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WATER RESILIENCE UNDER CLIMATE CHANGE IN AZERBAIJAN

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Abstract: Water resilience under climate change in Azerbaijan is increasingly vital as rising temperatures and erratic precipitation patterns strain water resources. Addressing these challenges requires a comprehensive strategy that integrates adaptive water management practices and stakeholder collaboration to ensure sustainable water access and mitigate the impacts of climate variability. The aim of this article is to analyze the challenges posed by climate change on water resources in Azerbaijan and propose strategies to enhance water resilience. The paper discusses how effective are existing water conservation policy in Azerbaijan, are and what effective solutions can be proposed to enhance water resilience in the face of scarcity under climate change. The research employs both quantitative and qualitative methodologies to comprehensively address various dimensions of water scarcity. Quantitative methods, including hydrological modelling and statistical assessments, enable an exploration of the tangible aspects of water availability and distribution, aiding in our understanding of the physical dynamics involved. In terms of ensuring water resilience in Azerbaijan during the analysis of changes in the volume of water taken from natural water sources was observed a decrease in the volume of water taken from surface water sources, an increase in the volume of water taken from groundwater sources. If the amount of extracting from water sources continues at the current rate, it is projected to reach 13.8 km^3 in 2030, 14.8 km3 in 2040, and 15.8 km^3 in 2050 in Azerbaijan.

Keywords: water resilience, climate change, water management, water scarcity, water, SDG 6: Clean water and sanitation, Azerbaijan

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INTRODUCTION

Under the conditions of population growth and development of the economy all over the world, the usage of water resources has increased rapidly and water provision has worsened sharply in most regions and countries. As a result of climate change and global warming, a tendency to decrease available water resources is observed. Aggravation of water problems directly affects food supply and ecological safety in certain regions. Water difficulties are growing more serious (Rockström et al., 2014). In major groundwater-dependent regions, the resource is being drained (Döll et al., 2012); pollution of water continues to deteriorate; more rivers are being depleted, and more river basins are closing (Falkenmark and Molden, 2008). Humans are an integral component of the natural system, and the water supply for human needs is inextricably linked to dynamic changes in the earth's biophysical processes (Falkenmark and Folke, 2010; Pahl-Wostl et al., 2012). Sakal (2022) investigates shared water resources in the South Caucasus and the impact of Turkey on them. Ahmadov et al. (2021) discuss government investments to improve of irrigation network and main infrastructure matters of climate change adaptation in Azerbaijani agriculture. Rovshan Abbasov describes and analyzes water resources in Azerbaijan from various lenses (Abbasov and Mahmudov, 2009a; 2009b; 2012).

Campana et al. (2012) discuss hydropolitics in the Kura-Aras river basin. Hasanova and Imanov (2010) highlight flood issues in governance in Azerbaijan. Barabadze (2003) investigates water governance in South Caucasus. The existing literature on water issues and the nexus with climate change in Azerbaijan is noticeably short, indicating a major gap in understanding and solving the country's particular concerns. The complicated dynamics of the Azerbaijani setting, characterized by distinct geographical, climatic, and socioeconomic elements, necessitate a targeted examination that the present body of research does not give. This study seeks to address that hole by diving into the nuances of water resilience in Azerbaijan in the face of climate change. It aims to close the literature gap by integrating current information, including international frameworks, and providing context-specific insights into the vulnerabilities and adaptive capacity of water systems.

Azerbaijan, a country at the crossroads of Europe and Asia, is facing a rising issue that crosses geographical borders: water shortage. The complex interaction of climatic, hydrological, and human variables has put a significant strain on the country's water supplies. Rapid urbanization, agricultural needs, and industrial growth put further strain on the fragile equilibrium, making water sources even more vulnerable. This water scarcity situation has far-reaching repercussions, hurting not just agricultural production and food security, but also threatening ecosystems and biodiversity. At present, water has become one of the decisive factors for the sustainable development of the Azerbaijan Republic (Imanov et al., 2015). As Azerbaijan navigates this complicated hydrological terrain, understanding the underlying causes and creating

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adaptive methods is critical for long-term water resource management. In addition to the natural and human elements that contribute to Azerbaijan's water shortage, the geopolitical backdrop complicates matters further. The country has multiple transboundary rivers with neighbouring countries, and water management is frequently impacted by regional dynamics and collaboration. As global demand for water resources rises, effective collaboration becomes increasingly important for long-term water management. Furthermore, the Caspian Sea, an important water source for Azerbaijan, confronts environmental deterioration and variable water levels, limiting the country's availability of freshwater. The socioeconomic consequences of water shortage are severe, with rural areas and disadvantaged groups frequently suffering the burden of limited water supply.

In light of climate change, Azerbaijan's water landscape is changing, posing new challenges to water resilience. Rising temperatures and shifting precipitation regimes are substantial dangers to the country's water supplies. Irregular precipitation patterns, worsened by climate change, have caused fluctuations in water availability, affecting both surface water bodies and subsurface aquifers. Changes in hydrological cycles and precipitation patterns cause more frequent and long-lasting droughts, worsening water shortage concerns. Furthermore, the reliance on conventional water supplies is under strain, affecting both urban and rural areas. To address these issues, there is an increasing demand for comprehensive water management systems that include climate resilience measures. This involves adopting sustainable water practices, building resilient infrastructure, and enacting rules that encourage water saving. By increasing water resilience, Azerbaijan can better manage the effects of climate change on its water resources, guaranteeing a sustainable and secure water future for its people. The paper examines Azerbaijan's water management systems' adaptive ability and resilience in the face of rising shortage issues using Resilience Theory as a framework. The study highlights the need for resilience in dealing with changes to water availability and quality. The study dives into the complex interaction of social, ecological, and institutional aspects, examining how these elements influence water management systems' ability to absorb shocks, adapt to changing conditions, and retain functionality. Through this resilience lens, the research strives not only to identify vulnerabilities but also to suggest strategies and policy recommendations that strengthen Azerbaijan's water sector's adaptive ability, assuring its resilience in the face of an unpredictable hydrologic future.

