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ASSESSMENT OF THE IMPACT OF GLOBAL CLIMATE CHANGE ON RIVER WATER RESOURCES AND MODELING OF WATER CONSUMPTION REGULATION

(Представлено членом редакційної колегії д-ром геол. наук, ст. наук. співроб. О.Л. Шевченко)

Background. It is very difficult to deny or confirm the impact of climate change on the existing water resources of the republic, as there are very few reliable facts and data available. However, the undeniable fact is that climate factors change over a large period of time. One of the main indicators of climate change is the decrease in the number of cold autumn-winter days, the increase in the number of hot spring-summer days and the periodic occurrence of drought on the plain areas of the country.

Objective: Study of global climate change, its causes and consequences; assessment of the existing water resources in the country and the state of their use; assessment of the impact of global climate change on the existing water resources of the republic; forecasting the impact of climate change on water management for the near, medium and long term; application of a scientifically based approach and modeling of water resource consumption for the purpose of efficient use of water resources, as well as determination of the upper, average and lower limits of consumption.

Methods. Shewart control chart and extrapolation and summation of the water consumption methods are used.

Results. The analysis shows that the change in the dynamics of water resources is related to the increase and decrease in water taken from the river, changes in natural climatic factors, mainly the amount of precipitation over the years. The decrease in the domestic consumption of rivers does not at all give grounds to conclude that their natural flow consumption has decreased. An example of this is the floods that occurred in the Kura and Araz rivers in 2003 and 2010. In short, due to the number of anomalous events in nature, they can be considered a "product" of global climate change.

Conclusions. We came to the conclusion that the water consumption varies from year to year and depends on many factors, such as climate changes, population growth, industrial, and agricultural use. Analysis of existing meteorological data shows that nature is full of surprises, various natural phenomena, including severe and persistent droughts, can occur unexpectedly. To be ready for it, one of the important conditions is to gradually increase existing water resources, create water-saving techniques and technologies, and develop new agrotechnical measures.

Keywords: climate change, water resources, water consumption, temperature, decrease, water scarcity.

Background

Climate change, while not unprecedented in Earth's history, has markedly intensified in recent centuries, detrimentally impacting global water resources (Rosińska et al., 2024). This significantly impacts water systems worldwide. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events are leading to water scarcity in some regions, while others experience more intense floods. These changes affect water availability, quality, and the overall reliability of water resources, impacting ecosystems, human populations, and various sectors like agriculture and industry (Fecht, 2019).

According to Alsaadawi and Ozkoç (2022) opinion the climate change, including evaporation, groundwater recharge, temperature, flow, and precipitation changes, has a significant impact on water quality and quantity. In addition, increasing water temperatures affect the chemical reaction kinetics and ecological status of the waters along with the deterioration of quality. With increased flow, such changes can affect the mobilization, distribution, mobility, dilution, and habitat of pollutants in the hydrological system.

Global climate change is characterized by changes in temperature, precipitation and evaporation (Abdullayev, & Rzayev, 2023; Huseynov, & Tagiyev, 2024; Huseynov, Tagiyev, & Balammadov, 2024; Nasibova et al., 2024). This is one of the main factors in the decline of water resources. In addition, there is another factor that does not leave water resources untouched. HUMAN FACTOR! It is the

interference of people in nature and their neglect of the preservation of ecological balance.

It is well known to everyone that the planet we live on is not that big. When you look at the world map, it becomes clear that there is no part (space) on Earth where bombs do not explode, new types of weapons are not tested, countless airplanes do not disrupt the structure of the atmosphere, mountains that ensure the balance of the earth are not gradually destroyed and devastated, forests are not cut down and destroyed, the beds of rivers, lakes and their surroundings are not ruthlessly exploited for various purposes, the living world of nature – flora and fauna – is not destroyed, the lands are not exhausted from excessive use, skyscrapers are not built in cities, the oceans and seas are not loaded with oil platforms, millions of tons of toxic gases and substances are not released into the air from industrial facilities and vehicles, areas are not polluted with household waste, and so on and so forth. These listed and unmentioned facts are some kinds of indicators of global climate change.

