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IMPACT OF CLIMATE CHANGE ON GROUNDWATER RESOURCES

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Abstract: This research article examines the impact of climate change on underground water conducted by scientists of foreign countries and the impact of Uzbek scientists on underground water resources in Samarkand region, in particular, on wheat and cotton cultivation, based on the analysis of the results of research and scientific articles conducted in the region. This study delves into the intricate relationship between climate change and groundwater resources, focusing on the Samarkand region in Uzbekistan. The research investigates the multifaceted impacts of climate variations, irrigation practices, and changing weather patterns on agricultural productivity, specifically targeting wheat and cotton farms. Employing a comprehensive approach, the study scrutinizes the differential effects of warming trends and precipitation shifts on crop yields, highlighting distinct vulnerabilities and resilience strategies across crop types. Analysis reveals that while rising temperatures detrimentally impact both wheat and cotton crops, precipitation variations distinctly affect their productivity. Adequate rainfall benefits wheat farming but poses challenges for cotton yields when excessive. The study emphasizes the pivotal role of efficient irrigation systems in mitigating climate-induced threats, although concerns arise regarding potential water shortages due to escalating warming trends and inefficient water usage. Strategic policy interventions targeting enhanced irrigation management and the adoption of water-saving technologies are proposed to bolster the resilience of agricultural producers in the face of impending climate extremes. However, the study underscores the necessity for extensive and prolonged research encompassing diverse crop types and spanning larger time frames to furnish policymakers with comprehensive insights for sustainable agricultural adaptation strategies.

Keyword: Climate Change, Groundwater Resources, Agricultural Productivity, Irrigation Management, Precipitation Variability, Temperature Trends, Hydrological Cycle, Crop-Specific Vulnerability, Water Scarcity, Adaptation Strategies, Regional Impacts, Sustainability, Climate Projections.

Induction: Water stands as a vital cornerstone for sustaining life, yet its consistent availability in both quality and quantity faces a myriad of threats, many of which stem from the influence of climate factors. The Intergovernmental Panel on Climate Change defines climate as the long-term average weather patterns and their fluctuations over a specific area and timeframe. It's within this context that the ongoing changes in climate, characterized by a statistically significant shift in the average climate conditions lasting for decades or longer, pose a considerable challenge. This shift is predominantly attributed to the escalating concentrations of greenhouse gases in the atmosphere, notably exemplified by the continual rise in atmospheric carbon dioxide levels since the mid-20th century. The ramifications of this climate transformation extend across both global and local scales, profoundly altering essential climate parameters like temperature and precipitation patterns. The mounting evidence indicates that if this trend persists, it could drastically impact the hydrological

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cycle, the very mechanism that governs the movement and distribution of water on Earth's surface. Increasing temperatures linked to climate change intensify various facets of the hydrological cycle, amplifying processes such as evaporation and precipitation [1-3].

Groundwater plays a hidden but key role in the complex network of extensive climate change impacts. Located far below the Earth's surface, this invaluable resource is vulnerable to the widespread effects of our changing climate. As temperatures rise, precipitation patterns change, and extreme weather events become more frequent, the delicate balance of groundwater aquifers faces unprecedented challenges. Examining the complex relationship between climate change and groundwater resources reveals issues of interdependence, where the effects of environmental change go beyond the obvious [4-7].

However, the consequences of these changes won't be uniformly distributed. While the hydrological cycle is expected to experience an overall intensification, the distribution of additional precipitation will be uneven across different regions worldwide. Some areas may encounter significant reductions in precipitation levels or substantial shifts in the timing and duration of wet and dry seasons, reshaping local water availability and ecosystems. Understanding and assessing the localized impacts of climate change on hydrological processes and water resources have emerged as critical focal points. As climate change continues to unfold, the need to grasp its specific effects on regional water availability and dynamics becomes increasingly pertinent for effective management and adaptation strategies [8-10].