RESILIENCE THEORY AND MIXED METHODS

Resilience in theory and practice throughout any field indicates a move toward more integrative ways to deal with the Anthropocene's more complex and unpredictable environment (Saikia and Jiménez, 2023). Over time, research on this idea has grown considerably, as has the desire for practical resilience assistance in a variety of sectors, including ecological management, adaptation to climate change, development, and catastrophe risk reduction (Sellberg et al., 2018). Adaptive governance has been clearly stated in the literature as the appropriate strategy to manage uncertainty and complexity in social-ecological systems, particularly water networks (Akamani, 2016; Berkes, 2017). Cumming (2011) shows that proactive governance of complicated structures such as river basins necessitates the inclusion of social, ecological, and economic factors in issue formulation and resolution. According to Rockström et al. (2014), the control of water resources is central to larger attempts to attain sustainability and socio-ecological resilience.

Resilience theory is important in the context of water shortage and forecasting, as it provides a useful framework for understanding and managing the issues connected with changing hydrological circumstances. In the context of water shortage, resilience theory highlights systems' ability to absorb shocks, adapt to changing conditions, and retain functionality. In the context of limited water supplies and rising demand, recognizing the resilience of water management systems is critical. Resilience theory enables the identification of vulnerabilities in these systems and gives insights into their adaptive ability, assisting stakeholders in developing strategies to improve resilience and guarantee sustainable water usage.

As discussed in the study, resilience theory emerges as a useful lens for analyzing and addressing the complex difficulties of water shortage in Azerbaijan. This theoretical approach is especially significant in light of the region's dynamic and varied water security situation. Resilience theory enables a comprehensive assessment of how Azerbaijan's water management systems react to disturbances, adapt to changing conditions, and recover from stressors. By highlighting the interconnection of social, ecological, and institutional factors, resilience theory allows for a more comprehensive understanding of the water sector's vulnerabilities. The adaptive capability of Azerbaijan's water systems, which is critical for negotiating the intricacies of climatic variability and anthropogenic stresses, becomes a focus point. Within this framework, the research aims not only to identify vulnerabilities but also to offer methods and policies that improve the water sector's adaptive ability, increasing resilience and assuring the long-term management of water resources in the face of uncertainty.

Peter Gleick's ideas, particularly those about water resilience and climate change, provide a useful framework for understanding and managing water issues in Azerbaijan (Gleick, 1993; 1996; 2009; 2014). Gleick calls for a holistic strategy that considers both the quantity and quality of water resources, recognizing the intricate linkages between climate trends and hydrological processes. This approach is consistent with the complex and changing water dynamics of Azerbaijan, where climate change is impacting precipitation patterns, river flows, and total water availability. Gleick's emphasis on studying the effects of climate change on water supplies is especially relevant in Azerbaijan, where changing climatic conditions threaten both urban and rural water systems. In a country where water shortage is becoming a major problem, comprehensive solutions that balance conflicting needs, such as agriculture, industry, and home consumption, are essential. Gleick's paradigm encourages the creation of adaptive solutions that take into account the interconnection of different water users, with the goal of achieving long-term sustainability.

Gleick's work frequently focuses on the physical and environmental components of water, but greater attention may be placed on the social factors. Integrating social scientific approaches might improve our knowledge of the human aspects of water consumption, governance, and equity. Water concerns sometimes necessitate transdisciplinary methods.

Gleick's work might benefit from more collaboration with specialists from many fields, such as ecology, economics, sociology, and political science, to address the complex and interwoven nature of water issues.

Elinor Ostrom's seminal work (1994) on common-pool resource management provides a significant theoretical framework that is directly applicable to the setting of water resilience in Azerbaijan under climate change. Ostrom's (1990) focus on the need for local government and community involvement is consistent with the need for inclusive and participatory ways to tackle water issues. In Azerbaijan, where water resources are inextricably related to rural populations' lives, Ostrom's theories promote the formation of community-based water management projects. Ostrom's principles also emphasize the significance of adaptive governance, which enables communities to customize their reactions to changing climatological conditions (Dietz et al., 2003). This is consistent with the dynamic nature of water resilience under climate change, in which flexibility and responsiveness are critical. Ostrom's research was done in contexts that were either steady or slowly changing. Her concept may require additional investigation into its relevance and adaptability to quickly changing situations, such as those caused by climate change. The role of gender in resource management is an important consideration that Ostrom's theory does not directly address. Investigating how gender dynamics impact collective action and resource governance might lead to a more complete understanding. The research approach used in the paper is carefully designed to match the study's intricacies. A combination of quantitative and qualitative research approaches is used to represent the multiple aspects of water shortage. Quantitative analysis, such as hydrological modelling and statistical evaluations, helps us understand the physical elements of water availability and distribution.

These approaches are useful in determining the effects of climate change on precipitation patterns, river flows, and aquifer levels. Qualitative approaches, such as observations, provide insights into the socioeconomic and institutional issues that influence water management. This dual method enables a comprehensive interpretation of data, allowing for a more nuanced understanding of the interactions between environmental, geopolitical, and sociological phenomena. The integrated character of the approaches used in this study is critical for informing policy recommendations, encouraging sustainable practices, and strengthening Azerbaijan's water resilience in the face of a changing hydrological landscape.