It is very difficult to deny or confirm the impact of climate change on the existing water resources of the republic. However, it is an undeniable fact that climatic factors change over a large period of time. One of the main indicators of climate change is the decrease in the number of cold autumn-winter days, the increase in the number of hot spring-summer days, and the periodic occurrence of drought on the plains of the country.

Methods

According to the World Bank report on droughts in Central Asia and the Caucasus in 2005, the air temperature increased by 0.3–0.6°C and the amount of precipitation decreased by 10 % in 1961–1990 (WB, 2005). Depending on the temperature, the flow of rivers decreased by 10–20 %, and at the same time, the snow cover falling on the territory of the country began to decrease. According to the same report, a decrease of 9.5–11.5 km³ of water resources is expected by 2050.

The impact of climate change is also reflected in the rivers flowing through the territory of Azerbaijan (Safarov, &

Mahmudov, 2011). Thus, the Kura, Alazan, Ayrichay (Ismailova et al., 2022; Mustafayeva & Tagiyev, 2023; Rzaeva, Tagiyev, & Zeynalova, 2022) and Araz rivers can be noted. The World Bank information on the flow of these rivers is given in the table below.

According to the information provided by the World Bank, or rather, the source it used (regional ecological center), the flow of the Kura River has decreased by more than 2 times compared to the natural multi-year data. A similar trend is observed in other sample rivers (Table 1, fig. 1, 2) (Aslanov, 2013).

Table 1

Flow of some rivers in 1981–2000, m³/sec					
Periods by year	Seasons				Annual average
	Winter	Spring	Summer	Autumn	
Kura River (Tbilisi region)					
1981–2000	98	429	251	135	230
1981–2000 (observed)	86	382	198	107	192
2000–2010 (observed)	119	351	185	115	190
Kura River (Salyan region)					
1981–2000	403	1528	897	527	840
1981–2000 (observed)	495	615	410	342	466
2000–2010 (observed)	500	510	332	334	411
Araks (Givrag point)					
1981–2000	86,6	399	181	99	190
1981–2000 (observed)	67,5	305	142	76,9	148
2000–2010 (observed)	105	211	69	91	119
Alazan-Ayrichay					
1981–2000	> 4	169	19	107	127
1981–2000 (observed)	>4	151	125	89	109
2000–2010 (observed)	>7	126	110	86	104

