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IMPACT OF CLIMATE CHANGE ON METEOROLOGICAL TRENDS IN THE CHIRCHIK RIVER BASIN: AN ANALYSİS OF 2008–2024

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Abstract: This study assessed the long-term changes in the main meteorological indicators observed in the Chirchik River Basin during 2008–2024. The objective of the study was to identify the dynamics of air temperature, land surface temperature, precipitation, and wind speed in the upper, middle, and lower parts of the basin and to evaluate their significance for water resources management. The analysis used observational data from the Charvak, Tashkent, and Chinaz meteorological stations, as well as land surface temperature data obtained from the MODIS satellite. The datasets were subjected to quality control, and the monthly values were converted into annual mean or cumulative indicators. Trends were identified using linear regression, and the rates of change were evaluated on a decadal basis.The results showed an increasing air temperature trend at all stations. The warming rate was approximately 0.7–1.0 °C per decade at the Tashkent and Chinaz stations, while it ranged from 0.3 to 0.5 °C per decade at Charvak. MODIS data indicated an increase in land surface temperature, particularly in urbanized areas and over dry surfaces. Precipitation exhibited high interannual variability; however, no stable and statistically significant overall trend was identified. Wind speed also varied mainly within the range of natural fluctuations.The findings indicate that the warming process in the basin has intensified in recent years, while the precipitation regime remains unstable. These changes should be considered in the planning of evaporation losses, irrigation water demand, and seasonal water allocation.

Keyword: Chirchik River Basin; climate change; meteorological trends; air temperature; land surface temperature; precipitation; wind speed; water resources

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Introduction

Changes occurring in the global climate system affect air temperature, precipitation, evaporation, snow cover, glacier conditions, and the processes governing river flow formation. Rising air temperatures may intensify the hydrological cycle, alter atmospheric moisture exchange, and increase the probability of extreme meteorological events. These processes are particularly important in arid regions where water resources are limited and agricultural production depends heavily on irrigation.

Central Asia is characterized by a sharply continental and predominantly arid climate. The flow of the region's major rivers is largely formed by snow accumulated in mountainous areas during winter and by the seasonal melting of glaciers. Therefore, changes in air temperature and precipitation regimes in mountain regions directly influence the volume, seasonal distribution, and timing of river runoff. Increasing temperatures may lead to earlier snowmelt, a shorter duration of snow cover, and reduced river discharge during summer. These changes create additional challenges for reservoir operation, irrigation water allocation, and the reliable functioning of hydropower systems [1].

The impact of climate change on water resources is not limited to changes in precipitation or river discharge. Rising air and land surface temperatures increase evaporation intensity, reduce soil moisture, and raise crop water requirements. Consequently, climate change may alter both

the natural conditions of water resource formation and the level of irrigation water demand. The uneven distribution of precipitation between years and seasons further increases uncertainty in water management. Wet years may be associated with a greater risk of flooding and mudflows, whereas hot and dry years may intensify drought and water scarcity [2].

The Chirchik River Basin is one of the most important natural and water management regions in northeastern Uzbekistan. The water resources generated within the basin are widely used to meet the municipal, industrial, energy, and agricultural needs of Tashkent City and Tashkent Region. River flow is closely connected with reservoir operations, irrigation systems, hydropower facilities, and the water supply of settlements. Therefore, investigating long-term changes in meteorological indicators within the Chirchik River Basin is essential for ensuring regional water security.

The natural conditions of the basin are characterized by sharp elevation differences, extending from high mountain areas to arid lowlands. The upper part of the basin consists of mountainous areas strongly influenced by snow and glaciers, the middle part includes the intensively urbanized Tashkent–Chirchik Valley, and the lower part consists of relatively hot and dry plains. Differences in relief, elevation, land cover, and human activity cause air temperature, precipitation, wind speed, and land surface temperature to vary considerably across the basin. Therefore, basin-wide average values may not fully represent local climatic changes [3].

