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STATISTICAL ASSESSMENT OF THE RELATIONSHIP BETWEEN CLIMATE FACTORS AND AGRICULTURAL PRODUCTIVITY IN UZBEKISTAN

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ABSTRACT:

This study statistically examines the relationship between climate factors and agricultural productivity in Uzbekistan during 2020–2024. Average air temperature and annual precipitation were used as key climate indicators, while wheat and cotton yields represented agricultural performance. The results show that temperature has a stronger association with crop yields, particularly cotton, whereas the effect of precipitation is limited under irrigated farming conditions. The findings highlight the importance of climate adaptation, efficient water use, and the advancement of agrotechnological practices.

Introduction

In recent years, global climate change has been recognized as one of the most significant factors affecting the sustainable development of agricultural systems. In particular, rising air temperatures, variability in precipitation, and the increasing frequency of drought events are exerting a noticeable impact on agricultural productivity. According to the Sixth Assessment Report of the IPCC, climate change has already begun to negatively affect agricultural productivity in many regions, and this pressure is expected to intensify in the coming decades [1].

Central Asia, including Uzbekistan, is considered one of the regions highly vulnerable to climate change. According to the World Bank's Climate Change Knowledge Portal, the average temperature in Uzbekistan increased by approximately 1.7°C over the period 1991–2020, and further intensification of heat stress is projected in the future [2].

Agriculture is a key sector of Uzbekistan's economy and is highly dependent on land and water resources. According to FAO data, the share of irrigated land in the country is high, which increases the sector's sensitivity to changes in climate and water availability [3].

During 2020–2024, certain shifts in climate indicators were observed across the country, including an increase in the number of extremely hot days in some regions and a growing risk of water scarcity. According to observations by Uzhydromet, the frequency of extreme heat events has been rising in recent years [4].

At the same time, technological modernization and improvements in agronomic practices have contributed to yield growth for some crops. However, there remains a need for a comprehensive statistical assessment of the relationship between climate factors and agricultural land productivity, particularly for recent years.

The purpose of this study is to statistically assess the dynamics of climate change indicators and their relationship with agricultural land productivity in Uzbekistan during 2020–2025. The study analyzes key climate indicators (temperature and precipitation), major crop yields, and the relationships between them. The findings are intended to support the development of adaptation measures in agriculture and to improve the efficient use of land resources.

Literature review

The impact of climate change on agriculture has become one of the most widely studied research areas in recent years. International studies indicate that rising temperatures and instability in precipitation patterns affect crop yields in different ways, but predominantly negatively. The IPCC (2022) report identifies heat stress, drought, and water scarcity as the main risk factors affecting agricultural production at the global level [5].

Studies conducted by the FAO also emphasize that climate change poses particularly high risks in regions where irrigated agriculture predominates. According to the organization, increasing pressure on water resources and intensified evaporation may negatively affect yield stability [6].

Analyses from the World Bank's Climate Change Knowledge Portal show a steady upward trend in temperatures in Central Asia, including Uzbekistan. According to the

portal's projections, the increasing number of hot days in the region creates additional stress for crops during the growing season [7].

There are also dedicated studies focusing on Central Asia. For example, reports prepared jointly by the World Bank and other international institutions identify water scarcity and glacier retreat in the region as long-term risks for irrigated agriculture. This issue is particularly relevant for countries dependent on the Amu Darya and Syr Darya river basins [8].

Similar conclusions are found in national studies on Uzbekistan. According to Uzhydromet, the frequency of heat waves in the country has increased over the past decades, which may affect crop vegetation processes [9].

At the same time, some studies note that the negative effects of climate change can be partially offset by technological progress in agriculture, the introduction of improved crop varieties, and government support measures. FAOSTAT data show that in many countries, crop yields continue to grow despite climate pressures due to technological factors [10].

However, the review of existing literature indicates that, in the case of Uzbekistan, comprehensive statistical assessments of the relationship between climate indicators and agricultural land productivity specifically for the period 2020–2025 remain limited. While many studies examine long-term trends, the recent rapid climate changes and their implications for the agricultural sector have not been sufficiently analyzed.

