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Fazilat QOYSINOVA[a]
[a]*Doctor of Political Sciences, Associate Professor*
Tashkent, Uzbekistan
Email: f.qo'ysinova@iiau.uz

CLIMATE CHANGE AND ENVIRONMENTAL SECURITY IN CENTRAL ASIA: NEW FACTORS AFFECTING REGIONAL STABILITY

Abstract. *The article examines climate change in Central Asia as a factor of environmental security and regional stability. Based on ERA5 reanalysis data (Copernicus), the warming rate over 1960–2025 was 0.37 °C per decade in Kazakhstan and 0.33 °C in Uzbekistan, almost 1.8 times the global average (0.19 °C). In Uzbekistan, the mean temperature of 2016–2025 was 1.95 °C higher than in 1951–1980. According to the World Bank, greenhouse gas emissions of the countries of the region amounted to 709.9 Mt CO_2-equivalent in 2023. The shrinking of Tien Shan glaciers, dust and salt storms from the dried Aral Sea bed, water scarcity and heat extremes are assessed as new threats to environmental security. Proposals are made for a regional monitoring system and for coordinating adaptation policies and the transition to a green economy.*

Keywords: *climate change, environmental security, Central Asia, temperature anomaly, glaciers, Aral Sea, greenhouse gases, regional stability.*

INTRODUCTION

Climate change has become one of the principal factors influencing the security of states and regions in the twenty-first century. The Intergovernmental Panel on Climate Change (IPCC), in its Sixth Assessment Report, stated unequivocally that human activities have warmed the atmosphere, ocean and land and that heat extremes and droughts are becoming more frequent (IPCC, 2023). Owing to its landlocked continental location, arid climate, reliance on irrigated agriculture and dependence on runoff from mountain glaciers, Central Asia is among the regions most vulnerable to climate change (Reyer et al., 2017; Xenarios et al., 2019).

Historically, environmental security in the region has been associated with the Aral Sea disaster. Since 1960, the sea level has fallen by 23 m, its area has declined by 74%, and its volume by 90% (Micklin, 2007). Its exposed seabed has become a persistent source of dust and salt storms (Indoitu et al., 2015). These long-standing pressures are now compounded by new climate-related factors: rapidly rising temperatures, glacier retreat and changes in river-flow regimes (Farinotti et al., 2015; Sorg et al., 2012). Bernauer and Siegfried showed that climate change may increase the risk of disputes over transboundary water resources (Bernauer & Siegfried, 2012).

The international community has also recognized environmental threats in the region. United Nations General Assembly Resolution A/RES/75/278 of 18 May 2021 declared the Aral Sea region a zone of ecological innovations and technologies (United Nations General Assembly, 2021). This study aims to assess key indicators of climate change in Central Asia using official data and to examine their implications for environmental security and regional stability.

MATERIALS AND METHODS

For the temperature analysis, the study used annual country-level temperature anomalies (relative to the 1991–2020 mean) calculated by Our World in Data (Our World in Data, 2026) using ERA5 reanalysis data produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) under the Copernicus programme (Hersbach et al., 2020). Greenhouse gas emissions were obtained from the World Bank's World Development Indicators (World Bank, 2026). Linear temperature trends for 1960–2025 were estimated using ordinary least squares; decadal averages and mean anomalies for selected periods were also calculated.

Peer-reviewed international studies on glaciers, the Aral Sea and the socioeconomic consequences of climate change (Farinotti et al., 2015; Hugonnet et al., 2021; Micklin, 2007; Reyer et al., 2017; Sorg et al., 2012), together with Uzbekistan's policy documents on climate and the green economy (President of the Republic of Uzbekistan, 2019; Republic of Uzbekistan, 2021), were reviewed. Statistical, comparative and systems-analysis methods were applied. The author did not conduct field observations; findings

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are based on the processing and synthesis of publicly accessible data. The figures were produced using Python (Matplotlib).