Unraveling the Intricacies of Water Scarcity

Water scarcity and inadequate water supply and sanitation services adversely affect food security and human well-being in many countries around the world. Drought leads to hunger and poor living conditions in many poor countries. It is no coincidence that 6 of the 17 goals of sustainable development are dedicated to clean water and sanitation[1]. It is noted that by 2050, one in four people living in the countries of the world will be exposed to a chronic or recurring shortage of fresh water. Taking into account all these risks, one of the important factors is the assessment of the priority directions of ensuring water security in Azerbaijan. Taking into account all these risks, one of the significant factors is the assessment of the priority directions of ensuring water security in Azerbaijan.The convergence of population expansion and economic development, notably in agricultural operations, has greatly increased Azerbaijan's need for water, resulting in an alarming rise in water shortage. As the population grows and urbanizes, the need for water for household, industrial, and agricultural reasons increases. Agriculture, a cornerstone of Azerbaijan's economy, is critical in this circumstance. Economic development frequently leads to industrial expansion, which increases water use. The combination of these causes puts enormous strain on water resources, resulting in over-extraction from rivers and aquifers, depletion of water tables, and degradation of water quality (Ahmadzadeh and Hashimov, 2006). The lack of water resources, global climate change and the decrease of water resources coming from neighboring countries, on the other hand, the rapid growth of the population, the development of agriculture, and the increase in the demand for water as a result of the expansion of agricultural areas, irrigation and drinking water supply networks, require the implementation of measures to ensure the water security of the republic (Imanov and Alakbarov, 2017; Ismayılov, 2017).

The State Commission established by the Decree of the President of the Republic of Azerbaijan dated April 15, 2020, operates in order to ensure the efficient use of water resources, improve water management and coordinate activities in this area[2]. Currently, the average annual water deficit in Azerbaijan is 3.7 km^3, and in low-water years it is 4.75 km^3 (Ahmadzade and Hashimov, 2006). If we take into account the forced release of water from rivers for environmental, energy and other purposes, the quantitative indicators of water shortage will have an unimaginable value. So that 60-70% of the water taken from Azerbaijan's water sources is used for irrigation purposes, 20-25% for production needs, and the rest is used for domestic water supply (Ahmadzadeh, 2003; Imanov and Alakbarov, 2017; İsmayılov, 2017).

The military conflict between Armenia and Azerbaijan has had serious and negative consequences for water resilience in Azerbaijan, aggravating an already difficult situation in the area. The fighting, notably in the Nagorno-Karabakh area, has affected water infrastructure, resulting in damage to reservoirs, canals, and other critical water-related assets. This physical degradation has had a direct influence on the availability and distribution of water resources, limiting the country's capacity to manage water properly. The water resources in Karabakh, comprising rivers, lakes, and groundwater, are estimated to be over 780 million cubic meters, accounting for around 20% of Azerbaijan's local water resources (Ahmadi et al., 2022). Furthermore, the environmental consequences of the war, including as pollution and ecosystem deterioration, put further strain on water quality, posing threats to both human and ecological health. The conflict has also hampered collaboration on transboundary water management in the South Caucasus. The region's shared water resources require coordinated and cooperative methods, yet political conflicts have hampered effective collaboration between Armenia and

[1] Water https://www.worldbank.org/en/topic/water/overview (accessed on 24 January 2024)

[2] Su ehtiyatlarından səmərəli istifadənin təmin edilməsi ilə bağlı tədbirlər haqqında Azərbaycan Respublikası Prezidentinin Sərəncamı https://president.az/az/articles/view/36558 (accessed on 24 January 2024)

Azerbaijan. As the violence continues, the prospects for comprehensive transboundary water management remain bleak, exacerbating difficulties in addressing water resilience and sustainability in the South Caucasus. Resolving the armed conflict and encouraging regional collaboration are critical precondition for establishing effective and inclusive policies to improve water resilience and solve the complex water-related concerns in Azerbaijan and the wider South Caucasus area.

Table 1. Water resources with 4 subdivisions, water resources km^3, water withdrawals with km^3 and finally total amount of them (Ismayilov, 2021)

Water resources		Water resources, km^3	Water withdrawals from sources, km^3
Surface water	Local water resources	10.6	10.2
	Transboundary	20.3	
Groundwater		4.38	1.40
Total		35.3	11.6

The highest number of water resources is transboundary and the major water withdrawals from surface water (Table 1). While the local river water resources are on average 10.6 km^3, in recent years 11.5 km^3 of water is used annually. Unfortunately, approximately 70% (20.3 km3) of our river water resources are formed in the territory of neighboring countries and enter the territory of Azerbaijan through transboundary rivers (Rustamov and Gashgay, 1989). As a whole, the Republic of Azerbaijan is considered a country with limited water resources. The amount of water per person is 3253 m^3/year. If we consider only local water resources, then this figure will be equal to 1051 m^3/year (Ismayilov, 2021). According to the forecast of the World Resources Institute, in 2025, Azerbaijan will be among the countries with the lowest local water resources per person (972 m^3/year). According to the researchers conducted in recent years, annual flow of transboundary and local rivers has decreased. Over the last 20 years, the annual flow at the closing section (Salyan) of the Kura River, that is not only the largest transboundary river in Azerbaijan, but also in the entire South Caucasus region, has decreased by 10-15% and thus has comprised an approximate half of naturalized flow (425 m^3/s). Decrease in the amount of 325 m^3/s in the basin of the Kura River, 100 m^3/s in the basin of the trans-boundary Aras River, the main branch of the Kura River has been registered. 138 - various sized reservoirs were built in Azerbaijan for efficient use of water resources and 21599.0 mln.m^3 water is stored in them. Takhtakorpu (268 mln.m^3), Shamkirchay (164 mln.m^3) and Tovuzchay (20 mln. m^3) were put into operation in 2013, 2014 and 2015 respectively (Imanov, 2016).

The Aggravation of Water Scarcity by Climate Change

The nexus between water resilience and climate change underscores the critical interplay between environmental dynamics and societal well-being. As climate change intensifies, altering precipitation patterns, increasing the frequency of extreme weather events, and accelerating sea-level rise, water resources face unprecedented stress. Water resilience, therefore, becomes paramount in safeguarding communities, ecosystems, and economies against the impacts of climate variability. Resilient water systems are characterized by their capacity to adapt to changing conditions, efficiently manage water resources, and mitigate risks associated with water scarcity, flooding, and degradation. Achieving water resilience amidst climate change requires a holistic approach that integrates sustainable water management practices, robust infrastructure investments, ecosystem conservation efforts, and stakeholder engagement.