Methods: The paper uses field research methods, analysis of system data, and common methods of soil survey and chemical analysis of groundwater and surface water. The use of modern GIS technologies and digitalization programs was chosen.

Objects and subject of research: The Andijan region has experienced and is experiencing water shortages.

Precipitation downscaled in climate change studies often exhibits poor reliability due to a lack of correlation between predictors and predictands. This discrepancy is often attributed to mesoscale processes at site-specific levels, not adequately represented in regional models due to their differing spatial and temporal scales. Mesoscale precipitation, primarily occurring in summers as convective clouds, stems from local evapotranspiration driven by heightened temperatures and solar radiation. Despite widespread recognition of climate change, research on its impacts on groundwater systems remains limited. The complexity arises from the necessity for extensive historical data to analyze climate change patterns, often unavailable, alongside unclear driving forces behind such changes. Frequent climatic abnormalities further complicate predictions. Even with available data, uncertainties persist within model parameters and structures, compounded by the unpredictability of Earth's driving forces. Developing a physically based groundwater system model amid climate change remains crucial for preventing future regional water resource degradation, despite inherent uncertainties [1-2,8-9].

Understanding the nexus between climate change and the depletion of fresh groundwater resources holds significance for distinct regional characteristics. Developing nations like India, heavily reliant on agriculture, face heightened vulnerability due to population growth, demanding more energy, freshwater, and food. Despite uncertainty regarding the precise extent of regional climate change impacts, proactive measures are imperative to anticipate, prevent, or mitigate its adverse effects [3,8].

Groundwater recharge, influenced by hydrologic processes and land surface attributes, deserves attention beyond temporal changes. While assessing average changes in recharge and groundwater levels is crucial, such alterations vary spatially across catchment areas. Effective long-term water resource planning demands both temporal and spatial insights into groundwater recharge,

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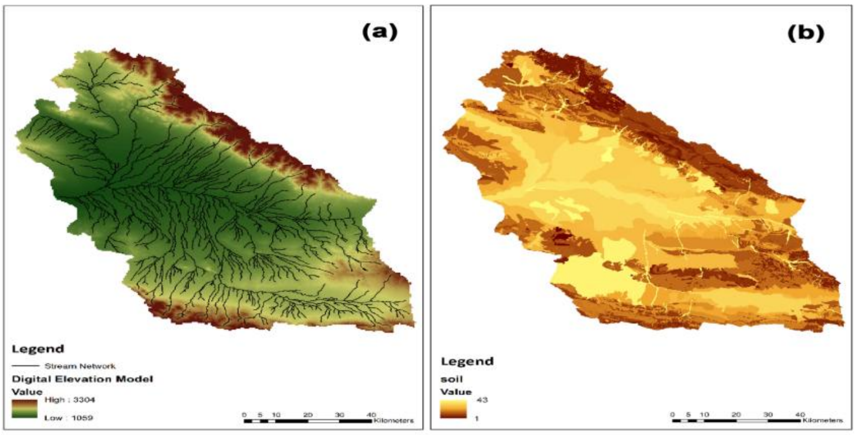
critical not only for managing water use but also for land use planning. To comprehensively evaluate the potential consequences of groundwater recharge changes driven by climate and socio-economic shifts, interdisciplinary collaboration becomes essential. Hydrogeologists must collaborate with socio-economists, agricultural modelers, and soil scientists. This collaboration is vital for a holistic understanding that incorporates hydrological, socio-economic, and land-use dynamics, ensuring informed strategies to address the multifaceted challenges posed by climate-induced groundwater changes [2,8,8-10].