In the mountainous part of the basin, meteorological conditions influence the formation of snow reserves and the natural regime of river runoff. In the middle part, urbanization processes play an increasingly important role. The expansion of built-up areas, the increase in asphalt and concrete surfaces, the reduction of green spaces, and anthropogenic heat emissions may contribute to higher land surface temperatures in urban areas [4]. As a result, the urban heat island effect may intensify, causing air temperature and evaporation conditions to differ from those in the surrounding natural landscapes. In the lower plains, high temperatures, low precipitation, and dry land surfaces are the main factors controlling the regional thermal regime.

Air temperature is measured directly at meteorological stations, whereas land surface temperature reflects the thermal condition of soil, vegetation, water bodies, asphalt, and other surface types. Although these two indicators are related, their values and controlling mechanisms are not identical. Land surface temperature is strongly affected by solar radiation, surface moisture, vegetation cover, soil type, and the degree of urbanization [5]. Therefore, combining meteorological station observations with satellite data, such as MODIS products, makes it possible to assess climatic processes in greater spatial and temporal detail.

A number of studies have investigated long-term trends in air temperature, precipitation, and other meteorological variables in Central Asia and Uzbekistan [6]. These studies have generally reported a regional warming trend, while precipitation has shown considerable spatial and interannual variability. However, results obtained at national or regional scales do not fully represent the specific orographic, urban, and hydrological conditions of the Chirchik River Basin. In particular, local studies simultaneously covering the upper, middle, and lower parts of the basin and integrating meteorological station observations with remote sensing data remain limited [7].

To address this research gap, meteorological indicators should be compared across different elevation and landscape zones of the basin. Such an approach makes it possible to determine how warming rates differ among mountainous, urbanized, and lowland areas, to assess the spatial characteristics of precipitation, and to identify long-term changes in wind speed. Furthermore, a combined analysis of air temperature and land surface temperature is important for understanding potential changes in evaporation from soil and water surfaces, urban microclimate, irrigation water demand, and seasonal water allocation [8].

The objective of this study was to identify the long-term trends in air temperature, land surface temperature, precipitation, and wind speed in the upper, middle, and lower parts of the Chirchik River Basin during 2008–2024 and to assess the potential significance of the observed changes for water resources management [9]. To achieve this objective, observational records from the Charvak, Tashkent, and Chinaz meteorological stations were subjected to quality control, annual indicators were calculated from monthly data, and the direction and rates of change were estimated using linear regression. In addition, changes in land surface temperature were evaluated using MODIS satellite data, and spatial differences among the stations were compared [10].

The results of this study provide a scientific basis for assessing meteorological changes in the Chirchik River Basin, identifying their potential implications for water resources, and supporting long-term water management planning. The findings may be applied in reservoir operation, estimation of irrigation water demand, improvement of seasonal water allocation, and the development of climate change adaptation measures.

Materials and Methods

Study Area. The Chirchik River Basin was selected as the study area. The basin is located in northeastern Uzbekistan, primarily within the Tashkent Region, and covers a total area of approximately 14,900 km² (Figure 1). The Chirchik River is formed by the confluence of the Pskem and Chatkal rivers, which originate in the Western Tien Shan Mountains. Its flow is regulated by the Charvak Reservoir, after which the river passes through the Tashkent–Chirchik Valley and eventually joins the Syr Darya River in its lower reaches.

The topography of the basin changes sharply from high mountainous areas to lowland plains. Elevations exceed 3,000 m in the upper part of the basin and decrease to approximately 250–300 m in the lower areas near Chinaz. Consequently, the mountainous part of the basin has a relatively cold and humid climate, whereas the lowland areas are characterized by hot and dry conditions. Annual precipitation may reach 1,200–1,600 mm in the high mountains, while it is approximately 450–500 mm in the middle part of the basin and 300–350 mm in the lower part. Most precipitation occurs during the winter and spring seasons.

