TRANSFORMATION OF WATER RESOURCES IN THE AMU DARYA RIVER BASIN UNDER GLOBAL CLIMATE CHANGE AND ANTHROPOGENIC PRESSURE: PROBLEMS AND GEOGRAPHICAL SOLUTIONS

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Abstract. This article analyzes the changes in the hydrological condition of the Amu Darya River Basin under conditions of global climate change and anthropogenic pressure. Based on hydrometeorological observations, remote sensing data, and reports of the Interstate Commission for Water Coordination of Central Asia (ICWC), the factors influencing the decline in river flow were assessed. The analysis showed that global warming, the shrinking area of glaciers, and imbalances in water use are intensifying water scarcity. To mitigate the problem, scientific recommendations were developed for the implementation of integrated management, digital monitoring, and water-saving technologies.

Keywords: Amu Darya Basin, global climate change, anthropogenic pressure, hydrological changes, water scarcity, transboundary waters, integrated water resources management.

ТРАНСФОРМАЦИЯ ВОДНЫХ РЕСУРСОВ БАССЕЙНА РЕКИ АМУДАРЬИ В УСЛОВИЯХ ГЛОБАЛЬНОГО ИЗМЕНЕНИЯ КЛИМАТА И АНТРОПОГЕННОГО ВОЗДЕЙСТВИЯ: ПРОБЛЕМЫ И ГЕОГРАФИЧЕСКИЕ РЕШЕНИЯ

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Аннотация. В статье проанализированы изменения гидрологического состояния бассейна реки Амударьи в условиях глобального изменения климата и антропогенного воздействия. На основе гидрометеорологических наблюдений, данных дистанционного зондирования Земли и отчетов Межгосударственной координационной водохозяйственной комиссии Центральной Азии (МКВК) проведена оценка факторов, влияющих на сокращение речного стока. Результаты анализа показали, что глобальное потепление, сокращение площади ледников и дисбаланс в использовании водных ресурсов усиливают дефицит воды в регионе. Для смягчения данной проблемы разработаны научно обоснованные рекомендации по внедрению интегрированного управления водными ресурсами, цифрового мониторинга и водосберегающих технологий.

Ключевые слова: бассейн реки Амударьи, глобальное изменение климата, антропогенное воздействие, гидрологические изменения, дефицит водных ресурсов, трансграничные воды, интегрированное управление водными ресурсами.

Introduction

One of the most pressing global environmental and geographical problems facing humanity in the 21st century is the shortage of freshwater resources [5].

The Amu Darya is the most water-abundant and, strategically, one of the most important transboundary rivers in Central Asia, linking the territories of Tajikistan, Kyrgyzstan, Afghanistan, Turkmenistan, and Uzbekistan [7]. This river basin serves as the primary water source meeting the drinking-water, irrigated-agriculture, and industrial needs of millions of people [9].

However, today the Amu Darya Basin faces serious challenges due to climate change and geopolitical factors [4]. According to expert forecasts, by 2050 the natural water resources of the Amu Darya Basin may decline by a further 15 percent [9]. This hydrological crisis poses a direct threat to the stability of

agricultural landscapes in the river's lower reaches and to the ecological security of the Aral Sea region [8].

Methods

The study employed comparative, statistical, cartographic, and geomorphological methods of analysis to assess the hydrological, hydrochemical, and ecological condition of the Amu Darya Basin. The analysis drew on more than 90 years of hydrometeorological data, reports of the Interstate Commission for Water Coordination of Central Asia (ICWC) [6], and remote sensing data obtained via the GRACE [11] and Landsat [12] satellites. In addition, changes in the glacier-covered area in the upper reaches of the Amu Darya (the Pamir Mountains) were assessed using cartographic and geomorphological methods [14, 21], and the resulting data were compared to form the study's scientific conclusions. The study area and field infrastructure are summarized in Figure 1.

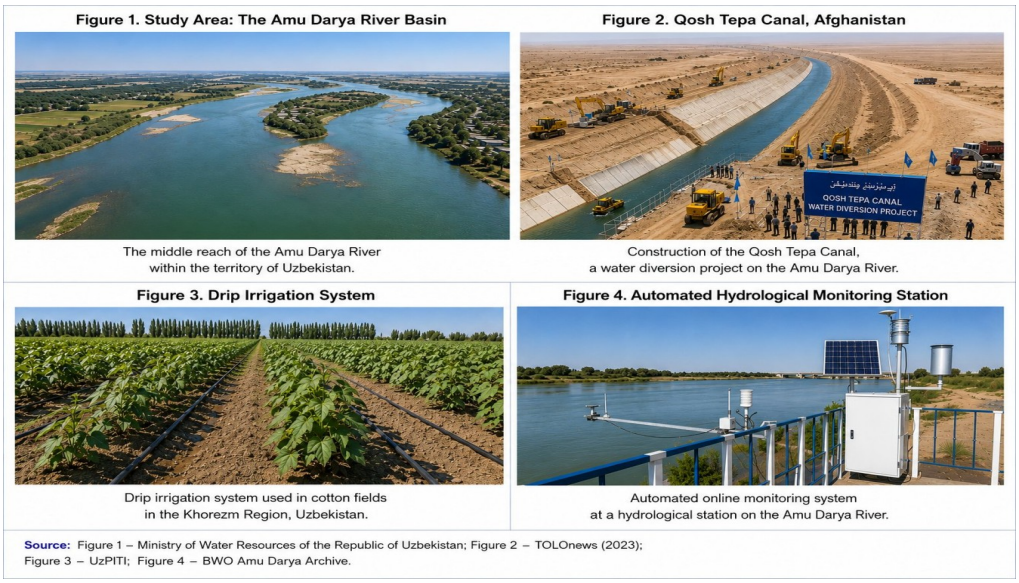

Figure 1. Study area and field infrastructure in the Amu Darya Basin.

a) Study area: the middle reach of the Amu Darya River within Uzbekistan — [24];

b) Construction of the Qosh Tepa Canal, Afghanistan — [25];

c) Drip irrigation system in cotton fields, Khorezm region — [26];

d) Automated hydrological monitoring station on the Amu Darya — [20].