Many scientists have conducted research on the effects of climate change and irrigation management on groundwater in an arid region with intensive groundwater extraction in the Neishaboor watershed of Iran. These scholars include Saadatpour, A., Izady, A., Bailey, R. T., Ziaei, A. N., Alizadeh, A., & Park, S. They used SWAT and MODFLOW programs in their research. They cited the following in their research. The predominant land cover in the watershed is agriculture, particularly farming, which holds a dominant presence. Over recent years, the extent of irrigated lands has notably expanded, reaching a peak of 71,000 hectares. This substantial increase encompasses various cultivation types, with 51,500 hectares dedicated to winter cultivation, 16,500 hectares for summer cultivation, and 3,000 hectares specifically designated for gardens. The surge in irrigated lands finds its primary impetus in the escalating growth of the population within the region. This population expansion has led to heightened demands for agricultural produce, prompting increased abstraction from the aquifer to sustain agricultural activities. Figure 1d, crafted using satellite imagery, provides a precise delineation of sub-basins and Hydrological Response Units (HRUs) within the watershed. This visualization offers detailed insights into the specific areas allocated for summer irrigation, winter irrigation, and garden cultivation, aiding in a more accurate and comprehensive understanding of the spatial distribution of these agricultural practices within the region [9-10]. The results obtained in the cases where these programs were used gave the results that can be the basis for continuing these programs in the Kashkadarya and Samarkand region of Uzbekistan.



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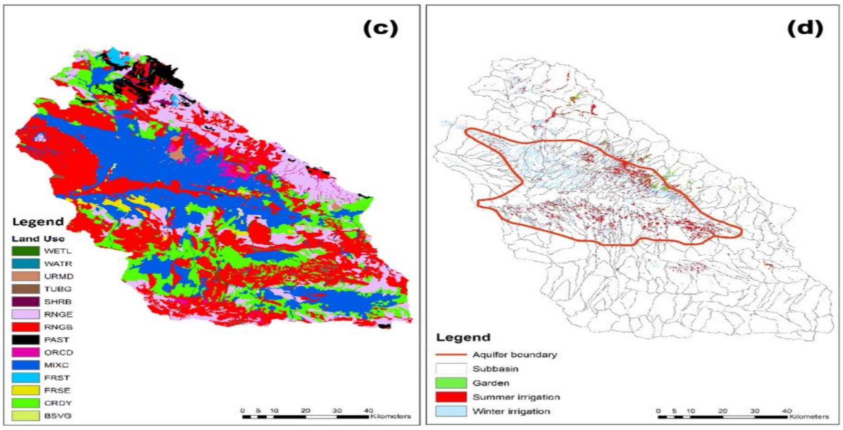

a DEM (Digital elevation model) and stream network; b Soil data in 43 classes; c land use of the watershed d Sub-basins and HRUs with summer irrigation, winter irrigation, and gardens [9]

The profound impacts of climate change on groundwater resources underscore a critical need for comprehensive understanding and proactive management strategies. The intricate interplay between shifting climate patterns and groundwater dynamics necessitates a multifaceted approach to mitigate potential adversities. Climate-induced alterations in precipitation patterns, temperature regimes, and hydrological cycles have far-reaching consequences on groundwater availability and quality. Increasing temperatures intensify evaporation rates and alter the balance of the hydrological cycle, potentially leading to uneven distribution and depletion of groundwater reserves. Changes in precipitation patterns exacerbate this challenge, with some regions experiencing reduced rainfall and altered wet and dry seasons, further stressing groundwater resources.

However, the complex nature of groundwater systems and the inherent uncertainties within climate models present challenges for predicting and assessing the full extent of these impacts. The scarcity of long-term data, coupled with uncertainties in model parameters and the multifaceted drivers of climate change, adds layers of complexity to understanding the future trajectory of groundwater resources under changing climatic conditions.

The investigation into climate change impacts on groundwater resources demands a holistic approach integrating multidisciplinary perspectives. Enhancing our understanding requires collaborative efforts bridging hydrogeology, climatology, remote sensing, and socio-economic studies. Empirical evidence through long-term monitoring and data collection becomes pivotal to discerning trends in groundwater levels, recharge rates, and quality changes. Moreover, advancing predictive models using advanced computational techniques, coupled with high-resolution climate data, allows for more accurate projections of future groundwater scenarios.