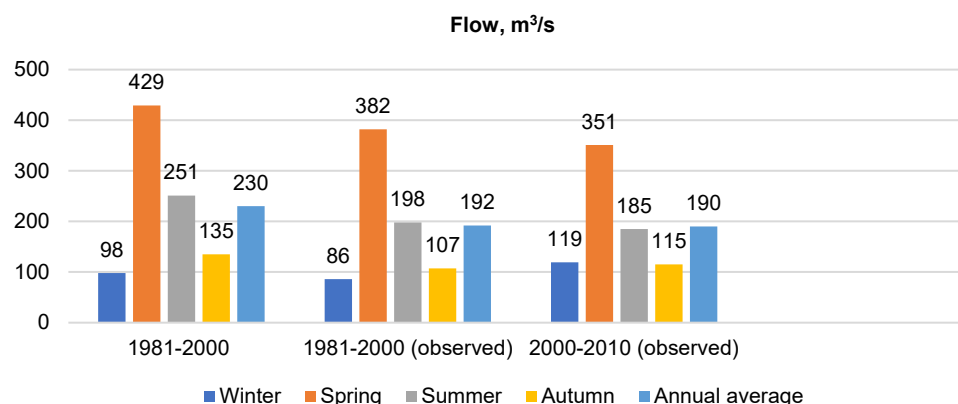


Fig. 1. Flow rate of the Kura River through the Tbilisi region, m³/s

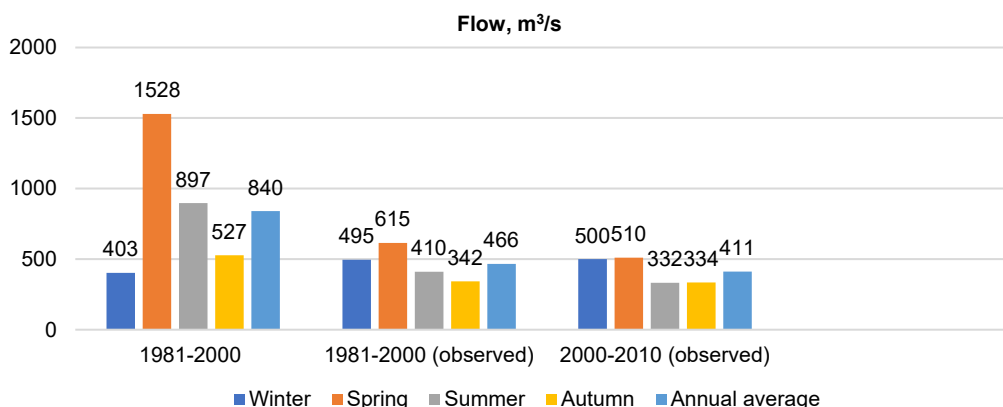


Fig. 2. Flow rate of the Kura River through the Salyan region, m³/s

Data from after 2000 and even before 2000 are presented in different sources with different figures. For example, in the literature (WB, 2005) it is shown that the natural flow rate of the Kura River in the Salyan settlement was 854 m³/sec until 1989. However, in the literature (Aslanov, 2013) it is stated that this flow rate was

354 m³/sec, and in the World Bank report it is stated that it was 840 m³/sec (see table 1). The data of recent years also show that the flow rate of the Kura and other rivers has decreased in the headwaters (Aslanov, 2013).

The above-mentioned fact is more clearly visible from the hydrometric data (Table 2).

Table 2

Average monthly water consumption at various points, m³/sec													
Period per year	Monthes, water consumption, m³/sec												Av./y
	1	2	3	4	5	6	7	8	9	10	11	12	
Zardab point													
1980–2010	242	255	349	805	1059	797	445	275	263	345	328	252	452
2011–2020	384	399	370	318	317	361	318	253	264	264	300	361	328
Surra (Sabirabad) point													
1980–2010	420	437	615	1270	1834	1411	791	484	423	525	524	443	765
2011–2020	589	596	614	806	913	687	395	326	399	440	486	554	566
1981–2007	523	522	521	536	589	507	341	328	306	321	406	498	450
Salyan point													
1980–2010	390	595	542	1142	1687	1226	636	331	315	417	452	386	660
2011–2020	567	548	586	771	883	666	360	272	354	401	405	526	531
1981–2010	483	485	493	512	566	514	325	250	294	308	384	477	426

Data from hydrometric stations located on the Kura River show that the flow of the river in the estuary of the Kura River (in the Salyan point) is lower than the flow in its upper part (in the Surra point of the Sabirabad region) in all observation periods. While the average multi-year domestic flow of the Kura River in 1980–1910 was 765 m³/sec in the Surra point, 566 m³/sec in 2011–2020, and 450 m³/sec in 1981–2007, these values were 660, 531, and 426 m³/sec in the Salyan point, respectively, for the same periods. That is, the Kura is higher in the upper part of the flow, and lower in the estuary. At first glance, this seems to be anomalous. In fact, as mentioned above, this is due to the withdrawal of water from various places along the river for irrigation and other purposes.

It is clear that the instability of the Kura River's domestic flow over the decades is related to demand (Table 3). The average domestic flow of the Kura River during the 1970–1980s was 607.8 m³/sec, during the 1981–1990s it was 438.1 m³/sec, during the 1991–2000s it was 411.2 m³/sec, during the 2001–2010s it was 398.4 m³/sec, and during the 2011–2020s it was 435.6 m³/sec. In the 1970–2010s, the domestic flow of the Kura River gradually decreased, but later began to increase. Analyses show that this change is due to the increase and decrease in water taken from the river, and changes in natural climatic factors, mainly the amount of precipitation over the years. The decrease in the river's domestic consumption does not at all give grounds to conclude that its natural flow consumption has decreased. An example of this is the floods that occurred in the Kura and Araks rivers in 2003 and 2010. In short, the number of anomalous events in nature can be considered a "product" of global climate change (Rzaeva, Guseynov, & Tagiyev, 2023; Shiraliyev, & Mahmudov, 2008).