In Azerbaijan, climate change can impact water resources through altered precipitation patterns, changing temperatures, and shifting hydrological cycles. Changes in precipitation may affect the availability of water, impacting agriculture and ecosystems. Rising temperatures can lead to increased evaporation, potentially reducing water availability. Sustainable water management strategies and adaptation measures are crucial to address these challenges in the context of climate change. Azerbaijan's climate is highly varied, with different areas of the country containing examples of nine of the world's eleven climate zones. This includes semi-arid zones in the center and east of the country (including the capital, Baku), temperate zones in the north, continental zones in the west, cold and tundra zones, meaning that there are marked variations in average annual temperature and precipitation in different regions. In general, more mountainous parts of Azerbaijan receive higher levels of precipitation and lower average temperatures than the central lowlands and Caspian Sea coast, where the climate is drier and hotter. Azerbaijan experiences hot summers (especially in lowland areas) and moderate winters. Average temperatures for the latest climatology, 1991–2020, ranged between approximately 24°C in the summer months of July and August, and −1°C to 1°C during the winter (December to February).

The average monthly temperatures vary significantly between different regions and altitudes across Azerbaijan (Huseynov and Huseynov, 2022). Average temperatures in Baku and other parts of the east and southeast reach approximately 27°C during the hottest months of July and August, while temperatures during these months remain between 15°C and 20°C in parts of the mountainous north and west. Similarly, during the winter (December to February) temperatures in Baku average between 3°C and 4°C, whereas in western and northern areas average monthly temperatures fall to between −5°C and −10°C[3]. In the report of the US Central Intelligence Agency on climate change, the name of Azerbaijan was mentioned among the 39 countries that will suffer the most from climate change.

Given the predictions that the air temperature will increase by 2-3ºC, both surface and groundwater are expected to decrease by 15% over the next 50 years. Precipitation is highest in May and June months in the northern and western areas of Azerbaijan, where it can exceed 100 mm per month in places. On the other hand, precipitation in Baku remains

[3] Ministry of Ecology and Natural Resources (2015). Republic of Azerbaijan. Third National Communication to the UNFCCC on Climate Change. https://unfccc.int/sites/default/files/resource/azenc3.pdf (accessed on 22 January 2024)

below 25 mm per month on average for much of the year (from January to September) and averages only 33 mm in the wettest months of October and November (Safarov et al., 2020; Huseynov and Huseynov, 2022).

Average rainfall in Azerbaijan follows a bimodal distribution throughout the months of the year, with average levels above 40 millimeters (mm) per month from April to June, and again in October (Figure 1).

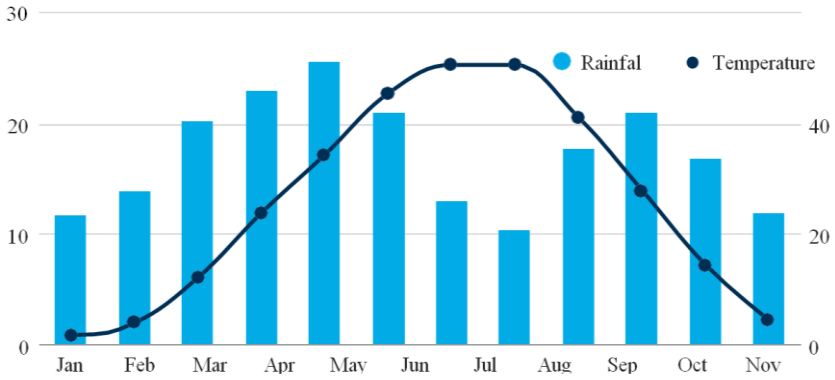

Figure 1. Average monthly temperature between 0 and 40 from January to November and rainfall between 0 and 30 mm in Azerbaijan (1991–2020)[4]

The decrease in the amount of precipitation in the country is 7% in the lowland areas consisting mainly of plains, 8% in the middle highlands at a height of 1500-2000 meters, and 11% in the area of the middle highlands with a height of 1500-2000 m. Compared to 1961-1990, the temperature indicators in 1991-2020 have changed by 0.80C in the country. At the same time, the main increase is 0.9-1.00C, being in the upper parts of the lowlands (500-1000 m) and in the upper parts of the middle highlands (1500-2000 m). In plain zones, this indicator is 0.80C. Thus, during this period, the amount of precipitation decreased by 7% in the 0-500 m altitude area where the plateau, lowland and coastal plains are located. The amount of precipitation decreased by 9% in the lowland zone of 500-1000 meters (Huseynov and Huseynov, 2022). A further decrease in precipitation is around 10% in the 1000-1500 m zone of the highlands. Although the decrease in precipitation occurred less in the higher parts of the lowlands, this fluctuation was 13% in the lower parts of the middle highlands.

During a detailed study of climate changes, if we look at the trend of multi-year average temperature and precipitation for every 10 years, it can be seen that the amount of precipitation across the country has a decreasing trend, and the temperature has an increasing trend. During the years 1961-2020, the average annual temperature of the Republic of Azerbaijan has increased. Also, during this period, more precipitation fell on the territory of the country in 1961-1970 (Safarov et al., 2020). During this period, as less precipitation fell in 1991-2020, the dry areas in the area expanded. Over the past 30 years, precipitation has been steadily decreasing. If we look at the pictures, it is possible to see that the amount of precipitation decreases with the temperature (Figure 2).