Strategies aimed at sustainable groundwater management must prioritize both conservation efforts and adaptive measures. Implementing water-saving agricultural practices, promoting groundwater recharge initiatives, and instituting robust groundwater monitoring networks are crucial steps toward sustainable resource utilization. Public policy interventions and regulatory frameworks need to integrate scientific findings to enact measures that safeguard groundwater resources. Collaborative governance involving stakeholders, local communities, policymakers, and scientists fosters a more inclusive approach toward sustainable groundwater management.

Underground water, or groundwater, originates from various sources and undergoes a complex process before becoming part of underground reservoirs. Here's a breakdown of its formation:

Infiltration: Precipitation, such as rain or snow, seeps into the ground through a process called infiltration. This water either percolates directly into the soil or runs off the surface into streams and rivers, eventually infiltrating into the soil.

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Percolation: Once water infiltrates the soil, it continues its downward journey through the unsaturated zone, also known as the vadose zone. The unsaturated zone contains air and water, with the water occupying the spaces between soil particles.

Saturation and Aquifers: As water percolates deeper, it reaches a level where all the spaces between soil or rock particles are filled with water, creating a zone called the saturated zone. The water collects in formations of permeable rocks, sands, or gravels known as aquifers, where it accumulates as a reservoir of underground water.

Recharge: The process of water seeping down and replenishing the aquifers is known as recharge. It occurs continuously as precipitation infiltrates the ground, contributing to the renewal of groundwater reserves.

Geological Processes: Geological features and formations heavily influence the presence and movement of underground water. Some aquifers are formed in porous rocks like sandstone or conglomerate, while others might exist in fractured or cavernous limestone.

Movement: Groundwater doesn't remain stationary; it moves through the interconnected pore spaces within the rock or sediment layers of aquifers. The movement is influenced by gravity, pressure differences, and the geological structure of the subsurface.

Understanding the formation of underground water is crucial for managing and sustaining these resources. Human activities, such as excessive pumping, pollution, and changes in land use, can significantly impact groundwater availability and quality, emphasizing the importance of responsible management and conservation efforts.

Changes in the level of underground water in Samarkand region were monitored, and groundwater saturation was observed due to seasonal changes in weather and rainfall.

Table 1. The level of seepage water of irrigated land areas in Samarkand region in 2021-2022

Region	Years	indicators	Total	This is the area under surveillance	The depth of the water table division into areas accordingly July 1					
					0-1 up to a meter	1-1,5, up to a meter	1,5-2, up to a meter	2-3, up to a meter	3-5, up to a meter	>5, above a meter
Samarkand region	**2021**	irrigated fields	**380,20**	**380,20**	**1,575**	**8,191**	**25,23**	**88,71**	**91,80**	**164,70**
		of which the fields without ditches	**234,30**	**234,30**	**0,00**	**0,20**	**0,29**	**31,14**	**62,61**	**140,06**
	2022	irrigated fields	**380,20**	**380,20**	**1,60**	**8,17**	**25,04**	**89,34**	**92,72**	**163,34**
		of which the fields without ditches	**233,80**	**233,80**	**0,00**	**0,00**	**0,00**	**31,14**	**62,61**	**140,06**

The general area and the areas under observation are shown here. These results were obtained as of July 1. The same indicators were observed for the situation of October 1 and were determined in the form of Table 2.

Table 2. The level of seepage water of irrigated land areas in Samarkand region in 2021-2022