Results

If we look at the exploitation of rivers, we will see that the decrease in their flow in the upstream part is not directly related to global climate change. It is simply that water is taken from these rivers for various purposes, for example, irrigation, water supply, etc., and these waters are used without being returned. Therefore, the flow of rivers is not a natural flow, but a domestic flow. At the same time, water is taken directly from the river through pumping stations located at various points on the rivers and directed for various purposes.

Irregular use of water resources leads to scarcity. Many methods are used to regulate such negative situations.

Examples of Surface Water Regulation:

1) The Surface Water Treatment Rule (SWTR): the SWTR establishes minimum treatment requirements for public water systems using surface water as a source.

2) The Water Framework Directive (WFD): the WFD aims to achieve good ecological and chemical status for all surface water bodies.

3) River Basin Management Plans: outline strategies for managing water resources within specific river basins.

In essence, a surface water regulation system is a complex but vital framework for ensuring that surface water resources are managed sustainably, protecting both human health and the environment (internet materials).

In our study, the Shewhart control chart method was used. Control charts were constructed and analyzed using average annual and characteristic flow rates (Table 3) in the Salyan region located along the Kura River. (Fig. 3, 4, 5).

Levels of water consumption vary significantly across the Salyan point of the Kura River.

Given that access to fresh drinking, irrigation, industrial uses waters is a global problem, every drop counts. Applying responsible tendency at home, in industry, in irrigation not only reduces consumption but also helps preserve natural water resources. Little changes, such as taking short showers, reusing water for irrigation purposes, and using effective appliances, make a big difference.

Water is the only substance found on earth in three forms – solid, liquid, and gas. A person can live more than a month without food, but only about a week, depending on conditions, without water. 66 % of the human body is water; 75 % of the human brain is water. A person must consume 2.5 quarts of water per day from all sources (drinking, eating) to maintain health. Water regulates the earth's temperature. It also regulates the temperature of the human body, carries nutrients and oxygen to cells, cushions joints, protects organs and tissues, and removes wastes (Environmental Protection Agency, 2024). Therefore, the regulation of the water resources is a crucial challenge.

The visualization shows the average level of water consumption per year (Fig. 3).

Based on the method, the average, upper and lower limits of the average annual water consumption have been determined: $X_{av}=458.22$ m³/s; $X_{upper}=840.72$ m³/s; $X_{lower}=75.72$ m³/s. The upper and lower limits of regulation are symmetrical with the middle limit. Although the

consumption is within the regulation limits, there are fluctuations in water consumption. As shown, there is a large variance in levels of water consumption rates across the Salyan region. This can depend on a range of factors, including climate and the importance of a region's agricultural or industrial sector.

The visualization below (Fig. 4) shows the maximum annual water consumption of the Kura River which is used for irrigation, municipal and industrial purposes. The average, upper and lower limits of maximum water consumption by year have been determined: $X_{av.}=1053 \text{ m}^3/\text{s}$; $X_{upper}=2233 \text{ m}^3/\text{s}$; $X_{lower}=127 \text{ m}^3/\text{s}$. The upper and lower limits of the adjustment are symmetrical with the average limit.

As mentioned above, the water is used by costumers continously. Their use fluctuates widely depending on factors such as temperature (a major driver climate change), cases of droughts leading to water scarcity. For this reason, the water needs of the population of the settlements on the banks of the Kura River are increasing. Thus, the maximum water consumption occurred in 1979 and amounted to $2350 \text{ m}^3/\text{s}$. This exceeded the upper regulatory limit of the water consumption. These fluctuations lead to demand peaks. Peaks reflect the deviation of water consumption of settlements located along the Kura River for a certain period of time (day, week, month or year), from the average value for the same period. The peaks are used to eliminate the water loses and exceeding regulatory water consumption limits.