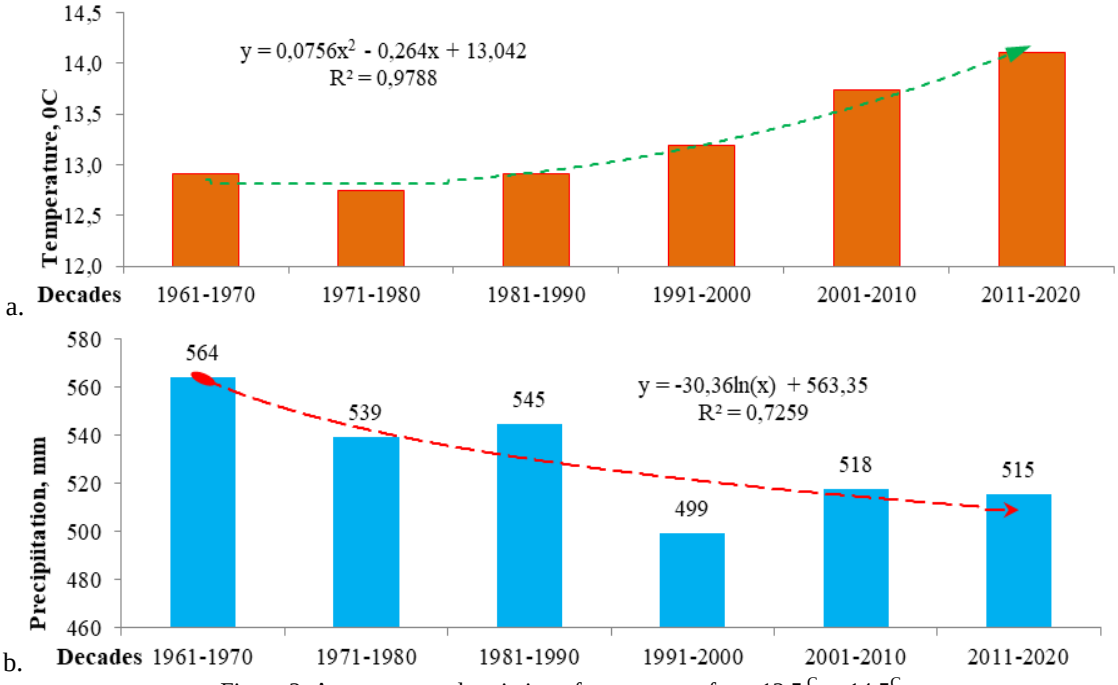

Figure 2. Average annual variation of temperature from 12.5 ^{C} to 14.5^{C} (a) and precipitation from 460 mm till 580 mm (b) in decades from 1960 till 2020[5]

[4] Ministry of Ecology and Natural Resources, the Republic of Azerbaijan https://eco.gov.az/

[5] Ibid

The research conducted using the precipitation and temperature observation data in the territory of Azerbaijan shows that the average annual temperature increased by 0.80C in 1961-2020 compared to 1881-1961. This indicator was 0.80C in 1991-2020 compared to 1961-1990. The amount of precipitation decreased throughout the period. Precipitation fell 7% less in 1891-1960 and 1991-2020 (Safarov et al., 2020; Huseynov and Huseynov, 2022). The increase in temperature is one of the main reasons for the decrease in precipitation. The change in the amount of precipitation is also related to the change in the characteristics of the air masses penetrating the regions as a result of the effects of global climate changes on the general circulation. If the climate regime continues to change at this rate, the size of the area where the semi-desert and arid climates exist will increase. A sharp increase in air temperature at the beginning of summer will lead to the melting of glaciers and acceleration of processes such as flooding, and the desertification process will begin to grow.

Climate change can significantly impact water resources in the Republic of Azerbaijan. Shifts in precipitation patterns may lead to changes in water availability, affecting rivers and reservoirs crucial for agriculture and domestic use. Increased temperatures may contribute to evaporation, potentially reducing water storage. Changes in glacier melt could impact river flow, influencing hydroelectric power generation. Additionally, altered weather patterns may increase the risk of extreme events like floods or droughts, posing challenges for water management and infrastructure. Adaptation strategies are crucial to mitigate these effects and ensure sustainable water resources in the Republic of Azerbaijan.

Implementing a comprehensive strategy that combines these measures can help Azerbaijan adapt to the challenges posed by climate change on its water resources. To mitigate the impact of climate change on water resources in Azerbaijan, consider implementing sustainable water management practices, enhancing water efficiency, promoting afforestation to protect watersheds, and investing in climate-resilient infrastructure. Collaborate with local communities, engage in climate research, and adopt policies that address both adaptation and mitigation strategies.

Water resilience assessment and water withdrawal projections

The downstream portion of the Kura-Aras River Basin in Azerbaijan is one of the most susceptible, with a combination of natural and human variables increasing its sensitivity to negative consequences. First, climate change has caused shifts in precipitation patterns and rising temperatures, affecting the river basin's hydrological dynamics. The downstream areas, which are on the receiving end, experience the combined consequences of diminished water supply and increasing frequency of extreme weather events such as droughts and floods. Furthermore, upstream agricultural and industrial activities contaminate water supplies, increasing the vulnerability of downstream ecosystems and populations. The cumulative impact of these stresses on water quality and quantity endangers the delicate balance of the downstream region's ecosystems, reducing biodiversity, agricultural production, and the general resilience of populations who rely on the Kura-Aras River. Given these issues, assessing and managing downstream vulnerabilities is critical for developing effective adaptation strategies and sustainable water management practices that will maintain the Kura-Aras River Basin's long-term resilience.