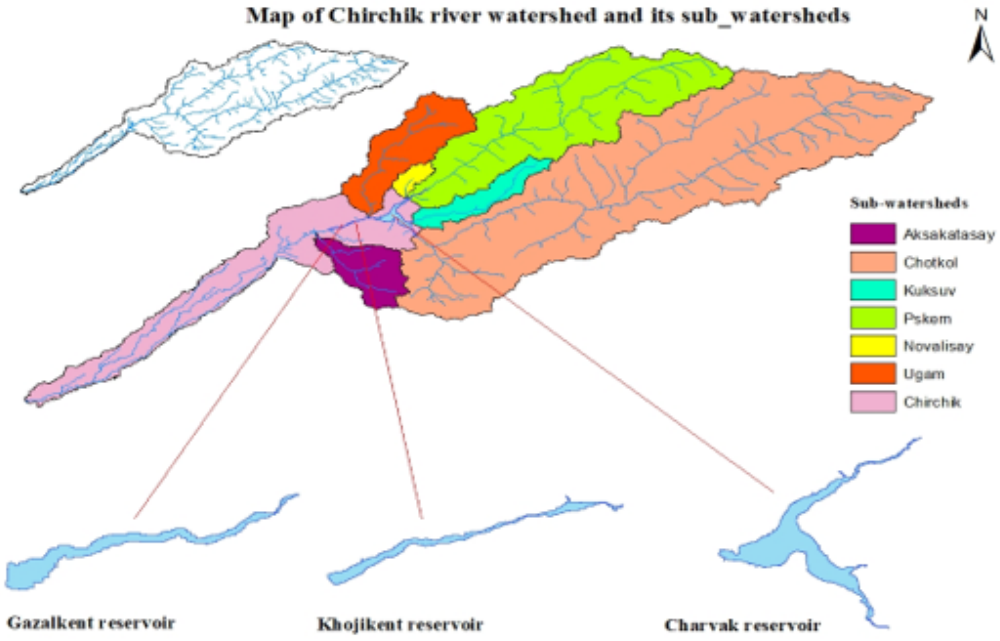


Figure 1. Location of the Chirchiq River basin and its hydrographic network

Data Sources and Data Preparation. Meteorological observation records of air temperature, precipitation, and wind speed for the period 2008–2024 were used in this study. The Charvak, Tashkent, and Chinaz stations were selected because they represent different elevation and landscape zones of the basin. Land surface temperature was evaluated using the MODIS MOD11A2 satellite product, while ERA5 reanalysis data were used as an auxiliary source for spatial comparison and validation of the results.

First, the completeness and logical consistency of the datasets were examined. Missing, duplicated, and physically implausible values were identified and removed from the corresponding data series. Because data for 2014–2015 at the Charvak station were insufficient, these years were excluded from the trend analysis. During data screening, particular attention was paid to avoiding any artificial modification of the general structure of the observation series.

Table 1. Regional characteristics of the meteorological stations used in the study

Station	Location within the basin	Landscape conditions	Role in the analysis
Charvak	Upper part	Mountainous area and reservoir surroundings	Represents the cold and relatively humid upper zone of the basin
Tashkent	Middle part	Urbanized valley	Enables the assessment of the urban heat island effect and conditions in the middle reaches
Chinaz	Lower part	Arid plain	Represents the hot and arid conditions of the low-elevation area

Statistical and Spatial Analysis Methods. Monthly observations were aggregated into annual mean values for air temperature and wind speed, and into annual totals for precipitation. Mean, minimum, and maximum air temperatures were analyzed separately. MODIS images were filtered for cloud contamination and low-quality pixels, after which annual mean land surface temperature layers were generated. Temporal changes in each meteorological variable were assessed using a simple linear regression model:

$$Y_t = a + bt + \varepsilon_t \quad (1)$$

where Y_t is the value of the meteorological variable in year t, a is the regression intercept, b is the annual trend coefficient, and ε_t is the random error term. The decadal rate of change was calculated as $10b$. The statistical significance of the trend coefficient was evaluated using a t-test. To identify spatial differences, the station results were compared according to elevation and landscape conditions. Graphs were prepared using MS Excel, OriginLab, and Python, while maps were produced in ArcGIS Pro.