Table 3

Average annual and characteristics of consumption of the Kura River in the Salyan point, m^3/sec

Years	Annual water consumption, m^3/s	Maksimum	Minimum	Years	Annual water consumption, m^3/s	Maksimum	Minimum
1970	630	1400	+97	1996	216	718	37
1971	403	833	123	1997	412	798	88
1972	277	521	60	1998	622	1500	356
1973	819	1990	222	1999	354	733	148
1974	719	1740	222	2000	347	1012	135
1975	524	1060	229	2001	372	1030	181
1976	473	1310	164	2002	433	750	235
1977	490	1770	125	2003	698	1763	369
1978	663	2220	242	2004	624	1126	304
1979	736	2350	138	2005	382	418	92
1980	344	772	160	2006	339	544	107
1981	219	436	82	2007	252	544	119
1982	461	1047	116	2008	346	602	214
1983	518	1160	183	2009	271	454	23
1984	461	1060	145	2010	267	617	75
1985	382	1220	132	2011	171	375	832
1986	564	1770	225	2012	286	77	170
1987	424	868	160	2013	670	1295	190
1988	589	1720	214	2014	497	940	241
1989	410	896	215	2015	485	760	237
1990	353	682	167	2016	483	1060	306
1991	327	623	64	2017	372	785	158
1992	563	983	195	2018	343	1050	265
1993	390	676	150	2019	356	965	311
1994	546	1150	219	2020	693	1385	196
1995	335	1090	104				

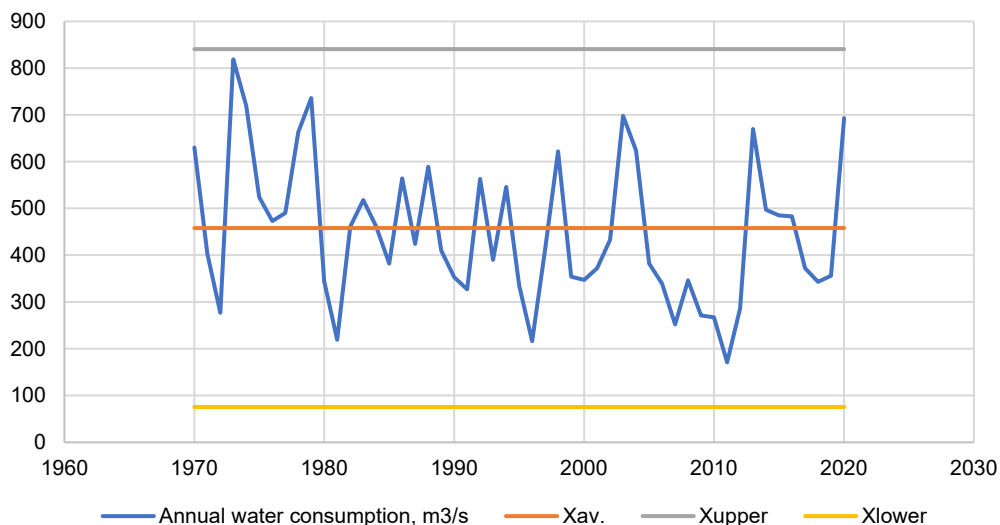


Fig. 3. Annual water consumption regulation chart of the Kura River in the Salyan point

