in the Tallish Mountains, this regularity is violated (Hajiyev, 2015; Safarov, 2022). Mesoscale atmospheric circulations, air masses and local air circulation play the main role in falling of atmospheric precipitation in the country. The basis of this process is the creation of temperature differences on individual surfaces that move air masses. Thus, high heating in plain areas causes to the acceleration of evaporation and the formation of vertical movements towards higher altitudes. The temperature of the air particles rising towards the highlands decreases and begins to saturate, and clouds and associated precipitation are formed (Huseynov, 2011; Otto, 2023). It is already known to everyone that modern warming has been rapidly expanding its effects over the past 30 years on Earth. The increase in global temperature in 1.5...2.0^{0}C compared to previous years has accelerated the disruption of the traditional climate regime in all regions and the recurrence of anomalous atmospheric events (Mahmudov, 2022; Hajiyev, 2023). Global warming has caused beside with increase in air temperature in the South Caucasus region as well as a decrease in precipitation. A decrease in atmospheric precipitation will lead for a decrease in water reserves, which will create conditions for a decrease in the flow volume of most rivers that take their source from the mountains. This means a decrease in underground water reserves, drying up of swamps and acceleration of salinization in plain areas, especially in the Kura-Aras lowland (Huseynov, 2020). The research of the temporal-spatial distribution of precipitation in the country area had been widely investigated by many researchers. A.M. Shikhlinski, A.A. Madatzade, N.Sh. Huseynov, F.A. Imanov, Said H. Safarov, R.N. Mahmudov, A.S. Mammadov, C.S. Huseynov, Kh.Sh. Rahimov, H.S. Nabiyev and others, carried out such researches. In such researches, the distribution of precipitation in the territory of the republic for regions, altitude zones throughout the year, it had been considered to dynamics within time (Huseynov, 2020; Safarov, 2021). However, in recent times, the increase of time series, refinements through new research methods, and the effect of climate changes on precipitation require a re-examination of the time-space distribution of atmospheric precipitation in the Kura-Aras lowland, which is the largest agricultural region of the country.

Purpose of work

Determining the modern distribution characteristics of atmospheric precipitation in Kura-Aras lowland is the main goal of the conducted research. For this purpose, determination of precipitation series in different limits, distribution on the surface of the station and the plain and multi-year dynamics were evaluated.

MATERIAL AND METHODS

All the analyzes conducted in the research work are based on the precipitation observation data conducted in Kura-Aras plain in 1992...2022. In the analysis, time-space dependencies of precipitation distributions were investigated based on mathematical, statistical and cartographic methods, using the primary data of 10 hydrometeorological stations (Goychay, Kurdamir, Zardab, Imishli, Jafarkhan, Hajigabul, Bilasuvar, Salyan, Neftchala, Goytepe). In the study, a comparative analysis of the indicators of the amount of precipitation for the years 1961...1990 and the corresponding indicators of the years 1991...2022 was carried out (WMO, 2017). From the obtained results, graphs, histograms and tables are illustrated with the support of MS Excel and map ArcGIS software (Hydrometeorological conditions and dangerous hydrometeorological events in the territory of the Republic of Azerbaijan, 2001...2017).

DISCUSSION

The physical and geographical location of the Kura-Aras lowland creates conditions for the different distribution of atmospheric precipitation here in time and space. First of all, the location of the southeastern regions of the lowland on the coast of the Caspian Sea and the abundance of moisture reserves make it possible for the amount of precipitation to be higher in those areas. Thus, the air masses entering this region from the east and southeast are constantly transformed over the sea, the humidity of the air masses increases due to evaporation, and the warm, dry air masses are slightly moistened. Meridional currents, which form the main conditions for rainfall in the country, play a key role in the entry of more humid air masses into this region (Abdullayev, 2015). For the continental climate prevails in the central and western parts of the plain, the amount of precipitation is relatively lower than the surrounding areas. On the other hand, the average annual air temperature observed in the plain (15.5^{0}C) is the highest average temperature in the country. This leads for long-term droughts and high evaporation rates which are harmful to agriculture in the area. Usually, moist, cold air masses from the north cannot directly enter the Kura-Aras plain. However, hot and dry air masses from the south of the lowland - the Iranian plateau dominate here in the hot season. In the coastal plain and surrounding regions, the moderating effect of the sea manifests itself in the region throughout the year (Safarov, 2021). Continentally is higher in the center and west of the plain (Mammadov, 2015). In the northwest, passing through the Jeyranchol lowland, air masses from Asia Minor and the Black Sea also affect the central part. The analysis shows that the average annual precipitation in Kura-Aras plain was 315 mm (226...606 mm) in 1991...2022. In the lowland, 40 % of the perennial precipitation fell in the warm half-period and 60% in the cold half-period (Safarov and et al., 2021).

