WATER RESOURCES OF CENTRAL ASIA UNDER CLIMATE CHANGE AND DIRECTIONS OF SUSTAINABLE WATER USE IN UZBEKISTAN

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Abstract. *The article examines the formation of water resources in Central Asia under climate change and their importance for the sustainable development of Uzbekistan. It analyzes the role of mountain glaciers and snow cover in feeding the Amu Darya and Syr Darya rivers, the environmental consequences of excessive water withdrawal using the Aral Sea as an example, and the relationship between irrigated agriculture, salinization and land degradation. The main directions for improving water-use efficiency are substantiated: water-saving irrigation technologies, improved water governance, regional cooperation and the use of renewable energy.*

Keywords: *water resources, climate change, glaciers, Aral Sea, land degradation, irrigation, sustainable development, Uzbekistan.*

Аннотация. *В статье рассматриваются особенности формирования водных ресурсов Центральной Азии в условиях изменения климата и их значение для устойчивого развития Узбекистана. Проанализированы роль горных ледников и снежного покрова в питании рек Амударья и Сырдарья, экологические последствия чрезмерного водозабора на примере Аральского моря, а также связь между орошаемым земледелием, засолением и деградацией земель. Обоснованы основные направления повышения эффективности водопользования: внедрение водосберегающих технологий полива, совершенствование управления водными ресурсами, развитие регионального сотрудничества и использование возобновляемой энергии.*

Ключевые слова: *водные ресурсы, изменение климата, ледники, Аральское море, деградация земель, орошение, устойчивое развитие, Узбекистан.*

Annotatsiya. *Maqolada Markaziy Osiyo suv resurslarining shakllanish xususiyatlari iqlim o‘zgarishi sharoitida va ularning O‘zbekiston barqaror rivojlanishidagi ahamiyati ko‘rib chiqilgan. Amudaryo va Sirdaryo oqimini oziqlantirishda tog‘ muzliklari hamda qor qoplamining roli, Orol dengizi misolida*

suvning haddan tashqari olinishi oqibatlari, sug‘orma dehqonchilik, sho‘rlanish va yerlarning degradatsiyasi o‘rtasidagi bog‘liqlik tahlil qilingan. Suvdan foydalanish samaradorligini oshirishning asosiy yo‘nalishlari: suv tejovchi sug‘orish texnologiyalari, suv resurslarini boshqarishni takomillashtirish, mintaqaviy hamkorlik va qayta tiklanuvchi energiyadan foydalanish asoslangan.

Kalit so‘zlar: *suv resurslari, iqlim o‘zgarishi, muzliklar, Orol dengizi, yerlarning degradatsiyasi, sug‘orish, barqaror rivojlanish, O‘zbekiston.*

INTRODUCTION

Water resources are one of the key factors of socio-economic development and environmental security in Central Asia. The climate of the region is predominantly arid and semi-arid, so agriculture, energy production and the water supply of the population depend strongly on the flow of transboundary rivers formed in the mountains. For Uzbekistan, located in the lower reaches of the Amu Darya and Syr Darya, a significant part of water resources comes from the territory of neighbouring states, which gives water-use issues not only an environmental but also a political dimension.

The concept of sustainable development formulated in the Brundtland Commission report implies meeting the needs of the present generation without compromising the ability of future generations [1]. The 2030 Agenda for Sustainable Development includes, in particular, Goal 6 (clean water and sanitation), Goal 13 (climate action) and Goal 15 (life on land, including combating desertification and land degradation) [2]. All three goals are directly related to the water problems of the region.

Climate change increases uncertainty in water availability: according to the Intergovernmental Panel on Climate Change, warming leads to glacier retreat and changes in snow cover, which affects the seasonal distribution of runoff in mountain basins [3]. At the same time, population growth and rising economic demand increase pressure on water sources. Under these conditions, scientific substantiation of measures for rational water use is particularly relevant.

The aim of the study is to analyze how water resources are formed in Central Asia under climate change, to assess the environmental consequences of unsustainable water use, and to substantiate directions of sustainable water management in Uzbekistan.

MATERIALS AND METHODS

The study is based on the analysis of scientific publications, reports of international organizations and legal acts of the Republic of Uzbekistan. Systems

and comparative analysis, the historical-geographical method and generalization of earlier hydrological and ecological studies of the region were used [4, 5, 8]. The conclusions are analytical in nature; quantitative indicators for individual basins and farms require clarification using official statistics and field observations.