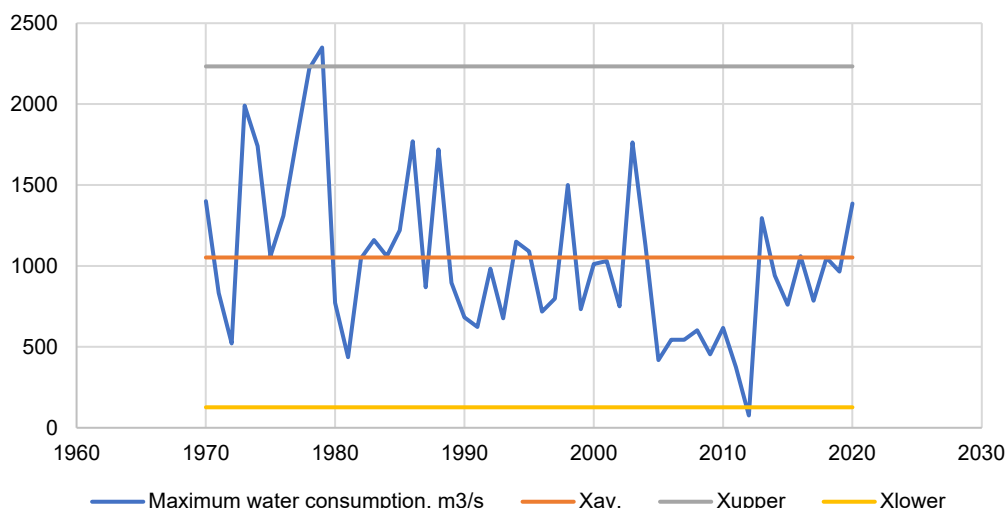


Fig. 4. Maximum water consumption regulation chart of the Kura River in the Salyan point

The minimum water consumption of the river water coincides with 2003, which is 127 m³/s.

Figure 5 shows the minimum water consumption of Kura River in a certain time period (1970–2020).

The average, upper and lower limits of minimum water consumption have been determined by year: $X_{av.}=187$ m³/s; $X_{upper}=460$ m³/s; $X_{lower}=87$ m³/s.

As can be seen in Figure 5, the minimum water consumption regime differs from the maximum one. The

minimum water consumption regulation limit is not symmetrically relative to the average limit. There are peaks beyond the lower control limit. Except for 2001, water consumption exceeded the upper limit. While the upper limit of water consumption was 460 m³/s, the consumption in this year was 832 m³/s, the consumption in all years was between the average and lower limit and beyond the lower limit.

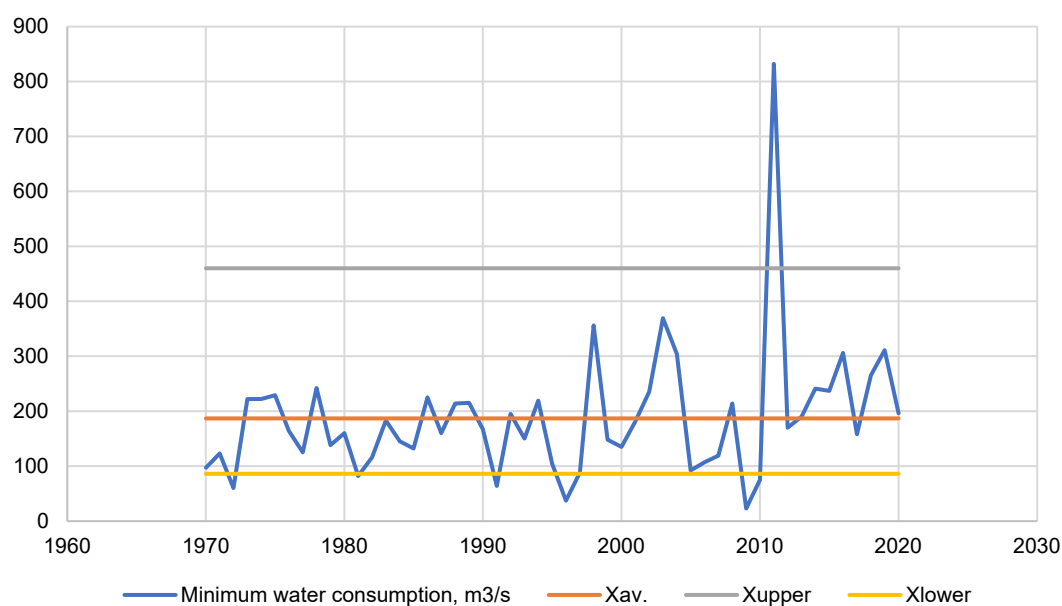


Fig. 5. Minimum water consumption regulation chart of the Kura River in the Salyan point

It can be concluded that the peak factors depend on climate changes over years. The reason for this situation is drought, which is a consequence of climate change.

The second method for regulation of water resources is extrapolation and summation of the water consumption per population living along the bank of the Kura River. This method is more detailed and requires much more annual data. Extrapolation is based on the assumption that water consumption increases or decreases by a fixed growth coefficient as noted by the following formula:

$$\text{consumption}_p + n = \text{consumption}_p \times \text{GC}_n$$
 where: consumption_p – consumption in period p ; $\text{consumption}_p + n$ – consumption in period $p+n$; n – number of years; GC = Growth Coefficient per year.