Because the analysis period was limited to 17 years, the results were interpreted not as long-term geological or century-scale climate normals, but as recent trends observed during 2008–2024. This approach allows the influence of individual extreme years on the estimated trends to be assessed with appropriate caution.

Results

Long-Term Changes in Air Temperature. During 2008–2024, an increasing trend in mean annual air temperature was observed at all three meteorological stations. The rate of change was higher in the lower and urbanized parts of the basin, while it was relatively lower in the mountainous upper part. According to the regression results, the warming rate was approximately 0.7–1.0 °C per decade at the Tashkent and Chinaz stations and 0.3–0.5 °C per decade at the Charvak station.

At the Tashkent station, the mean annual air temperature increased from approximately 15.0°C in 2008 to 16.0°C in 2024, while at Chinaz it rose from 14.3 °C to 15.5°C. At the Charvak station, annual values generally varied between 8.3 and 10.7 °C, and the overall warming trend was less pronounced than at the lowland stations. Because of considerable fluctuations in some annual values, the regression trend provides a more reliable indicator than a simple comparison between the initial and final years of the observation period.

Changes in minimum temperatures also indicated a gradual moderation of winter conditions. At Chinaz, the minimum temperature declined to 24.5 °C at the beginning of the observation period, whereas in recent years it generally did not fall below 18 °C. At Tashkent, minimum temperatures also increased from approximately 17 °C to 9 °C. Maximum temperatures remained relatively stable, generally ranging from 40 to 42 °C at Tashkent and Chinaz and from 30 to 33 °C at Charvak. These results suggest that the observed warming was more evident during the cold season and in minimum temperature values.

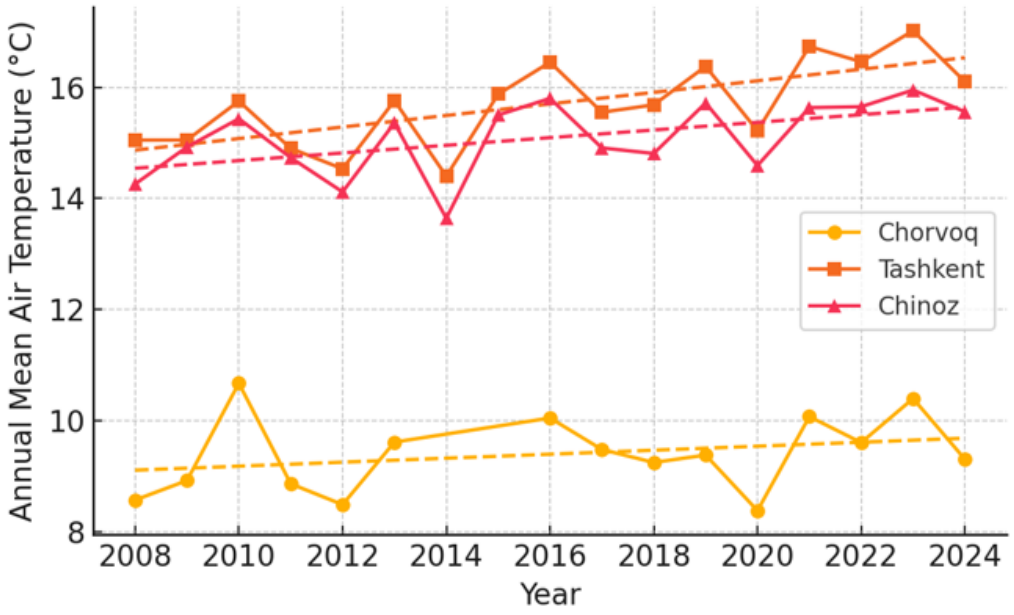


Figure 2. Dynamics of mean annual air temperature at the Charvak, Tashkent, and Chinaz stations during 2008–2024.