Results

Temperature increase. ERA5 data indicate that temperatures in Uzbekistan have risen consistently since the second half of the twentieth century (Figure 1). The average anomaly was −1.01 °C in 1951–1980 and reached +0.94 °C in 2016–2025, a difference of 1.95 °C. Over the same periods, the global difference was 1.07 °C (from −0.63 to +0.44 °C). The warmest years in Uzbekistan were 2025 (+2.02 °C) and 2023 (+1.85 °C). Since the 2000s, Uzbekistan's ten-year moving average has risen faster than the global average.

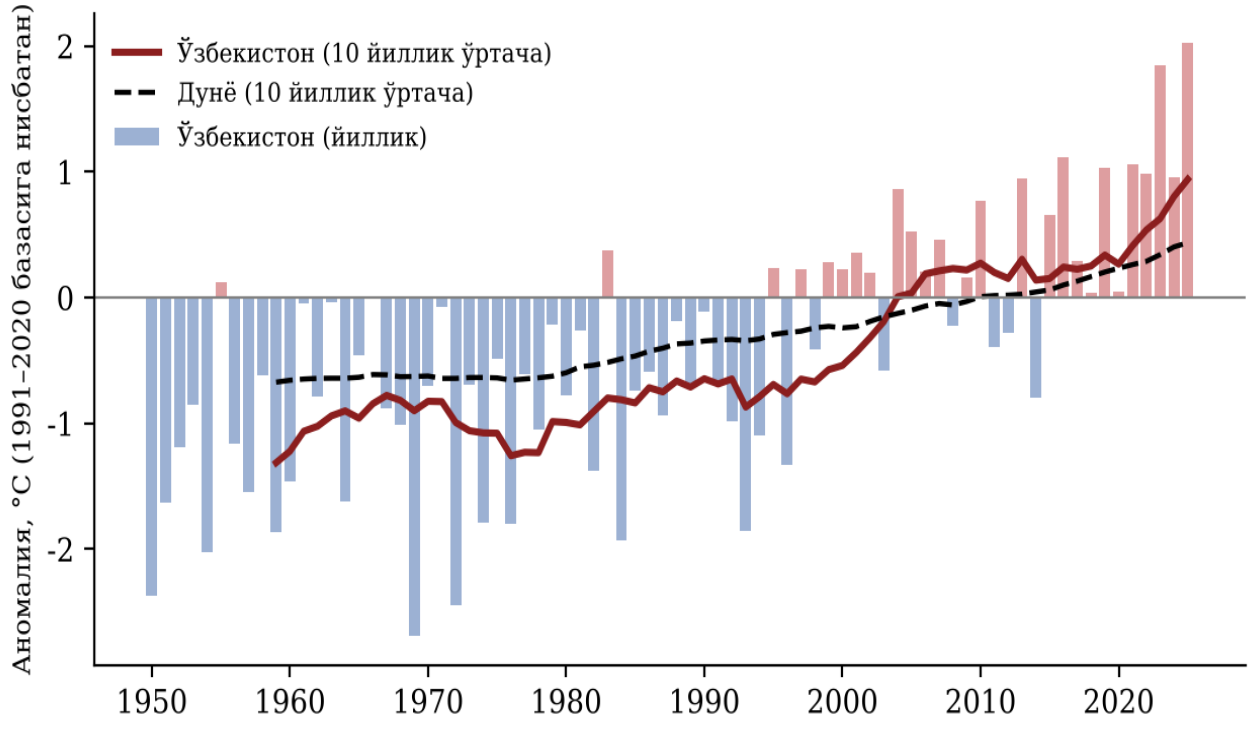

Figure 1. Annual temperature anomalies in Uzbekistan compared with the global average, 1950–2025 (based on Our World in Data, 2026, and Hersbach et al., 2020).

Linear trends calculated for 1960–2025 confirm that warming in every Central Asian country is faster than the global average (Figure 2). Temperature increases per decade were 0.37 °C in Kazakhstan, 0.34 °C in Turkmenistan, 0.33 °C in Uzbekistan, 0.31 °C in Tajikistan and 0.24 °C in Kyrgyzstan, compared with 0.19 °C worldwide. Warming in Uzbekistan is therefore approximately 1.8 times the global rate. This finding

is consistent with Hu et al.'s conclusion that Central Asia warmed by 0.36–0.42 °C per decade during 1979–2011 (Hu et al., 2014).