The most annual precipitation here is 610 mm, and it rains in the plain, foothills (Goytapa) areas located in its southeast, some distance from the sea. Goychay, located on the border with the foothills of the southern ones of the Greater Caucasus Mountains, receives more precipitation than other stations located in the coastal and interior parts of the plain. Here, the distribution of precipitation in different seasons of the year gradually changes from the coastal regions to the west of the plain. In other words, in the warm season, the amount of precipitation falling on the plain increases from east to west, and in the cold season, the amount of precipitation decreases on the contrary (Karimov, 2016; Huseynov, 2022). Seasonal distribution of precipitation becomes almost equal as you approach the border of the foothills of the southern slope of the Greater Caucasus Mountains. Precipitation in these regions is almost evenly distributed throughout the year (Table 1).

Table 1

Seasonal and semiannual distribution of precipitation in Kura-Aras plain

Station	Amount of precipitation, mm							Period, %	
	Winter	Spring	Summer	Fall	Year	**Period I**	**Period II**	Warm	Cold
Goychay	83	118	58	107	366	176	190	48	52
Kurdamir	78	105	45	104	332	150	181	45	55
Zardab	59	88	40	84	271	128	143	47	53
İmishli	64	84	33	83	265	118	147	44	56
Jafarkhan	75	82	26	80	263	108	155	41	59
Hajıgabul	66	70	20	70	226	91	135	40	60
Bilasuvar	91	89	21	106	306	110	196	36	64
Salyan	71	62	20	77	230	82	148	36	64
Neftchala	85	69	17	112	283	86	197	30	70
Goytapa	189	127	53	237	606	181	425	30	70
Lowland	**86**	**90**	**33**	**106**	**315**	**123**	**192**	**40**	**60**

Note: All indicators are normalized.

The change trend of atmospheric precipitation in the Kura-Aras plain during 1991...2022 compared to the climate norm (1961...1990) is also of special interest (Table 2). As can be seen from Table 2, the average monthly precipitation in Kura-Aras plain in January (6%), March (6%), April (23%), May (22%), June (26%), August (11%), October (12%), November (5%) and December (13 %) precipitation decreased, only in February (13%), July (20 %) and September (14%) normal (1961...1990) has increased.

Table 2

Average monthly and annual precipitation anomalies (mm, %-dark black)