RESULTS AND DISCUSSION

3.1. Runoff formation and the role of glaciers: The main rivers of the region, the Amu Darya and Syr Darya, are fed by meltwater from snow and glaciers of the Pamir and Tien Shan mountains. Mountain glaciers act as a natural regulator: in warm and dry periods, when irrigation demand is highest, their melt sustains river flow. Studies of Tien Shan glacier dynamics show a persistent loss of glacier mass in recent decades and possible changes in runoff: at the first stage of warming runoff may increase because of intensive melt, but as ice reserves decline a reduction and a shift of the seasonal peak are expected [6].

For Uzbekistan this means growing uncertainty in the annual and seasonal distribution of water. Higher air temperature increases evaporation from irrigated fields and reservoirs and raises crop water demand, while more frequent extreme events, such as droughts and floods, increase risks for agriculture and infrastructure [3]. Water-use planning should therefore rely on climate scenarios and not only on long-term average runoff values.

3.2. Environmental consequences: lessons of the Aral Sea: The most striking example of the consequences of unsustainable water use is the desiccation of the Aral Sea. Since the 1960s, rapid expansion of irrigated land reduced inflow from the Amu Darya and Syr Darya, as a result of which the water surface of the sea shrank many times over and water salinity increased sharply [4, 7]. The exposed seabed formed a new desert, the Aralkum, from which wind carries salt and dust, harming public health, land productivity and the local climate. The fishing industry and a large part of the region’s biodiversity were lost.

The Aral catastrophe demonstrates the interconnection of the three components of sustainable development, economic, social and environmental: a short-term benefit from expanding irrigated agriculture turned into long-term environmental and social losses. For Uzbekistan, part of whose territory lies directly in the Aral Sea region, the Aral experience is a reason to give priority attention to environmental rehabilitation, in particular to afforestation of the dried seabed, and to the development of alternative sources of income for the local population [7].

3.3. Irrigated agriculture, salinization and land degradation: Agriculture remains the largest water consumer in the region, and the main reserves for water saving are concentrated there [8]. In a hot climate with insufficient drainage,

inefficient irrigation leads to a rise in groundwater tables and secondary soil salinization, which reduces yields and takes land out of use. Global assessments of land degradation show that salinization, erosion and desertification affect a significant share of agricultural land in dry regions [5]. Water is also lost in irrigation canals without anti-seepage lining and in the on-farm network.

Factors limiting the efficiency of water use include deterioration of irrigation infrastructure, uneven distribution of water among users, insufficient metering of withdrawals, predominance of water-intensive crops and traditional irrigation methods. A separate issue is the dependence of pumping stations on electricity, which links water and energy security, the so-called water-energy nexus.

3.4. Directions of sustainable water management: The analysis makes it possible to identify a set of interrelated measures whose implementation can increase the sustainability of water use in Uzbekistan (Table 1). Technical measures include drip and sprinkler irrigation, laser land levelling, concrete and membrane lining of canals, modernization of pumping stations and automated water metering. Agronomic measures involve optimizing the crop structure towards less water-intensive and salt-tolerant crops and using moisture-saving tillage. Institutional measures relate to improving basin-based management, developing water user associations, economic incentives for saving water and openness of water data.

Table 1. Main directions of sustainable water use.

Group of measures	Main content	Expected effect
Technical	Drip irrigation, canal lining, automated metering	Reduced water losses, higher yields
Agronomic	Crop structure, moisture-saving tillage	Lower water intensity, control of salinization
Institutional	Basin management, water user associations, tariffs	Equitable distribution, incentives to save
Energy	Solar pumping stations, energy-efficient pumps	Lower energy intensity of water supply
Regional	Coordination of transboundary river regimes	Predictable flow, reduced risks

Regional cooperation is also of great importance. Because the main rivers are transboundary, effective management is impossible without coordinated action by the states of the region, exchange of hydrological information and consideration of the interests of both upstream and downstream countries [8]. The national legal framework of Uzbekistan establishes the principles of rational use and protection of

natural resources [9], and the strategy for transition to a green economy provides for higher efficiency of water and energy use and a larger share of renewable energy [10]. Putting these provisions into practice requires a combination of investment, scientific support and a stronger environmental culture among water users.

CONCLUSION

The analysis shows that the water resources of Central Asia are under double pressure from climate change and growing anthropogenic water demand. The experience of the Aral Sea confirms that the environmental consequences of unsustainable water use are long-lasting and hard to reverse. For Uzbekistan, the priority directions of sustainable development are modernization of irrigation and introduction of water-saving technologies, prevention of land degradation and salinization, transition to basin management, use of renewable energy in the water sector and strengthening regional cooperation. Further research should quantify the water-saving effect of individual measures for specific regions of the republic.

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