Therefore, this study aims to fill the existing research gap by statistically assessing the relationship between climate indicators and agricultural productivity in Uzbekistan for the period 2020–2025.

Research methodology

This study examines changes in climate indicators in Uzbekistan and their relationship with agricultural land productivity during 2020–2025 using statistical analysis. The research was conducted based on aggregated data at the national level.

A set of interrelated methods was applied in the analysis. First, descriptive and dynamic analyses were used to identify year-to-year changes in climate and yield indicators. These methods made it possible to determine the overall trends of the variables. At the next stage, correlation analysis was employed to identify the relationship between climate factors and agricultural productivity. This approach is widely used in international statistical research.

In the study, the main climate indicators were selected as the annual average air temperature and annual precipitation. To assess agricultural performance, the yields of the

country's key crops—wheat and cotton—were used. These indicators are among the most commonly applied measures of agricultural production outcomes.

The data were compiled from open official statistical sources. Climate indicators were aggregated from meteorological observations, while crop yield data were collected from official agricultural statistics. The compiled dataset was organized into a unified table and analyzed in both graphical and tabular forms across years.

In the final stage of the research, the degree of association between climate factors and crop yields was evaluated using the Pearson correlation coefficient, a method widely applied to measure linear relationships between two variables [11].

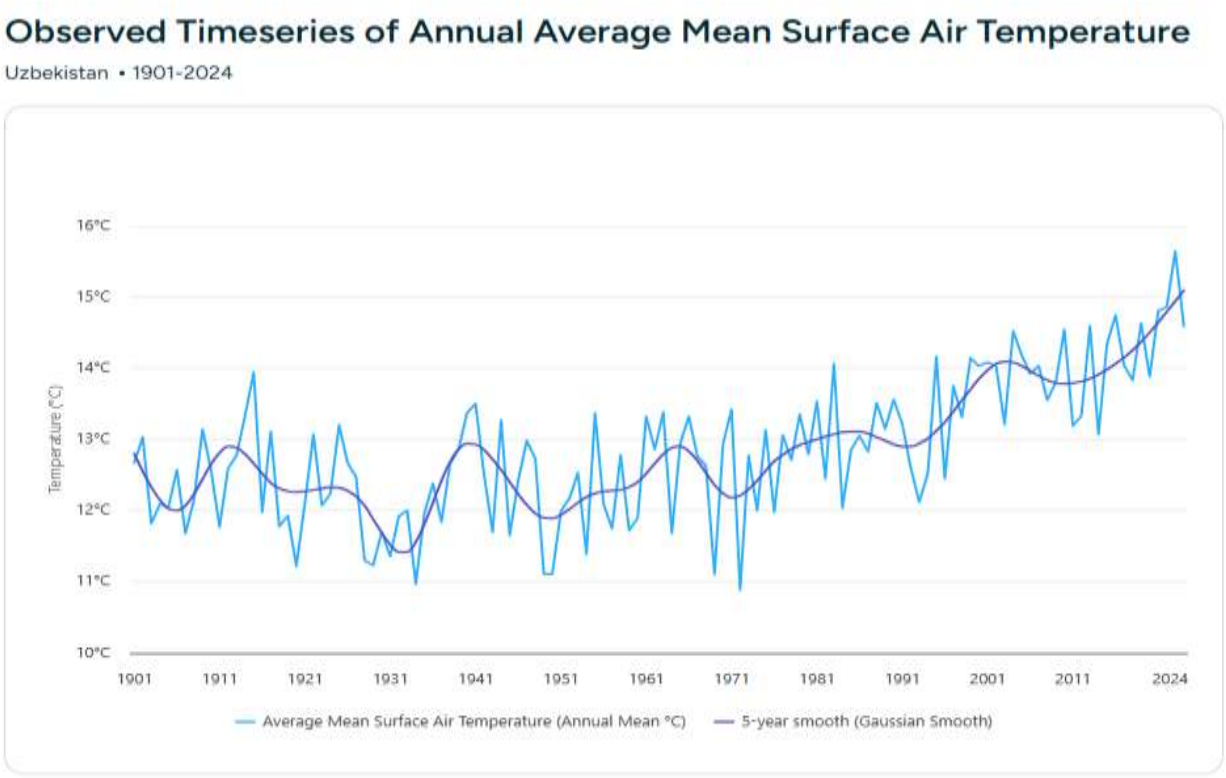
Overall, the applied methodology enables a comprehensive assessment of the trends between climate change indicators and agricultural productivity in Uzbekistan for the period 2020–2025.