Station	Months												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Goychay	-7	1	-5	-16	-18	-14	-7	-10	-5	-14	2	-7	-101
	-23	**2**	**-12**	**-31**	**-28**	**-32**	**-32**	**-45**	**-13**	**-27**	**5**	**-23**	**-22**
Kurdamir	3	1	2	-3	-1	-6	-1	-6	-2	-7	7	-6	-19
	13	**5**	**6**	**-8**	**-2**	**-21**	**-10**	**-41**	**-6**	**-15**	**27**	**-21**	**-5**
Zardab	0	-1	1	-3	-6	-2	-3	-7	-4	-9	3	-3	-35
	2	**-5**	**3**	**-11**	**-17**	**-8**	**-25**	**-47**	**-15**	**-22**	**13**	**-17**	**-11**
İmishli	2	0.2	1	-3	-7	-6	0.4	-3	4	-11	0	-6	-28
	12	**1**	**3**	**-10**	**-21**	**-22**	**-1**	**-37**	**20**	**-27**	**0**	**-25**	**-10**
Jafarkhan	1	2	-3	-6	-7	-9	1	-4	6	-11	-3	-5	-39
	6	**6**	**-8**	**-20**	**-20**	**-37**	**14**	**-48**	**31**	**-26**	**-11**	**-20**	**-13**
Hajıgabul	1	6	-3	-6	-5	-6	-3	-2	9	-5	-7	-2	-24
	8	**28**	**-12**	**-21**	**-20**	**-33**	**-44**	**-35**	**61**	**-15**	**-24**	**-10**	**-10**
Bilasuvar	-2	3	-2	-6	-7	-9	1	-5	6	-1	-2	-5	-29
	-6	**9**	**-4**	**-19**	**-22**	**-44**	**25**	**-52**	**33**	**-3**	**-4**	**-14**	**-9**
Salyan	-1	-2	-5	-14	-9	-5	-2	-2	2	-7	-4	-5	-55
	-4	**-6**	**-18**	**-40**	**-34**	**-28**	**-61**	**-31**	**11**	**-18**	**-11**	**-19**	**-19**
Neftchala	3	-2	1	-11	-9	-3	0.3	-1	10	1	-6	3	-15
	11	**-7**	**3**	**-32**	**-36**	**-23**	**-6**	**-22**	**56**	**3**	**-14**	**10**	**-5**
Goytapa	-11	19	-4	-4	-5	-3	2	4	6	6	-6	0	-15
	-18	**31**	**-7**	**-11**	**-12**	**-9**	**35**	**28**	**12**	**6**	**-8**	**0**	**-3**
Lowland	-1	3	-2	-7	-7	-6	-1	-4	3	-6	-2	-4	-36
	-4	**9**	**-5**	**-21**	**-20**	**-23**	**-13**	**-31**	**12**	**-12**	**-4**	**-13**	**-10**

Note: All indicators are normalized.

In the lowland, the greatest decrease in precipitation occurred in the months of March-June, that is, in the growing season, when agricultural plants need more moisture. The second period of greater decrease in precipitation lasts from mid-autumn to early winter, which also coincides with the initial cultivation period of grain crops. The annual indicator of the amount of precipitation in the plain decreased up to 10% or 36 mm in 1991...2022 compared to the base amount. Precipitation fluctuations based on average indicators in Kura-Aras plain are depicted in a special graph (Figure 1).

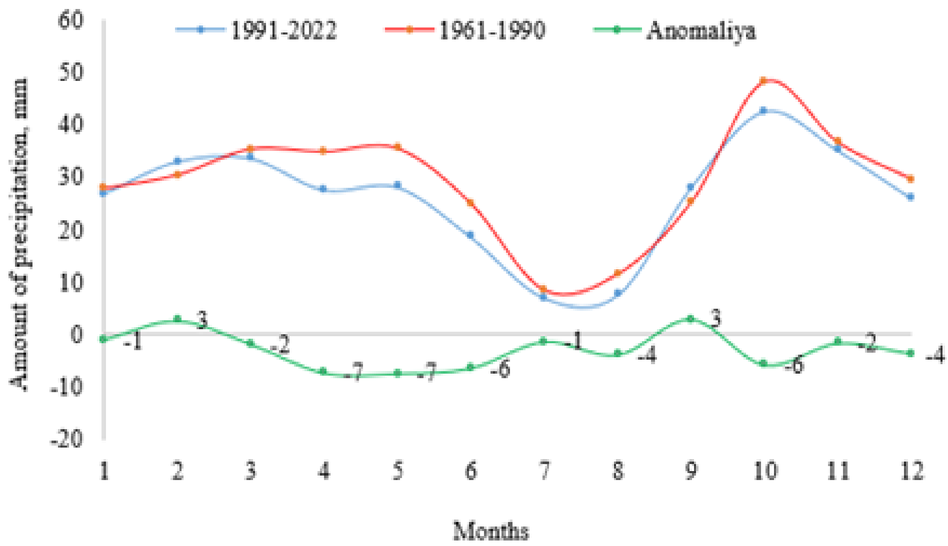


Fig. 1. *Fluctuations of average monthly precipitation range in the Kura-Aras plain*