Changes in Land Surface Temperature. MODIS satellite data indicated that land surface temperature increased in the same general direction as air temperature. During the summer period, land surface temperature was generally 30–35 °C in irrigated and vegetation-covered areas and approximately 25–30 °C on mountain slopes and in forested areas. In contrast, surface temperatures reached 50–60 °C in areas characterized by dry soil, dense development, and asphalt-covered surfaces.

In Tashkent City and the surrounding urbanized areas, the land surface was observed to cool more slowly during the evening and nighttime. This pattern may be associated with the increasing proportion of heat-absorbing surfaces and the reduction of green areas within the city. However, additional information on land-cover changes, building density, and anthropogenic heat sources is required to determine the specific contribution of urbanization.

Interannual Variability of Precipitation. Precipitation exhibited considerably greater interannual variability than air temperature. Annual precipitation ranged from approximately 500 to 1,600 mm at the Charvak station, from 300 to 580 mm at Tashkent, and from 200 to 400 mm at Chinaz in most years. In 2020, approximately 995 mm of precipitation was recorded at the Chinaz station, distinguishing that year as an exceptionally wet anomaly within the observation series.

Relatively wet conditions were observed in the mountainous part of the basin during 2018–2019, whereas 2021 was characterized as a comparatively dry year at all three stations. Although some calculations indicated a weak positive tendency at the Charvak station, no stable and statistically significant basin-wide trend was identified because of the large variability in the precipitation series and the relatively short observation period. The seasonal distribution of precipitation remained broadly unchanged, with the largest proportion occurring during winter and spring.



Figure 3. Annual precipitation at the Charvak, Tashkent, and Chinaz stations during 2008–2024

Wind Speed Trends. The wind speed analysis showed no clear, unidirectional long-term trend. At the Charvak station, annual values varied over a wider range than at the other stations because of topographic influences and local atmospheric circulation. In some years, the aggregated wind speed exceeded 12 m/s, whereas in other years it decreased to approximately 5–6 m/s.

At the Tashkent station, following relatively high values in 2008–2009, wind speed generally varied between 4 and 6 m/s. At Chinaz, annual values remained mainly within the range of 5–7 m/s. The decreases observed in some years at Tashkent may be associated with increasing building density and greater surface roughness. However, a separate analysis of urban morphology and prevailing wind directions is required to confirm this relationship.

