Assessment of Future Water Stress on Surface Waters in the West Kazakhstan Region Caused by the Combined Impacts of Climate Change and Increased Anthropogenic Pressure

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Abstract

The surface water resources of the West Kazakhstan Region (WKR) face escalating vulnerability due to the synergistic effects of a sharply continental climate, which intensifies climate change impacts, and rapidly increasing anthropogenic water demand. This study aims to quantify and project the future water stress on WKR's surface waters, assessing the combined influence of climate change and socio-economic development over the critical period of 2030–2050. This study presents a comprehensive quantitative assessment and future projection of water stress on the region's surface waters, integrating state-of-the-art CMIP6 climate scenarios (SSP2-4.5 and SSP5-8.5) with a novel model of water consumption growth accounting for regional demographic and economic developments. Employing advanced bias-corrected ensemble climate projections alongside physically interpretable water balance models, we estimate changes in river flows and lake volumes through mid-century. A newly developed Water Stress Index (WSI), supplemented by the Falkenmark Index, reveals an alarming increase in water stress, with projections indicating that over 70% of the WKR territory may face severe resource limitations by 2050. The analysis underscores significant spatial heterogeneity driven by climatic variability and socio-economic factors, emphasizing the urgent need for regionally tailored adaptation and water management strategies. These findings provide a robust scientific basis to guide policy decisions aimed at mitigating future water scarcity under evolving climate and development scenarios.

Keywords

climate models; surface water resources; river flow; lakes; water resources; forecast; water supply; water stress.

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