The long-term dynamics of the annual amount of atmospheric precipitation in the Kura-Aras plain is accompanied by a gradual decrease (Figure 2). Thus, although there were small fluctuations in the amount of precipitation in the plain in the period covering 1961...2022, the amount of precipitation decreased during the general period. Here, precipitation increases with a greater percentage are in Hajigabul (28%, February; 61%, September), Goytapa (35%, July), Neftchala (56%, September), Bilasuvar (25%, June) and Kurdamir (27%, October). stations, notable precipitation decreases occurred at Salyan (40%, April; 61%, July), Bilasuvar (44%, June; 52%, August) and Jafarkhan (37%, June; 48%, August) stations (Table 2). The average annual rainfall in Kura-Aras plain was 355 mm in 1961...1970, 343 mm in 1971...1980, 344 mm in 1981...1990, 305 mm in 1991...2000, 2001...2010 323 mm in 2011-2020, 313 mm in 2011...2020, and 255 mm in 2021...2022. Decades spanning 1991...2000 and 2011...2020 have higher multiannual declines in lowland precipitation. During the years 1961...2022, 1964, 1970, 1971, 1983, 1989, 1995, 1998, 2001, 2019 and 2022 are the least of the series, 1963, 1966, 1967, 1969, 1982, 1984, 1994, 2003, 2011 and 2016 are the 10 years with the most precipitation. The analyzes carried out for separate years show that 70% of the years with the most precipitation in the lowland occurred in 1994 and before. The amount of precipitation in Kura-Aras plain was 349 mm in 1961...1990, and 310 mm in 1991...2022. Difference integral curves were used to analyze multi-year dynamics of atmospheric precipitation of individual hydrometeorological stations in Kura-Aras plain (Figure 3 a, b). If we look at the graphs, in the multi-year integrated series, if we do not take into account small fluctuations in individual years, the amount of precipitation has increased in the period from 1991 to 1993 at all stations. Although this indicator decreased rapidly from 1994 to 2001, it increased again from 2002 to 2004, and from 2005 to 2015, there was a multi-year increase with occasional small fluctuations.

Since 2016, a sharp decrease in precipitation has been observed in most of the stations. There is some difference in the integral curves expressing the dynamics of precipitation in Goytapa, Neftchala and Goychay stations.