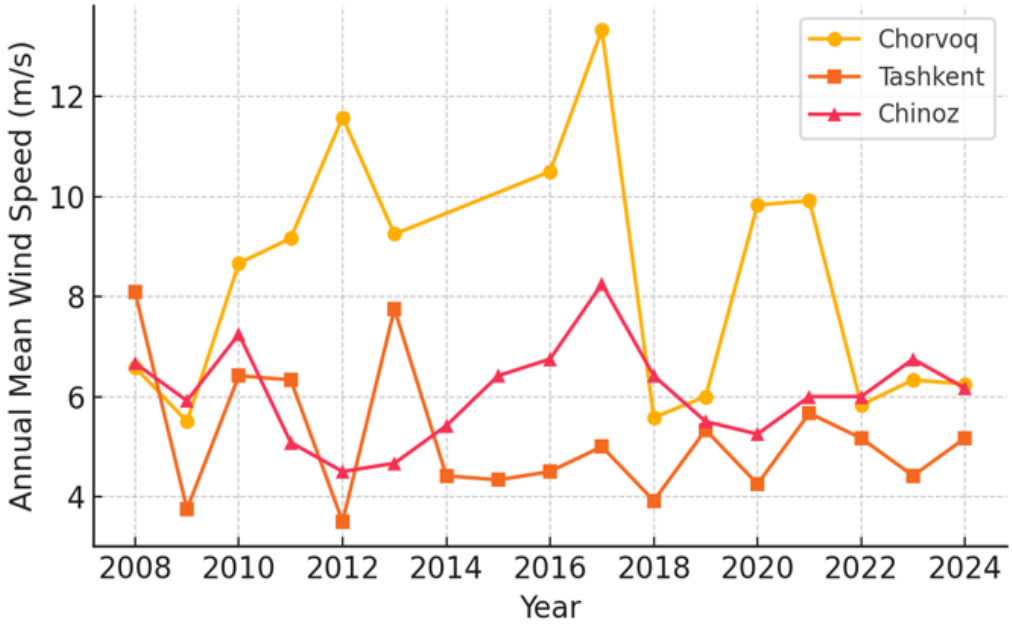


Figure 4. Dynamics of mean annual wind speed at the Charvak, Tashkent, and Chinaz stations during 2008–2024

Discussion

The research results indicate that a warming trend was observed in the Chirchik River basin during 2008–2024. The stronger trends recorded at the lowland Tashkent and Chinaz stations, compared with the mountainous Charvak station, may be explained by the combined effects of elevation, land cover, urbanization, and local atmospheric circulation. In particular, the simultaneous increase in air temperature and MODIS-based land surface temperature in Tashkent suggests the presence of an urban heat island effect. However, the present study does not separately quantify the contribution of this factor. The more rapid increase in minimum temperatures compared with maximum temperatures may indicate a weakening of cold winter periods. In mountainous basins, such changes may affect the timing of snow accumulation and melting and consequently alter the onset of spring runoff. However, river discharge, snow storage, and glacier area were not directly analysed in this study. Therefore, the influence of meteorological changes on the flow regime of the Chirchik River should currently be considered a potential hydrological mechanism that requires verification through additional observations.

The increase in land surface temperature may intensify evaporation and evapotranspiration, accelerate the depletion of soil moisture, and increase water losses from reservoirs and irrigation systems. In agricultural production, rising temperatures affect crop water requirements, the growing season, and crop yields. Therefore, water allocation planning should consider not only long-term average values but also scenarios of hot and dry years. The absence of a stable trend in the precipitation series does not imply the absence of climatic risk. On the contrary, sharp shifts between the wet conditions observed during 2018–2020 and the drought experienced in 2021 indicate a high level of annual uncertainty in water resources management. During wet years, flood control and the safe operation of reservoirs become important, whereas during dry years, irrigation water shortages and the maintenance of environmental flows become major concerns.

The main limitations of the study include the relatively short observation period, missing data for certain years at the Charvak station, the use of only three meteorological stations, and the absence of a direct analysis of hydrological indicators. MODIS data are also subject to uncertainties associated with cloud cover, pixel size, and mixed land-cover characteristics. Future studies should extend the observation period to at least 30 years, apply non-parametric methods such as the Mann–Kendall test and Sen's slope estimator, and jointly analyse river discharge, snow cover, evaporation, and land-cover changes.

Conclusions

Data for 2008–2024 showed that air temperature increased across all monitored parts of the Chirchik River basin. The rate of warming was approximately 0.7–1.0 °C per decade at the Tashkent and Chinaz stations, whereas it was about 0.3–0.5 °C per decade at Charvak. In addition to differences in elevation, urbanization and land-cover characteristics may also have contributed to the stronger warming observed in the lowland areas.

MODIS observations showed that land surface temperature was higher over urbanized and dry surfaces and exhibited an increasing trend over time. Such changes are important for assessing evaporation losses, soil moisture conditions, and irrigation water demand. Precipitation was characterized by high interannual variability. Although some wet and dry years were clearly distinguishable, no stable and statistically significant overall trend was identified across the basin. Similarly, no consistent long-term directional change was observed in wind speed.

Overall, the main meteorological signal observed in the Chirchik River basin is the increase in air and land surface temperatures. Combined with the instability of the precipitation regime, this process requires flexible planning in water resources management, the use of seasonal forecasts, and the development of specific management scenarios for extreme years. Integrated studies incorporating long-term hydrological observations are required to determine the direct effects of meteorological trends on river discharge.