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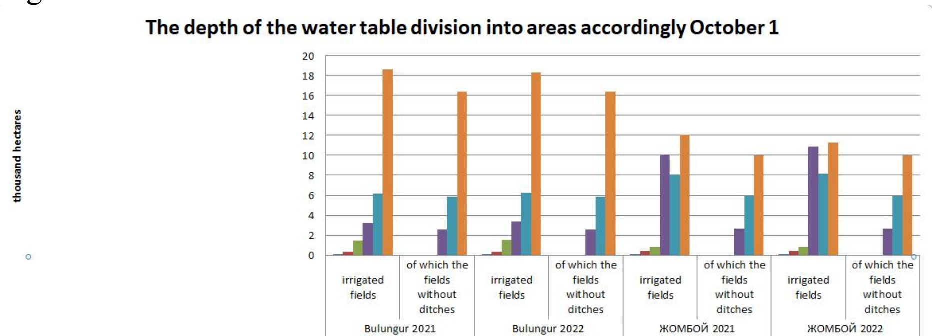
Region	Years	indicators	Total	This is the area under surveillance	The depth of the water table division into areas accordingly October 1					
					0-1 up to a meter	1-1,5, up to a meter	1,5-2, up to a meter	2-3, up to a meter	3-5, up to a meter	>5, above a meter
Samarkand region	**2021**	irrigated fields	**380,204**	**380,204**	**1,49**	**7,79**	**25,11**	**80,35**	**88,31**	**177,15**
		of which the fields without ditches	**234,297**	**234,297**				**31,14**	**62,61**	**140,06**
	2022	irrigated fields	**380,204**	**380,204**	**1,529**	**7,892**	**24,742**	**87,795**	**94,960**	**163,286**
		of which the fields without ditches	**233,800**	**233,800**				**31,14**	**62,61**	**140,06**

The general area and the areas under observation are shown here. These results were obtained as of october 1.

Between the months of July and October, there was no significant difference in the region, but when the analysis was carried out at the district level, it was possible to see large changes due to irrigation and water shortage in the summer months.



	Bulungur 2021 irrigated fields	Bulungur 2021 of which the fields without ditches	Bulungur 2022 irrigated fields	Bulungur 2022 of which the fields without ditches	ЖОМБОЙ 2021 irrigated fields	ЖОМБОЙ 2021 of which the fields without ditches	ЖОМБОЙ 2022 irrigated fields	ЖОМБОЙ 2022 of which the fields without ditches
The depth of the water table division into areas accordingly October 1 0-1 up to a meter	0,05		0,07		0,1		0,1	
The depth of the water table division into areas accordingly October 1 1-1,5 up to a meter	0,35		0,31		0,43		0,42	
The depth of the water table division into areas accordingly October 1 1,5-2 up to a meter	1,5		1,51		0,86		0,79	
The depth of the water table division into areas accordingly October 1 2-3 up to a meter	3,2	2,56	3,4	2,56	10,09	2,69	10,84	2,69
The depth of the water table division into areas accordingly October 1 3-5 up to a meter	6,19	5,85	6,25	5,85	8,1	5,95	8,18	5,95
The depth of the water table division into areas accordingly October 1 >5up to a meter	18,57	16,41	18,32	16,41	12,03	9,96	11,27	9,96

We can see the change of underground water in Bulungur and Jonboy districts in these graphs.

Sherzod Babakholov, Ikhtiyor Bobojonov, Shavkat Hasanov, Thomas Glauben expressed the following opinions about climate change in their studies. Figures 2. depict climate data sourced from the Climatic Research Unit (CRU, 2018), the World Bank (2018b), and the National Center of Hydro-Meteorological Service. Analysis of annual cultivating seasons spanning from 1982 to 2018 reveals a discernible trend: a consistent rise in average annual temperatures alongside relatively minor fluctuations in precipitation levels over the past three decades within the region.