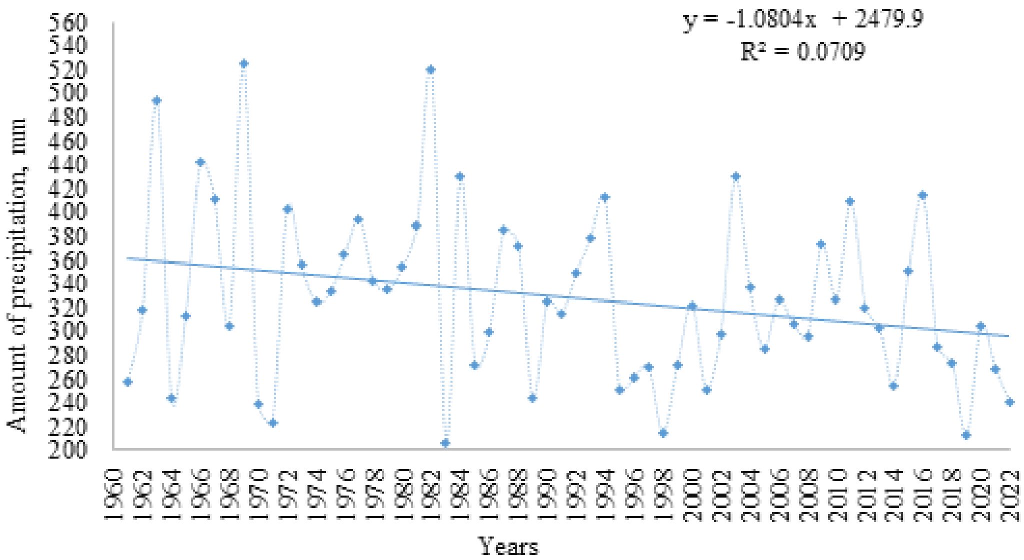
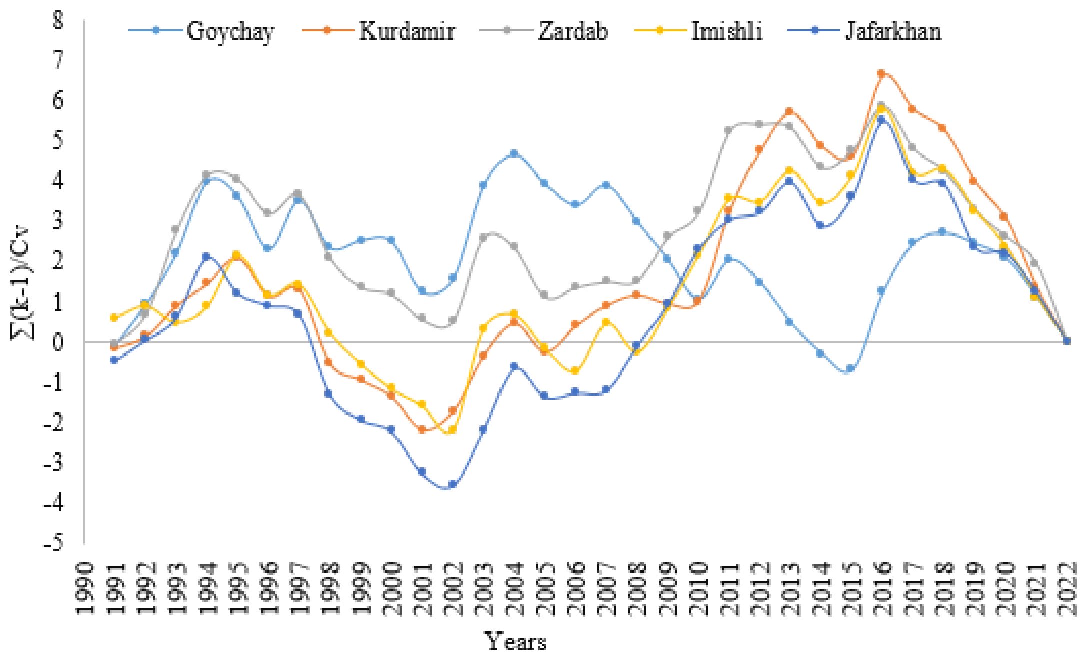
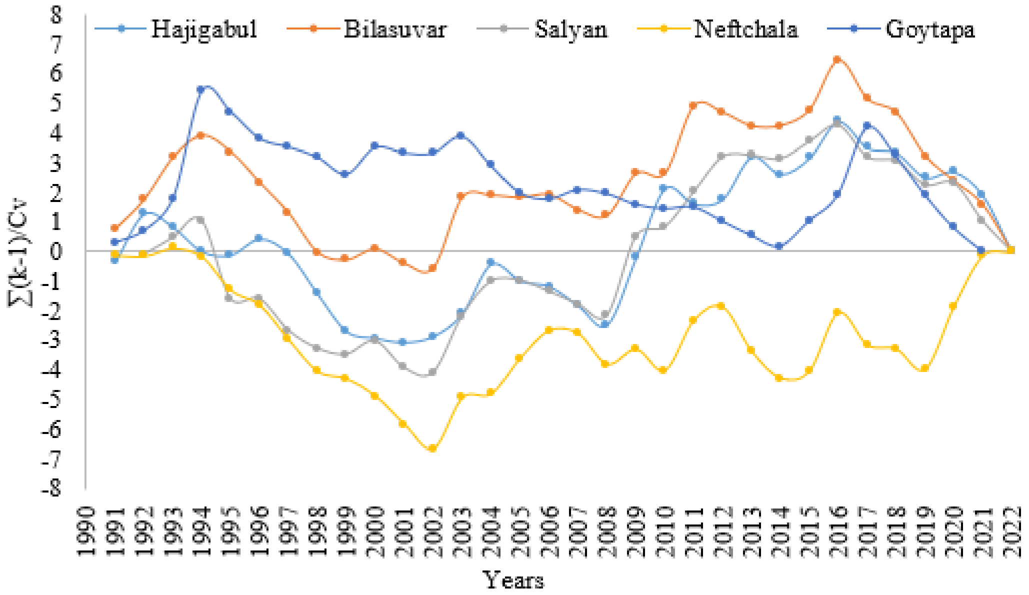