Author Contributions

Conceptualization, D.K.R. and I.B.Z.; methodology, D.K.R. and I.B.Z.; validation, F.K.B.; formal analysis, F.K.B., D.K.R., and I.B.Z.; investigation, D.K.R. and I.B.Z.; resources, D.K.R. and I.B.Z.; data curation, F.K.B.; writing—original draft preparation, D.K.R. and I.B.Z.; writing—review and editing, F.K.B., D.K.R., and I.B.Z.; visualization, F.K.B., D.K.R., and I.B.Z.; supervision, F.K.B. All authors have read and approved the final version of the manuscript submitted for publication.

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Data Availability Statement

The data supporting the findings of this study are presented within the article in the relevant tables and figures.

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Conflict of Interest

The authors declare no conflicts of interest.

Abbreviations

GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
R^2	Coefficient of Determination
CV	Coefficient of Variation
MA	Moving Average
OLS	Ordinary Least Squares
m^3/s	Cubic Metres per Second
FAO	Food and Agriculture Organization of the United Nations
UNEP	United Nations Environment Programme

References

[1] Hou, M., Cuo, L., and Xu, H. Hydrological response to twenty-first century climate change in the Amu Darya Basin, Central Asia. *Journal of Hydrology: Regional Studies* **2025**, *54*, 102606. https://doi.org/10.1016/j.ejrh.2025.102606

[2] Ososkova, T., Gorelkin, N., and Chub, V. Water Resources of Central Asia and Adaptation Measures for Climate Change. *Environmental Monitoring and Assessment* **2000**, *61*, 161–166. https://doi.org/10.1023/A:1006394808699

[3] Peng, S., Gang, C., Cao, Y., and Chen, Y. Assessment of climate change trends over the Loess Plateau in China from 1901 to 2100. *International Journal of Climatology* **2017**. https://doi.org/10.1002/joc.5331

[4] Sommer, R., Glazirina, M., Yuldashev, T., Otarov, A., Ibraeva, M., Martynova, L., Bekenov, M., et al. Impact of climate change on wheat productivity in Central Asia. *Agriculture, Ecosystems & Environment* **2013**, *178*, 78–99. https://doi.org/10.1016/j.agee.2013.06.011

[5] Brouder, S. M., and Volenec, J. J. Impact of climate change on crop nutrient and water use efficiencies. *Physiologia Plantarum* **2008**, *133*(4), 705–724. https://doi.org/10.1111/j.1399-3054.2008.01136.x

[6] Hanasaki, N., Fujimori, S., Yamamoto, T., Yoshikawa, S., Masaki, Y., Hijioka, Y., Kainuma, M., et al. A global water scarcity assessment under Shared Socio-economic Pathways – Part 2: Water availability and scarcity. *Hydrology and Earth System Sciences* **2013**, *17*, 2393–2413. https://doi.org/10.5194/hess-17-2393-2013

[7] Khamidov, S., Li, Z., Nasirova, M., Pulatov, B., and Pulatov, A. Assessment of temperature and precipitation trends in Kashkadarya, Uzbekistan. *E3S Web of Conferences* **2023**, *365*, 01005. https://doi.org/10.1051/e3sconf/202336501005

[8] Faye, B., Webber, H., Naab, J. B., MacCarthy, D. S., Adam, M., Ewert, F., Lamers, J. P. A., et al. Impacts of 1.5 versus 2.0 °C on cereal yields in the West African Sudan Savanna. *Environmental Research Letters* **2018**, *13*(3), 034014. https://doi.org/10.1088/1748-9326/aaab40

[9] Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Huang, M., et al. Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences* **2017**, *114*(35), 9326–9331. https://doi.org/10.1073/pnas.1701762114

[10] Wu, T., Lu, Y., Fang, Y., Xin, X., Li, L., Li, W., Jie, W., et al. The Beijing Climate Center Climate System Model (BCC-CSM): The main progress from CMIP5 to CMIP6. *Geoscientific Model Development* **2019**, *12*(4), 1573–1600. https://doi.org/10.5194/gmd-12-1573-2019

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