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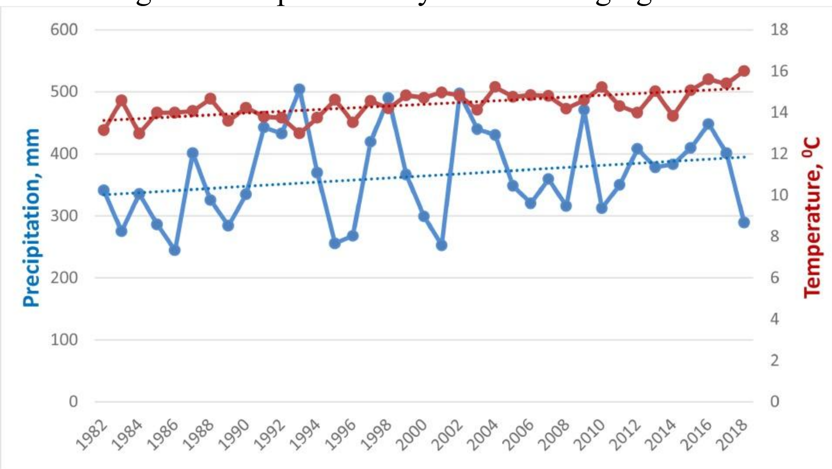
However, a noteworthy shift emerges post-2000, marked by dramatic increases in spring and summer temperatures coupled with a decline in precipitation across the region. Distinctly illustrates these trends, emphasizing pronounced temperature elevations predominantly during spring and summer seasons. Such escalating temperatures pose a heightened risk of heat stress for agricultural crops within the region. The implications of these temperature surges are significant, particularly concerning agricultural productivity. Elevated temperatures and subsequent heat stresses, as outlined by Sharma et al. (2008), emerge as critical constraints, potentially leading to considerable losses in total harvests for producers. This climatic shift underscores the vulnerability of agricultural systems to adverse impacts brought about by rising temperatures, demanding adaptive strategies to mitigate potential losses and sustain agricultural productivity amidst changing climate conditions [12,18].



An extensive review of climate change projections formed the foundation for assessing the interplay between weather variables, irrigation practices, and farm productivity in the context of the Samarkand region. The study focused on delineating the differential impacts of climate change on wheat and cotton farms, revealing distinctive responses across crop types within the region. Notably, the research highlighted a nuanced pattern: while an increase in warming adversely affects both crops, precipitation exhibits contrasting effects on wheat and cotton production. Wheat farmers benefit from adequate precipitation, whereas excessive rainfall negatively impacts cotton yields. This disparity underscores the crop-specific vulnerability to varying climate conditions. Moreover, the study underscored the crucial role of irrigation practices in mitigating climate-induced threats. Farms equipped with robust irrigation systems displayed greater resilience to climate-related challenges. However, a pertinent concern arises regarding potential water shortages faced by irrigated farms due to inefficient water utilization, amplified warming trends, and dwindling water resources projected in the near future [11-13].

The research advocates for strategic policies geared towards bolstering irrigation management and fostering the adoption of water-saving technologies in agricultural practices. Such initiatives aim to enhance the resilience of agricultural producers in the face of impending climate extremes. By improving irrigation efficiency and encouraging sustainable water practices, policymakers can potentially alleviate the vulnerability of farms to climate-induced risks.

Nonetheless, the study emphasizes the need for further extensive research, encompassing diverse crop types and spanning longer periods. Large-scale datasets can provide more comprehensive insights and actionable implications for policymakers, not only in the Samarkand region but also across Central Asia and beyond. These insights are crucial for fortifying the resilience of agricultural systems against future weather extremes, aiding policymakers in formulating effective strategies to sustainably navigate the evolving climate challenges faced by agricultural producers [11,15-17].

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Conclusion: This study examines the impact of climate change on groundwater resources in the Samarkand region of Uzbekistan, particularly on wheat and cotton production, based on the analysis of the results of research and scientific articles conducted in the region. It reveals that rising temperatures and shifting precipitation patterns influence crop productivity differently: while wheat benefits from adequate rainfall, excessive precipitation adversely affects cotton yields. The study underscores the significance of robust irrigation systems in safeguarding against climate-induced risks, yet raises concerns about potential water shortages. Proposed policy interventions aim to fortify irrigation practices and promote water-saving technologies to enhance agricultural resilience. Nevertheless, it stresses the need for further comprehensive research covering diverse crops and extended time frames to furnish policymakers with essential insights for sustainable adaptation strategies in agricultural production amidst evolving climate challenges.

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