Fig. 2. *Multi-year dynamics of precipitation amount in Kura-Aras plain.*

This is due to the physical and geographical position of the mentioned areas. Jafarkhan, Imishli, Kurdamir, Salyan, Hajigabul and Bilasuvar stations can be mentioned as stations with more similar difference integral trends in lowland. Although this indicator decreased rapidly from 1994 to 2001, it increased again from 2002 to 2004, and from 2005 to 2015, there was a multi-year increase with occasional small fluctuations. During the general period, the highest indicator of precipitation change of the listed hydrometeorological stations was observed in 2016, and the lowest indicator was observed in 2002, respectively. Although the internal time-space distribution of atmospheric precipitation is its main feature, the intensity and monthly amount of precipitation are also of particular importance. Determining monthly changes in rainfall within certain limits and comparing them with the climate norm are considered very important methods for detecting extreme features of dangerous precipitation.



a)



b)

***Fig. 3.** Dynamics of the difference integral of precipitation in 1991...2022*

For this purpose, in the study, during the repetition of precipitation at 9 hydrometeorological stations (Zardab, Kurdamir, Hajigabul, Goychay, Goytapa, Bilasuvar, Jafarkhan, Salyan and Neftchala) in separate months in 1961-2022, 0-9, 10- Precipitation exceeding 0...9, 10...19, 20...29, 30...39, 40...49, 50...59, 60...69 and over 70 mm was analyzed as a hazardous event (Figure 4). During the calculations, if the amount of precipitation meets the condition for the amount of precipitation for the analyzed months, «1», otherwise, the condition «0» is accepted, and a selection is made for the month under consideration. At the next stage, the sum of these events is found and finally the percentage of events is calculated.

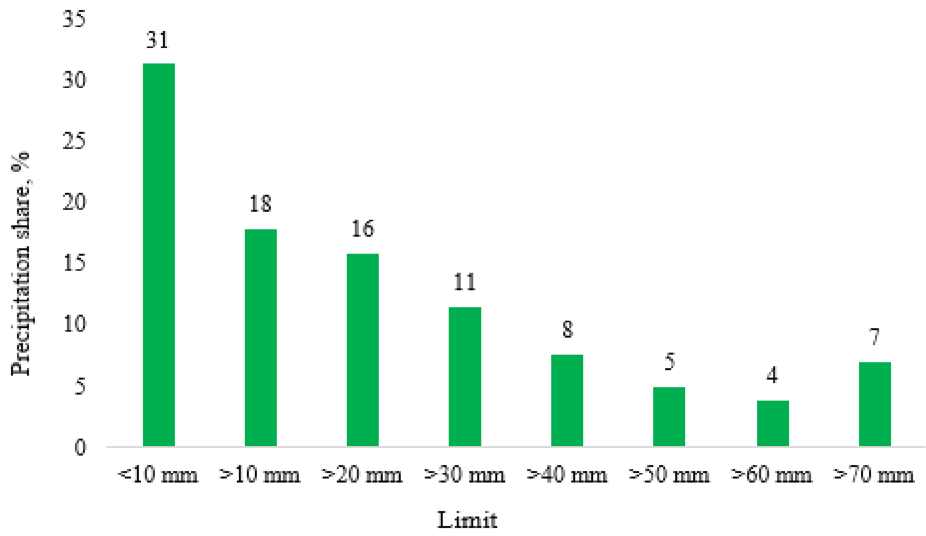


***Fig. 4.** Recurrence (%) of different precipitation thresholds in Kura-Aras plain*

From Figure 4, it is clear that in the Kura-Aras plain, within the considered gradations, precipitation less than 10 mm prevailed. 18% of the total precipitation was in the range of 10...19 mm, and 16% was in the range of 20...29 mm. Less frequent are months with precipitation in the range of 50...70 mm. The analysis shows that the intensity of precipitation falling on the Kura-Aras plain is very low and covers a small time phase. This is due to the lack of strong convective processes in the lowland, less observation of cumulonimbus clouds, and more precipitation falling from layered clouds. However, heavy rains also have a sufficient intensity (7%).