Rural regions downstream of the Kura-Aras River Basin are particularly vulnerable owing to a combination of physical, socioeconomic, and environmental reasons. To begin, many rural populations in these regions rely largely on agriculture as their major source of income. Changes in water availability and quality have a direct influence on agricultural output, posing a substantial risk to these people's economic well-being. Rural regions frequently lack the infrastructure and resources required to adapt and deal with the effects of climate change. Limited access to technology, knowledge, and financial resources impedes their capacity to implement resilient water management methods. Furthermore, rural communities may have fewer opportunities for income diversification, making them more vulnerable to swings in agricultural production induced by changes in water supply. Women in rural regions carry a disproportionate weight of vulnerability, especially in the face of water shortages and climate change. Tasked with home obligations, women frequently find themselves on the front lines of water collection, a task that grows increasingly difficult when water supplies decline or become polluted in the downstream part of the Kura-Aras River Basin in Azerbaijan. The resulting physical strain and safety concerns reduce their time for other productive pursuits or personal growth, continuing a cycle of restricted options. Women in agriculture-dependent communities are immediately exposed to the effects of shifting water availability, which affects both food security and economic stability for their families.

On the other hand, the Azerbaijani government has taken a diversified strategy to address water shortage concerns and improve water resilience, notably in the downstream section of the Kura-Aras river basin. The government aspires to enhance water resource management by implementing and enhancing water-related legislation and policies that prioritize sustainability and quality preservation. Significant expenditures in water infrastructure, including as reservoir building and repair, water delivery systems, and irrigation networks, help to improve the efficiency and reliability of water distribution in both rural and urban regions. Recognizing agriculture's importance to the economy, the government strongly supports climate-resilient agricultural methods, including as drought-resistant crops and efficient irrigation systems. Community involvement efforts encourage local citizens to participate in sustainable water practices, which improves the resilience of both rural and urban settings. The government also encourages research and innovation to better understand the unique effects of climate change on water resources, hence accelerating the development of personalized solutions.

Collaboration with international organizations and adjacent states, such as Turkey, improves the efficacy of water management techniques. Investments in water-efficient technology across multiple industries indicate the government's commitment to optimizing water consumption and boosting overall water efficiency. In order to increase the efficiency of water resources management, the Azerbaijan State Water Resources Agency ensuring activities in the field of extraction, processing, transportation and supply of water in the Republic of Azerbaijan, operation of state-owned reclamation and irrigation systems, drinking water supply, stormwater and wastewater processing and discharge systems, as well as

organization of services in this field, balanced water management implementation of regular control of the technical condition of the facilities, except for the main and auxiliary equipment that ensures their maintenance and protection of surface and groundwater resources, water and water management facilities, hydraulic structures (marine hydraulic structures located in the section of the Caspian Sea (lake) belonging to the Republic of Azerbaijan) in the Republic of Azerbaijan is a central executive authority that implements a unified state policy and regulation in the areas of water supply system monitoring. One of the main activities of the agency is to ensure the integrated management of water resources in the Republic of Azerbaijan. Depending on the water source and the type of water intake, all projects are implemented by modern standards and water treatment requirements. Suitable conditions are being established to ensure the achievement of fundamental changes in the water supply system of Azerbaijan via the provision of integrated water resources management.

Increasing water withdrawal from sources in Azerbaijan should be approached with caution to avoid negative environmental impacts. It's important to consider sustainable water management practices, including efficient irrigation methods, water conservation, and monitoring of water quality. Balancing increased demand with responsible usage is key to ensuring long-term water availability. Several factors can influence changes in water withdrawal from sources in the Republic of Azerbaijan. These may include population growth, agricultural demands, industrial activities, climate variations, and water management policies. Understanding and managing these factors are crucial for sustainable water resource usage and ensuring adequate water availability for various sectors in the country. Using the state water use accounting information (2000-2022), the amount of water withdrawal from water sources was analyzed by sector. Thus, during this period, the amount of water withdrawal from water sources sources varied from 9.91 to 13.03 km^3. The highest amount of water withdrawn from water sources was in 2022, and the lowest amount was in 2002 (Figure 3). In general, an average of 11.6 km^3 of water was withdrawn from natural water sources in the last 22 years. During this period, an increase of 2.20 km^3 (11.4%) was observed in the volume of water withdrawal from water sources.

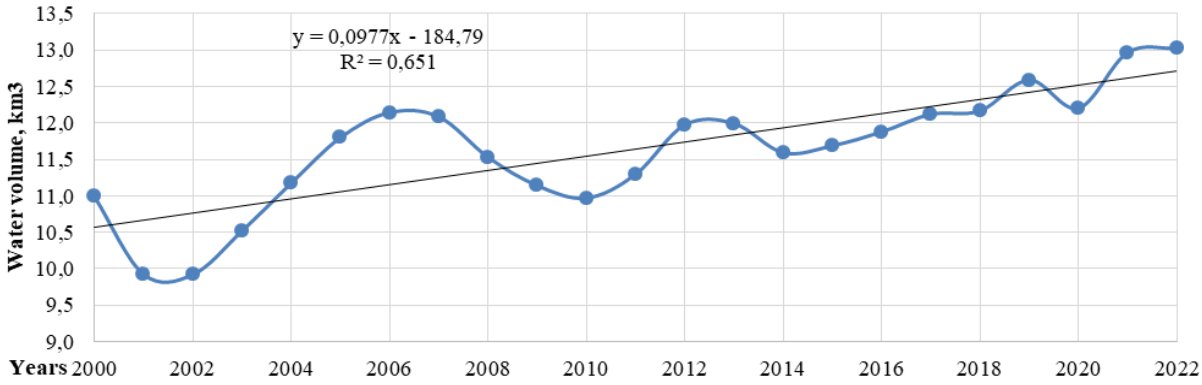

Figure 3. Changes in the volume of water withdrawal between 9.5 and 13.5 from sources every 2 years from 2000 till 2022 in Azerbaijan[6]