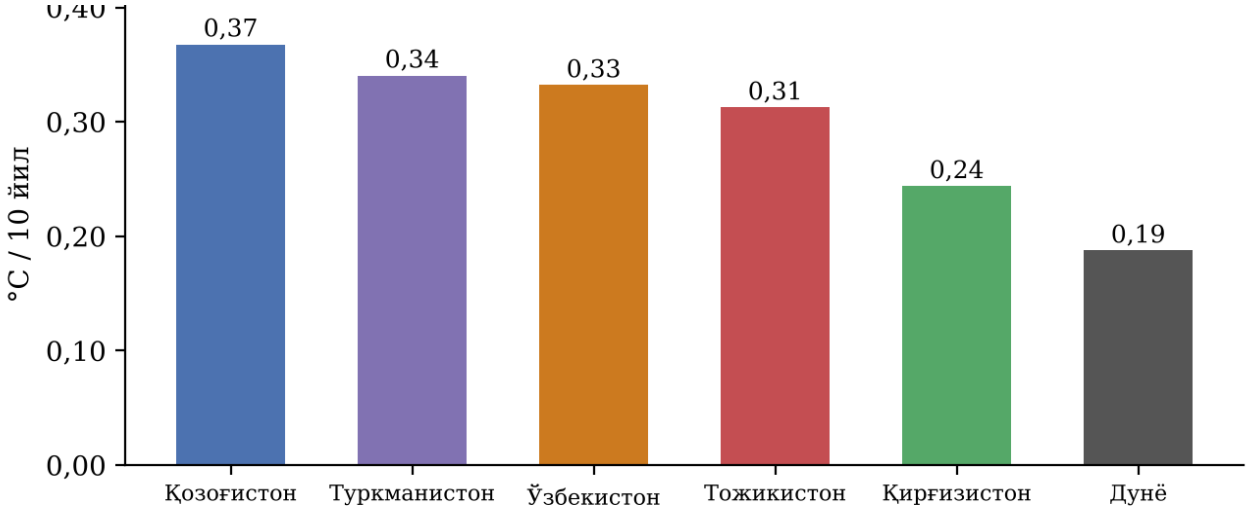

Figure 2. Linear rates of temperature increase, 1960–2025 (°C per decade; author's calculations based on Our World in Data, 2026).

An analysis by period indicates a sharp acceleration of warming in recent years (Figure 3). In Uzbekistan, the average anomaly was −0.82 °C in 1961–1990, −0.54 °C in 1991–2000, +0.27 °C in both 2001–2010 and 2011–2020, and +1.38 °C in 2021–2025. The highest anomaly during 2021–2025 was recorded in Tajikistan (+1.48 °C). Such increases in mountain regions directly affect glaciers and snow reserves.