In addition to the above, the research also paid attention to the changes in the thresholds where precipitation is more frequent compared to the corresponding climate norm (1961...1990). The analyzes show that in the years 1991...2022, in the Kura-Aras plain, there were significant decreases in the months when the amount of precipitation was higher than 50, 60, and 70 mm. Thus, a 19% decrease in monthly occurrences of precipitation above 50 and 60 mm, and a 15% decrease in precipitation above 70 mm was recorded. A smaller amount of variation in rainfall recurrence is observed for monthly rainfall above 10 and 20 mm (Figure 5).

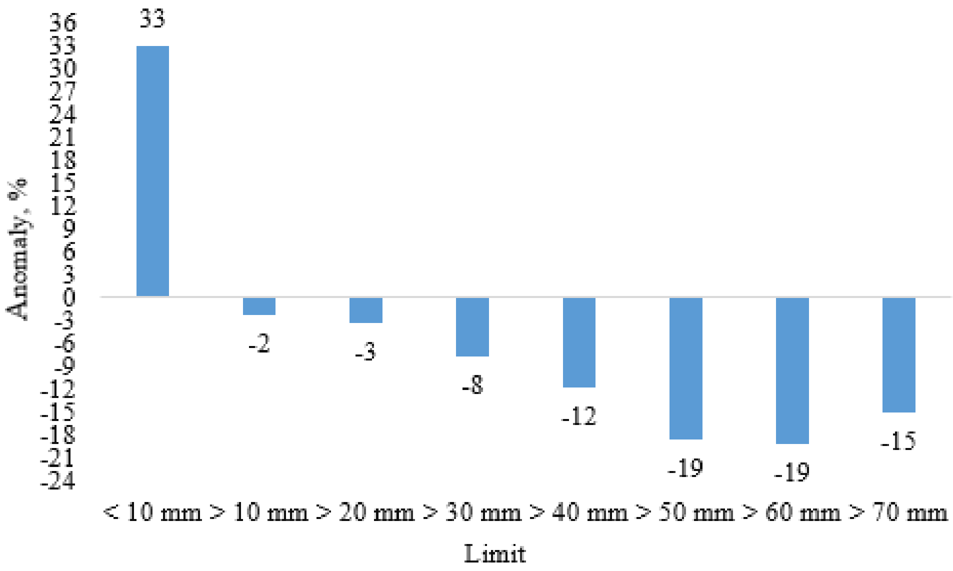


Fig. 5. *Fluctuations of precipitation thresholds in Kura-Aras plain (%)*

The amount of monthly precipitation is associated with a decrease in the recurrence of precipitation higher than 50... 60, and 70 mm, and a decrease in the recurrence of heavy intensity precipitation and showers. Because, in the months when continuous precipitations are not observed, the probability of repetition of precipitations in these limits is very low. However, in 1991...2022, a high (33%) increase was recorded in the recurring limit of precipitation below 10 mm. This factor creates more conditions for the expansion of droughts, which have been increasing rapidly in the region recently.

RESULTS

The following results were obtained from the analyzes carried out the basis of the preliminary data of the atmospheric precipitation of 1991...2022 in the Kura-Aras plain:

1. Average annual precipitation in Kura-Aras plain was 349 mm in 1961...1990, and 310 mm in 1991...2022.

2. 40% of the amount of precipitation in the area fell in the hot half-year and 60% in the cold half-year;

3. In January, March, April, May, June, August, October, November and December, the amount of atmospheric precipitation decreased, while in February, July and September, this indicator increased compared to the norm. The annual indicator of the amount of precipitation in the plain decreased by 10% or 34 mm during the period 1991...2022 compared to the base amount;

4. In the Kura-Aras lowland, the amount of observed precipitation less than 10 mm was more for individual months. 18% of the total precipitation was in the range of 10...19 mm, and 16% was in the range of 20...29 mm;

5. In the Kura-Aras lowland, in 1991...2022, compared to the base (1961...1990), a 19% decrease in monthly recurrences of precipitation above 50 and 60 mm, and a 15% decrease in precipitation above 70 mm was recorded. If the climate changes in the Kura-Aras plain continue with this dynamic, the reduction of precipitation and humidity in the Kura-Aras plain, which is considered a large agricultural region of the republic, will lead to the expansion of the area of major environmental crises (drought, salinization, etc.). The decrease in precipitation during the main periods when crops need water has led to the development of more drought-tolerant crops here. In order to mitigate the negative effects of climate changes in the area, prevention

of evaporation from the surface of existing water channels in the area, closing of the surface of water reservoirs with certain accessories (special plastic or rubber balloons), construction of field protection forest strips, mineralization of the water of artesian wells, etc. it is important to see.