When planning the future water consumption, it is important to determine when the capacity increase is necessary. So, the legal supply obligation is important, meaning that the available capacity must always be larger than the consumption. Growth Coefficient per decade and growth per year in the Table 4 was shown.

Table 4

Growth Coefficient per decade and growth per year				
	1961–1970	1971–1980	1981–1990	1991–2000
Growth Coefficient	1.72	1.16	1.22	0.96
Growth per year	5.6 %	1.5 %	2.0 %	-0.4 %
Average over				
Last 50 years	2.7 %	2.7 %	2.7 %	2.7 %
Last 40 years	2.2 %	2.2 %	2.2 %	2.2 %
Last 30 years		0.1 %	0.1 %	0.1 %
Last 20 years			0.8 %	0.8 %
Last 10 years				-0.4 %

Discussion and conclusions

Ultimately, we came to the conclusion that the water consumption varies from year to year and depends on many factors, such as climate changes, population growth, industrial, and agricultural use.

By considering the rate of climate change and population growth, water consumption will continue to decrease from year to year if we do nothing.

Analysis of current meteorological data shows that nature is full of surprises, various natural phenomena, including severe and persistent droughts, which can occur unexpectedly. To be prepared for them, one of the important conditions is to gradually increase existing water resources, create water-saving techniques and technologies, and develop new agrotechnical measures.

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ОЦІНКА ВПЛИВУ ГЛОБАЛЬНОЇ ЗМІНИ КЛІМАТУ НА РІЧКОВІ ВОДНІ РЕСУРСИ ТА МОДЕЛЮВАННЯ РЕГУЛЮВАННЯ ВОДОСПОЖИВАННЯ

Вступ. Заперечити чи підтвердити вплив зміни клімату на існуючі водні ресурси республіки дуже важко. Оскільки достовірних фактів та даних дуже мало. Однак незаперечним фактом є те, що кліматичні фактори змінюються протягом великого періоду часу. Одним з основних показників зміни клімату є зменшення кількості холодних осінньо-зимових днів, збільшення кількості спекотних весняно-літніх днів та періодичне виникнення посухи в рівнинних районах країни.

Мета. Вивчення глобальної зміни клімату, її причин та наслідків; оцінка існуючих водних ресурсів у країні та стану їх використання; оцінка впливу глобальної зміни клімату на існуючі водні ресурси республіки; прогнозування впливу зміни клімату на управління водними ресурсами на найближчу, середньо- та довгострокову перспективу; застосування науково обґрунтованого підходу та моделювання споживання водних ресурсів з метою ефективного використання водних ресурсів, а також визначення верхньої, середньої та нижньої меж споживання.

Методи. Використано контрольну карту Шуарта та метод екстраполяції та підсумовування водоспоживання.

Результати та обговорення: Аналіз показує, що зміна динаміки водних ресурсів пов'язана зі збільшенням та зменшенням обсягів забору води з річки, змінами природних кліматичних факторів, головним чином кількості опадів протягом років. Зменшення побутового споживання річками зовсім не дає підстав робити висновок про зменшення їх природного стоку. Прикладом цього є повені, що сталися на річках Кура та Араз у 2003 та 2010 рр. Коротше кажучи, через кількість аномальних подій у природі їх можна вважати "продуктом" глобальної зміни клімату.

Висновки. Ми дійшли висновку, що споживання води змінюється з року в рік і залежить від багатьох факторів, таких як зміни клімату, зростання населення, промислове та сільськогосподарське використання. Аналіз існуючих метеорологічних даних показує, що природа сповнена сюрпризів, різні природні явища, включаючи сильні та стійкі посухи, можуть виникати несподівано. Щоб бути до цього готовим, однією з важливих умов є поступове збільшення існуючих водних ресурсів, створення водозберігаючих методів і технологій, а також розробка нових агротехнічних заходів.

Ключові слова: зміна клімату, водні ресурси, споживання води, температура, зниження, дефіцит води.

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