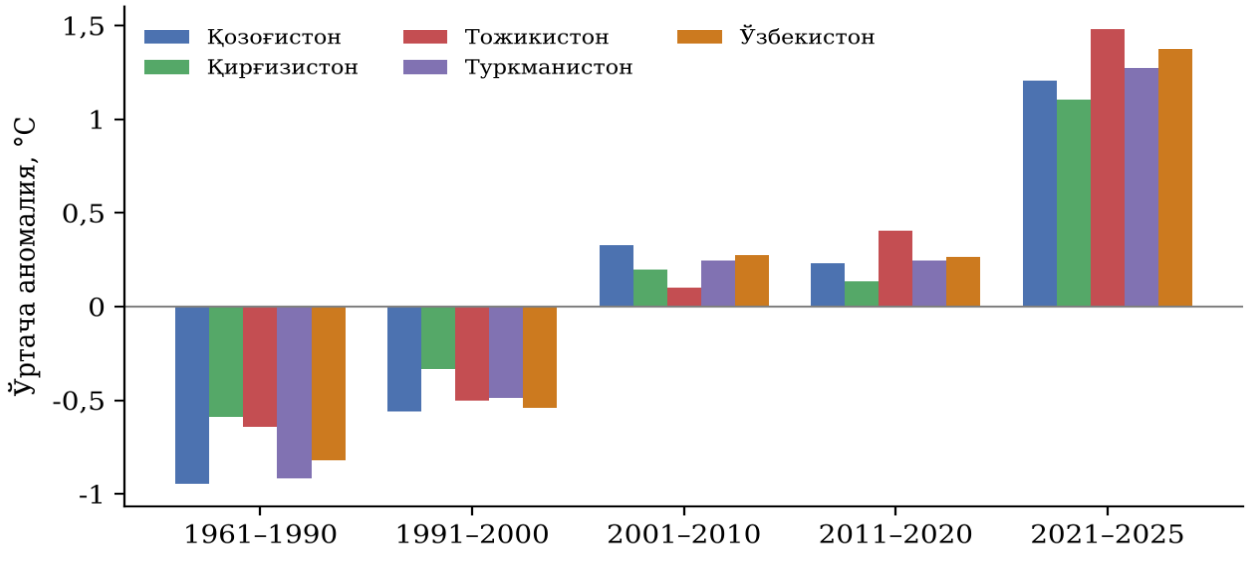

Figure 3. Mean temperature anomalies in Central Asian countries by period (°C; author's calculations based on Our World in Data, 2026).

Glaciers and water resources. According to Farinotti et al., Tien Shan glaciers lost 27 ± 15% of their mass during 1961–2012, with an average annual loss of 5.4 ± 2.8 Gt (Farinotti et al., 2015). Sorg et al. found that glacier retreat was particularly severe in lower mountain ranges closer to densely populated plains and that the seasonal peak in discharge had shifted in some rivers (Sorg et al., 2012). Globally, glacier mass loss also accelerated in the early twenty-first century (Hugonnet et al., 2021). Reyer et al. noted that accelerated snow and glacier melt may temporarily increase runoff but reduce water availability in the medium and long term. Under high-emissions scenarios, regional temperatures could increase by as much as 6.5 °C above pre-industrial levels by the end of the century (Reyer et al., 2017).

Greenhouse gas emissions. World Bank data indicate that total greenhouse gas emissions in Central Asia, excluding land use, amounted to 709.9 million tonnes of CO_2 equivalent in 2023 (Figure 4). Kazakhstan (326.9 Mt) and Uzbekistan (211.4 Mt) were the largest emitters. Emissions in Turkmenistan increased from 42.7 Mt in 1992 to 128.3 Mt in 2023, nearly tripling. Over 1992–2023, emissions in Uzbekistan rose by 38.4%.