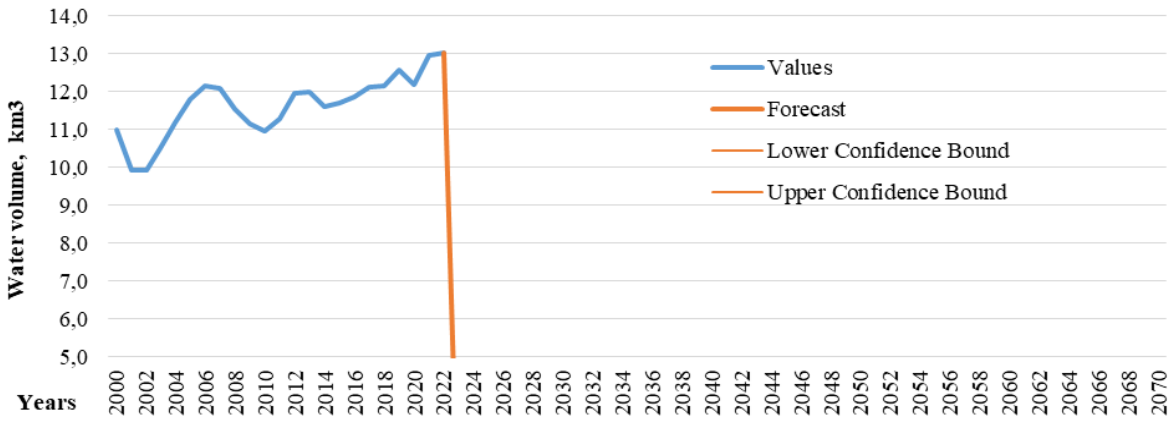

Figure 4. Shows predictions change in 3 paths between 5 km^3 and 30 km^3
in the volume of water withdrawal from water sources every 3 years from 2000 to 2069[7]

If the volume of withdrawal from water sources continues at this rate, it is predicted to be 13.8 km^3 in 2030, 14.8 km^3 in 2040, and 15.8 km^3 in 2050 (Figure 4). Predicting changes in water withdrawal volume in Azerbaijan requires considering various factors like population growth, industrial development, and climate patterns. Analyzing these can help anticipate potential impacts on water resources, allowing for informed resource management and conservation strategies. Future water withdrawal scenarios must be taken into account when implementing water management measures (Table 2). Lower confidence bound and upper confidence bound future water withdrawal must be taken into account during the implementation of the projects. This is very important for ensuring water security in the Republic of Azerbaijan against the background of climate changes. The analysis was carried out separately for both the amount of water withdrawn from

[6] (State Statistics Committee of the Republic of Azerbaijan https://www.stat.gov.az/?lang=en)
[7] Ibid

surface water sources and the amount of water withdrawn from groundwater sources. No major change was observed in the amount of water withdrawal from surface water sources during the multi-year period (Figure 3). During this period, an average of 0.28 km^3 of water was withdrawal from surface water sources.

Table 2. Future water withdrawal in 3 scenarios between 6.4 and 27.9 every 5 years from 2025 till 2070[8]

Years	Forecast	Lower Confidence Bound	Upper Confidence Bound
2025	13.3	10.5	16.2
2030	13.8	9.2	18.4
2035	14.3	8.5	20.1
2040	14.8	8.0	21.6
2045	15.3	7.5	23.0
2050	15.8	7.2	24.3
2055	16.2	7.0	25.5
2060	16.7	6.7	26.7
2065	17.2	6.6	27.9
2070	17.7	6.4	29.0

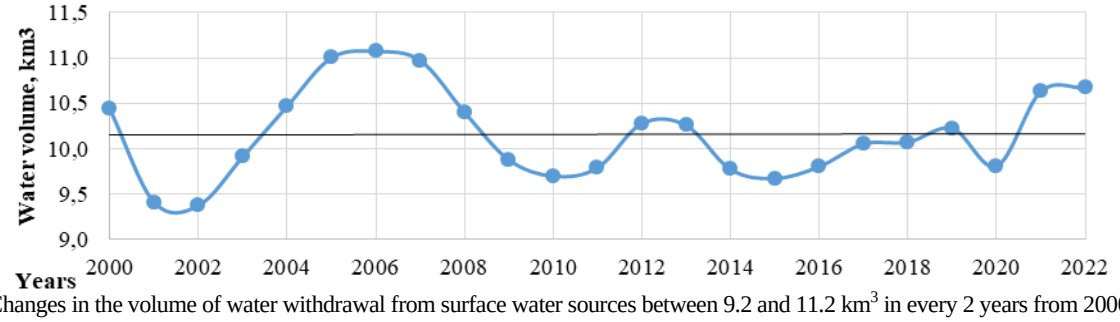

Figure 5. Changes in the volume of water withdrawal from surface water sources between 9.2 and 11.2 km^3 in every 2 years from 2000 till 2022[9]

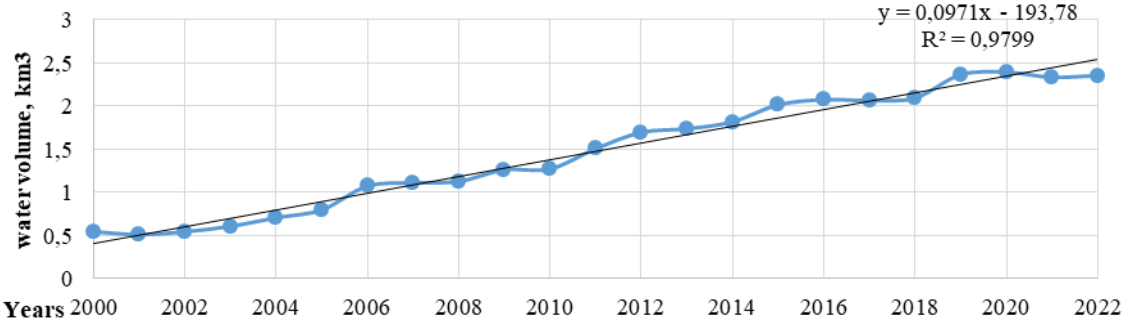

Figure 6. Changes in the volume of water withdrawal from groundwater sources between 0 km^3 and 3 km^3 in every 2 years from 2000 till 2022[10]