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ӘЗЕРБАЙДЖАН РЕСПУБЛИКАСЫНДАҒЫ КУРА-АРАКС ЖАЗЫҒЫНДАҒЫ АТМОСФЕРАЛЫҚ ЖАУЫН-ШАШЫННЫҢ УАҚЫТ-КЕНІСТІК БӨЛУІН БАҒАЛАУ

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Мақалада Кур-Аракс жазығындағы атмосфералық жауын-шашынның кеңістік-уақыттық өзгерістерінің ерекшеліктері қарастырылады. Талдау кезінде облыстағы 10 гидрометеорологиялық станциялардың 1992...2022 жылдардағы жауын-шашын деректері пайдаланылды. Зерттеу жұмысы математикалық-статистикалық және картографиялық әдістер арқылы жүргізілді. Талдау көрсеткендей, орташа жылдық жауын-шашын мөлшері Кура-Аракс жазығында 310 мм құрайды. Жазық аймақтарда жауын-шашынның 40%-ы жылы, 60%-ы суық жартылай кезеңде түседі. Суық мезгілде жауын-шашын мөлшері жағалық аудандардан жазыққа қарай азаяды, ал жылы мезгілде керісінше. Атмосфералық жауын-шашын қаңтар, наурыз, сәуір, мамыр, маусым, тамыз, қазан, қараша, желтоқсан айларында азайып, ақпан, шілде, қыркүйекте өсті. Жазықтағы жауын-шашынның жылдық мөлшері 1991...2022 жылдар аралығында бастапқы мөлшермен салыстырғанда 10%-ға азайды.Жалпы жауын-шашынның 18%-ы 10...19 мм, ал 16%-ы 20...29 мм аралығында болды. Құра-Аракс жазығында айлық жауын-шашынның 50 және 60 мм-ден жоғары төмендеуі 19%-ға, 70 мм-ден жоғары жауын-шашынның 15%-ға азаюы тіркелді. Зерттеу нәтижелерін экономиканың жаңа бағыттарын құру үшін пайдалануға болады.

Түйін сөздер: жауын-шашын, климаттың өзгеруі, ArcGIS, жауын-шашын шектері, ауытқулар, тренд қисығы, айырмашылық интегралы

ОЦЕНКА ВРЕМЕННО-ПРОСТРАНСТВЕННОГО РАСПРЕДЕЛЕНИЯ АТМОСФЕРНЫХ ОСАДКОВ НА КУРА-АРАКСИНСКОЙ НИЗМЕННОСТИ В АЗЕРБАЙДЖАНСКОЙ РЕСПУБЛИКЕ

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В статье рассмотрены особенности пространственно–временных изменений атмосферных осадков на Кура-Араксинской низменности. При анализе использовались данные об осадках с 10 гидрометеорологических станций района за период 1992...2022 гг. Исследования проводились математико-статистическими и картографическими методами. Анализ показывает, что среднегодовое количество осадков на Кура-Араксинской низменности составляет 310 мм. Здесь 40% осадков выпадает в теплый и 60% в холодный полупериод. В холодное время года количество осадков уменьшается от прибрежных районов к равнинам, а в теплое – наоборот. Атмосферные осадки уменьшились в январе, марте, апреле, мае, июне, августе, октябре, ноябре и декабре и увеличились в феврале, июле и сентябре. Годовой показатель количества осадков на равнине снизился на 10% за 1991...2022 годы по сравнению с базовой суммой. 18% общего количества осадков находилось в пределах 10...19 мм, а 16% - 20...29 мм. На Кура-Араксинской низменности зафиксировано снижение месячной выпадения осадков свыше 50 и 60 мм на 19%, а количество осадков свыше 70 мм - на 15%. Результаты исследований могут быть использованы при создании новых сфер экономики.

Ключевые слова: количество осадков, изменения климата, ArcGIS, пороги осадков, колебания, кривая тренда, интеграл разности

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