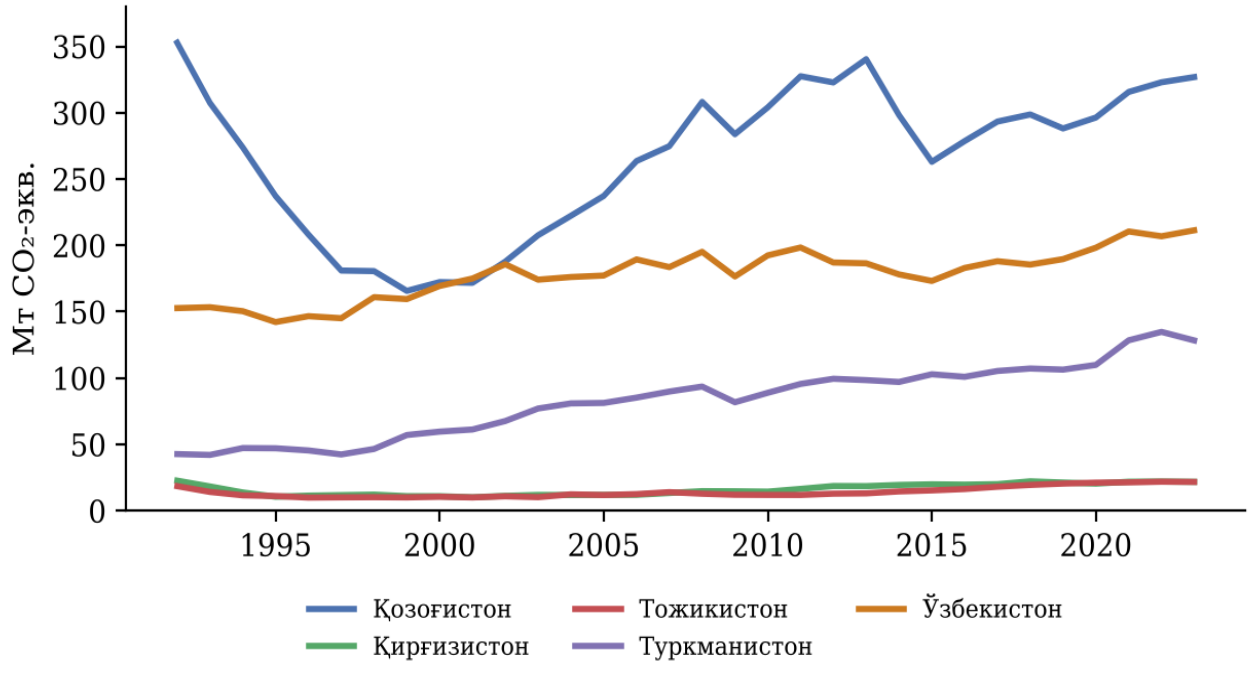

Figure 4. Greenhouse gas emissions in Central Asian countries, 1992–2023 (million tonnes of CO_2 equivalent; based on World Bank, 2026).

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Per capita CO_2 emissions differ substantially among Central Asian countries (Figure 5). In 2023, emissions were 12.86 tonnes per person in Turkmenistan and 12.56 tonnes in Kazakhstan, approximately 2.7 times the global average (4.68 tonnes). Uzbekistan recorded 3.72 tonnes, 20.5% below the global average; Kyrgyzstan recorded 1.44 tonnes and Tajikistan 0.90 tonnes. These differences reflect national energy mixes, including reliance on coal and gas or hydropower.

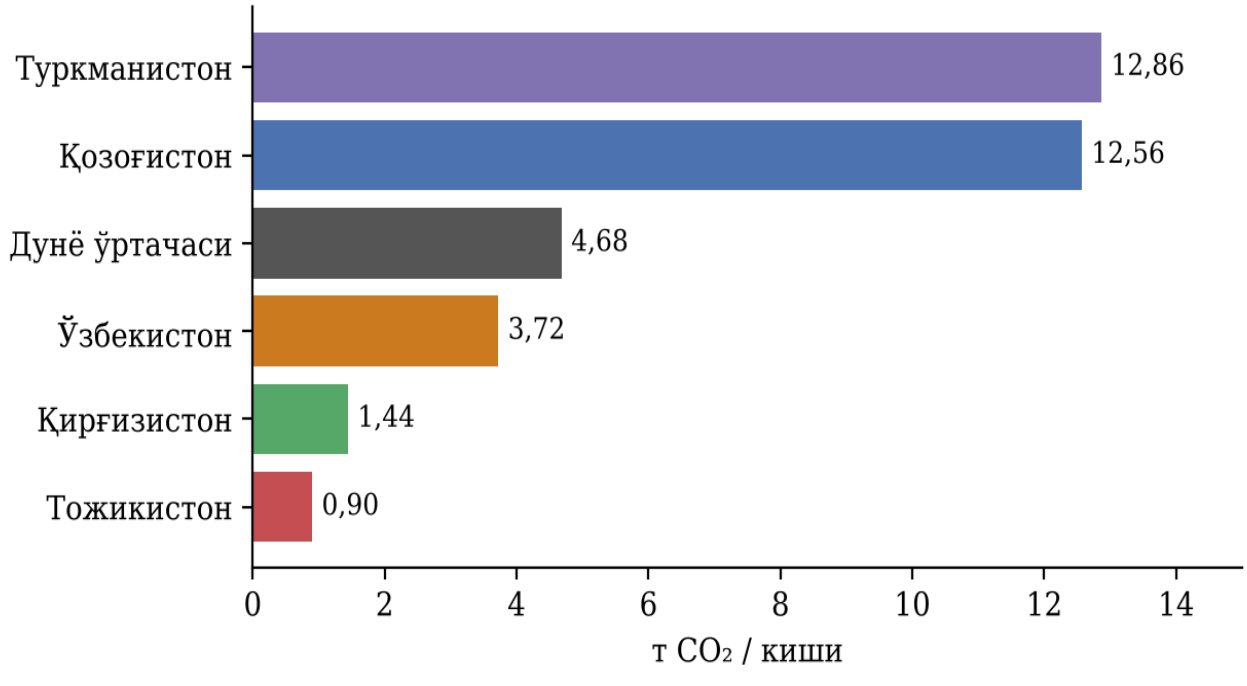

Figure 5. Per capita CO_2 emissions, 2023 (tonnes per person; based on World Bank, 2026).