Results and Discussion

Recent scientific studies indicate that the volume of river flow in the middle and lower reaches of the Amu Darya has decreased by 54 to 77 percent (Figure 2) [17]. Notably, although precipitation in the Pamir and Tian Shan mountains — which

feed the river — has increased somewhat, rising temperatures have intensified evaporation [4], and human activity (anthropogenic pressure) is preventing water from reaching the lower reaches [15].

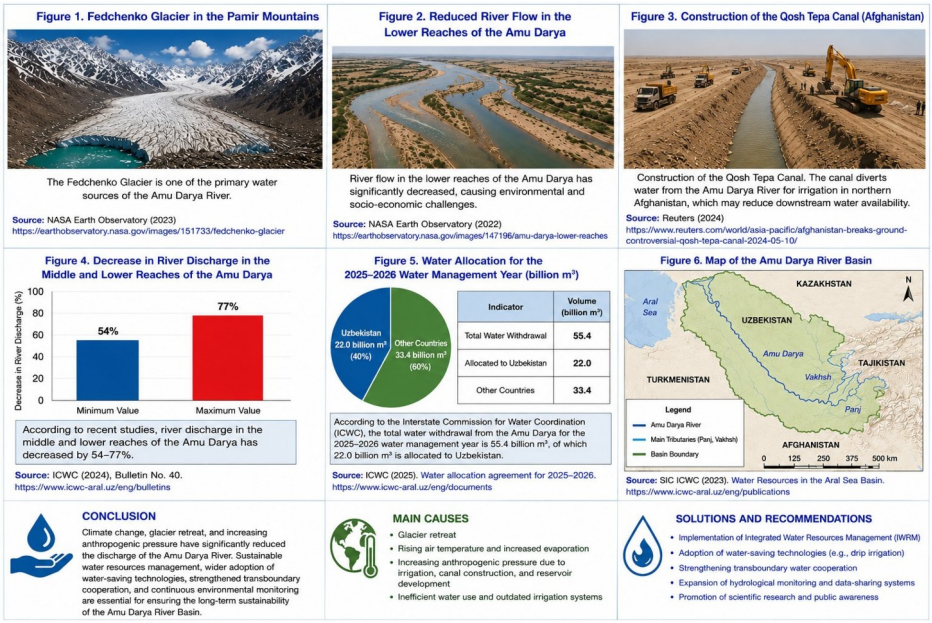

Figure 2. Hydrological changes and the state of water resources in the Amu Darya Basin (statistical indicators).

a) Retreat of the Fedchenko Glacier — [14];

b) Decline in water level in the lower reaches of the Amu Darya — [15];

c) Construction of the Qosh Tepa Canal (Afghanistan) — [16];

d) 54–77% decrease in flow volume in the middle and lower reaches — [17];

e) Water withdrawal limits for the 2025–2026 water management year — [18];

f) Map of the Amu Darya Basin — [7].

The water-related problems currently facing the Amu Darya Basin fall into three major categories:

Glacier melting. The glacier-covered area of the Panj and Vakhsh systems, the river's main sources, is shrinking year by year [14, 21]. This is causing seasonal changes in the hydrological regime.

Water allocation and limits. Under the ICWC agreement for the 2025–2026 water management year, the total water-withdrawal limit for the Amu Darya has been set at 55.4 billion cubic meters, of which 22 billion cubic meters have been allocated to Uzbekistan [18]. However, ensuring these limits in practice becomes more difficult during drought years [9].

Anthropogenic pressure and new hydraulic infrastructure. The construction of major projects such as the Qosh Tepa Canal may further increase the volume of water withdrawn from the Amu Darya and intensify water scarcity in the lower reaches [16].

Recommendations

To mitigate the water crisis in the Amu Darya Basin, the following fundamental scientific and practical measures are necessary:

1. Engaging Afghanistan within the international legal framework. Uzbekistan and other countries of the region should establish mutually beneficial agreements with Afghanistan and, within the framework of the ICWC, introduce a strict regulatory system, consistent with international norms, governing the volume of water withdrawn through the Qosh Tepa Canal [16].
2. Improving the agro-industrial model. In the lower reaches of the Amu Darya — the Khorezm and Karakalpakstan regions — it is advisable to optimize the area under water-intensive crops and to widely introduce water-saving technologies, particularly drip irrigation [19, 26].
3. Developing a digital hydrological monitoring system. It is necessary to convert all hydrological posts along the Amu Darya to an automated online monitoring system and, with the participation of BWO Amudarya, to ensure the transparency and efficiency of water allocation [20].

Conclusion

The results of this study show that, under the influence of climate change and anthropogenic pressure, significant changes are occurring in the hydrological processes of the Amu Darya Basin. In particular, the shrinking of glacier area, increased evaporation, and the irrational use of water resources are leading to a decline in river flow and an intensification of water scarcity. This situation poses a serious threat to the region's ecological stability, agriculture, and water security.

Therefore, improving the system of integrated water resources management in the Amu Darya Basin, developing digital hydrological monitoring, widely introducing water-saving technologies, and strengthening international cooperation

on the rational use of transboundary water resources are among the most pressing tasks.

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