The same analysis was performed for the volume of water withdrawn from groundwater sources. During the analysis, a significant increase in the amount of withdrawn from groundwater sources was observed during the multi-year period (Figure 4). During the average multi-year period, a decrease of 2.55 km^3 was observed in the volume of water withdrawal from groundwater sources. Increasing water withdrawal from groundwater sources can have several impacts on water management. Firstly, it can lead to the depletion of aquifers, reducing the availability of groundwater for future use. This poses a significant challenge for sustainable water management, as groundwater often serves as a crucial resource for agriculture, industry, and domestic purposes. Excessive withdrawal may also lead to land subsidence, where the land surface sinks due to the emptying of underground water reservoirs. This can result in damage to infrastructure and ecosystems. Furthermore, over-extraction can cause saltwater intrusion in coastal areas, jeopardizing freshwater supplies. To manage water resources effectively, it's crucial to implement sustainable practices, monitor groundwater levels, and regulate extraction to avoid long-term environmental and socio-economic consequences. During the analysis of water withdrawal by sources, the increase in the use of groundwater sources suggests that it will cause certain problems in the ecosystem of the area in the future. Future groundwater withdrawal scenarios must be taken into account when implementing water management measures too (Table 3). Lower confidence bound and upper confidence bound future groundwater water withdrawal must be taken into account during the implementation of the projects. This is very important for ensuring water security in the Republic of Azerbaijan. As it is known, the confirmed groundwater reserve of Azerbaijan is 4.38 km^3.

CONCLUSION AND RECOMMENDATIONS

This scientific investigation throws light on the severe difficulties that Azerbaijan faces in terms of water shortage such as a result of climate change. The complex combination of rising temperatures, fluctuating precipitation patterns, and developing hydrological cycles poses a significant danger to the country's water supplies. The intricate balance between supply and demand is exacerbated by outdated water management techniques that must be reconsidered immediately. In

[8]Ibid; [9]Ibid; [10]Ibid, [11]Ibid

this light, the last call to action is consistent with the need to transcend traditional paradigms. The discovered weaknesses in conventional water supplies, together with increased demand from other sectors, highlight the importance of tackling water shortage concerns comprehensively. The possible consequences go beyond only resource availability, as emerging risks to water resilience affect ecological stability, agricultural output, and local livelihoods. The findings underline the crucial need for quick and focused actions, stressing the adoption of adaptive measures, sustainable water management practices, and robust infrastructure development. Recognizing these problems and taking proactive actions can help Azerbaijan strengthen its water resilience, assuring a sustainable and secure water future in the face of climate change.

Table 3. Future groundwater water withdrawal in 3 scenarios between 2.66 km^3 and 4.81 km^3 in every 5 years from 2025 till 2040[11]

Years	Forecast	Lower Confidence Bound	Upper Confidence Bound
2025	2.66	2.36	2.95
2030	3.14	2.67	3.61
2035	3.62	3.02	4.22
2040	4.11	3.40	4.81

Water resilience in Azerbaijan faces challenges due to water scarcity. Factors such as climate change, inefficient water management, and population growth contribute to this issue. Evaluating current water usage patterns, promoting sustainable agriculture practices, and investing in water infrastructure can be vital steps toward ensuring water security in the Republic of Azerbaijan. International collaboration and innovative technologies may also play a role in addressing this complex issue. In order to ensure the water resilience of Azerbaijan, it is considered appropriate to prevent the pollution of water resources, to use water rationally and sustainably, to eliminate existing problems in the field of wastewater management, to strengthen cooperation, and carry out educational activities among the population. Against the background of climate change, it is proposed to take the following measures to ensure the water security of the Republic of Azerbaijan:

- Assessment of Water Resources and Infrastructures: Evaluate the current status of water resources in Azerbaijan, considering surface water, groundwater, and their distribution across regions; examine the balance between water demand and supply, including agricultural, industrial, and domestic usage, identifying any existing gaps; assess the condition and capacity of water-related infrastructure such as dams, reservoirs, and distribution systems to identify vulnerabilities; identify potential risks to water security and develop strategies to enhance resilience, considering both short-term and long-term scenarios; analyze the potential impact of climate change on water availability and patterns, considering historical data and future projections.
- Diversification of Water Resources: Implement initiatives to diversify water sources, minimizing reliance on one source and increasing resilience to shifting climatic patterns.
- Water Recycling and Reuse: Promote water recycling and reuse across a variety of sectors, including industry and agriculture, to reduce the total demand for freshwater supplies.
- Awareness and Community Engagement: Develop and implement programs to educate the public on water resilience, sustainable usage practices, and the importance of preserving water resources; involve local communities in the analysis to gather insights on water usage patterns, challenges faced, and potential solutions.
- Cross-Border Considerations: Evaluate transboundary water issues, particularly if Azerbaijan shares water resources with neighbouring countries, and propose collaborative strategies.
- Technological Solutions and Early Warning Systems: Explore innovative technologies for water conservation, purification, and efficient distribution, considering global best practices; establish or enhance monitoring systems to track water availability, quality, and usage, and develop early warning systems for potential crises.
- International Collaboration and Investment: Foster collaboration with international organizations and neighbouring countries to share knowledge, resources, and best practices in addressing water resilience issues; Upgrade and invest in water infrastructure to provide effective water storage, delivery, and treatment while accounting for changing climate conditions.
- Policy Recommendations: Compile a set of comprehensive policy recommendations based on the analysis to guide decision-makers in enhancing water resilience in Azerbaijan. In order to ensure water resilience under climate change, it is considered appropriate to minimize the pollution of water sources and improve protection, to effectively use water resources to meet the needs of current and future generations, to assess the needs of global water problems at the national level, to determine solutions, and to expand relations with international organizations.

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