Uzbekistan's policy response. Presidential Resolution No. PP-4477 of 4 October 2019 approved the Strategy for the Transition of the Republic of Uzbekistan to a Green Economy for 2019–2030 (President of the Republic of Uzbekistan, 2019). Under its updated Nationally Determined Contribution (NDC) of 2021, Uzbekistan pledged to reduce greenhouse gas emissions per unit of gross domestic product by 35% by 2030 relative to 2010 (Republic of Uzbekistan, 2021). At the international level, Resolution A/RES/75/278, adopted at Uzbekistan's initiative, provided a political basis for promoting ecological innovations in the Aral Sea region (United Nations General Assembly, 2021).

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DISCUSSION

The findings show that climate change in Central Asia is not a future threat but an ongoing process. Temperatures are rising almost twice as fast as the global average, creating new environmental-security risks in several areas. First, water resources: declining glacier mass (Farinotti et al., 2015; Sorg et al., 2012) and increasing irrigation demand place pressure on the balance of interests between upstream and downstream countries (Bernauer & Siegfried, 2012). Second, public health and agriculture: Reyer et al. particularly highlight risks associated with heatwaves, declining crop yields and intensified rural-to-urban migration (Reyer et al., 2017). Third, dust and saline aerosols from the exposed Aral Sea bed may spread across larger areas under drought conditions (Indoitu et al., 2015).

A second important issue is the mismatch between countries' contributions to climate change and their capacity to adapt. Tajikistan and Kyrgyzstan, which have the lowest per capita emissions, are among the countries most exposed to changes in glaciers and mountain ecosystems. Meanwhile, the high emissions levels in Kazakhstan and Turkmenistan point to the need for changes in their energy systems. Xenarios et al. emphasize that shortages of systematic observations in mountain areas and limited open access to data hinder the formulation of adaptation policy (Xenarios et al., 2019).

Accordingly, several measures are particularly important for regional stability: establishing an integrated regional system for hydrometeorological and glacier monitoring and openly exchanging data (Sorg et al., 2012; Xenarios et al., 2019); coordinating national adaptation plans at the level of transboundary river basins (Bernauer & Siegfried, 2012); expanding afforestation, land reclamation and ecological innovations in the Aral Sea region through international cooperation (United Nations General Assembly, 2021); and linking national commitments to the green economy and renewable energy (President of the Republic of Uzbekistan, 2019; Republic of Uzbekistan, 2021) with regional energy cooperation. Such an approach could transform climate-related risks from sources of interstate tension into opportunities for collaboration.

CONCLUSION

The study demonstrates that climate change is proceeding significantly faster in Central Asia than the global average. Between 1960 and 2025, warming rates across the region ranged from 0.24 to 0.37 °C per decade; in Uzbekistan, the average temperature during the most recent ten-year period was almost 2 °C higher than in 1951–1980. These developments directly affect environmental security through the retreat of Tien Shan glaciers, altered river-flow regimes, dust and salt storms around the Aral Sea, and heat extremes. By linking water, energy and food security, climate change has become a new factor influencing regional stability.

At the same time, Central Asian countries differ in both their contributions to climate change and their vulnerability to its effects. This requires coordinated cooperation that reflects each country's capacities rather than a uniform approach. Uzbekistan's green economy transition strategy, its updated NDC and its initiative to designate the Aral Sea region as a zone of ecological innovations have established important foundations. Their future effectiveness will depend on complementary regional monitoring, data exchange and transboundary adaptation plans—mechanisms that may turn climate risks into opportunities to strengthen interstate trust and cooperation.

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