Results and discussion

Temperature Change Trends in Uzbekistan

In recent years, a steady upward trend in air temperature has been observed across Uzbekistan. According to data presented on the World Bank's Climate Change Knowledge Portal, the country demonstrates a clear long-term increase in average temperature.

The presented graph illustrates a long-term upward trend in air temperature in Uzbekistan. In particular, the frequency of warmer years has increased in the most recent period. This trend may intensify heat stress during the crop growing season. Rising temperatures accelerate evaporation processes and further increase water demand under irrigated farming conditions.

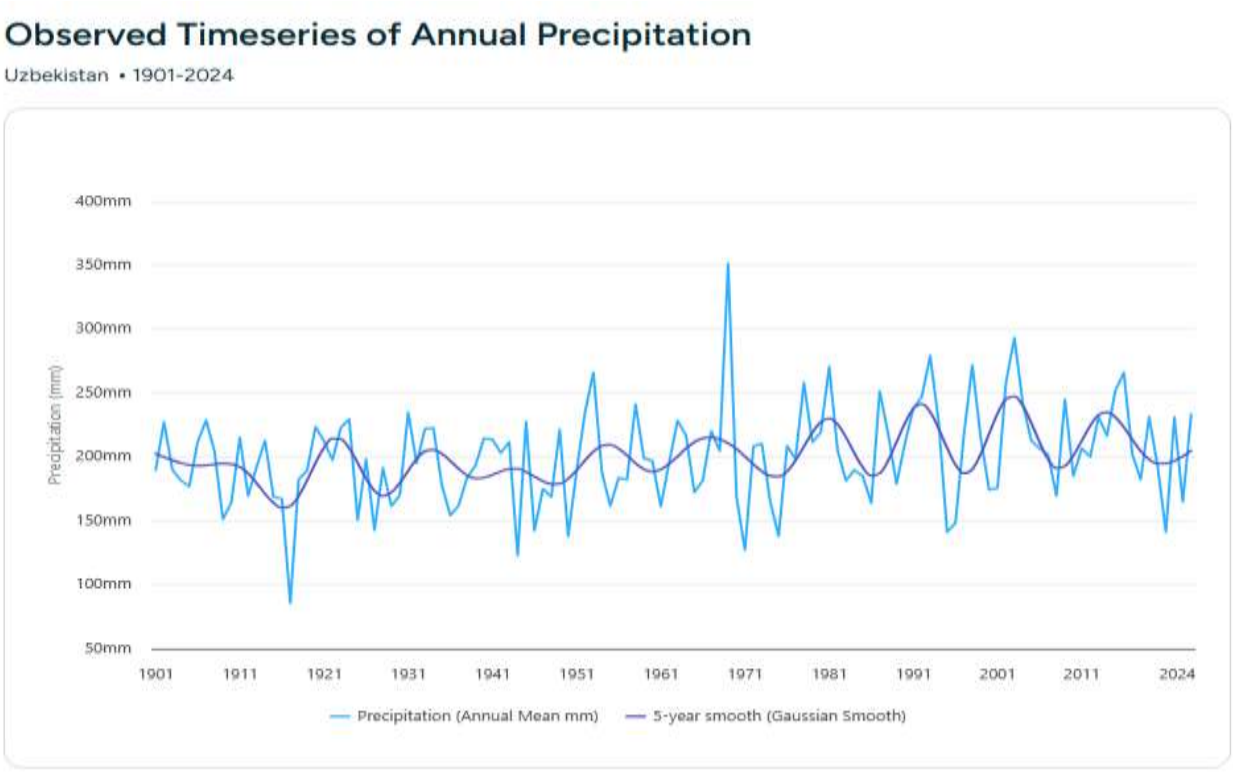


Source: *Prepared by the World Bank [12].*

Precipitation Dynamics

One of the key indicators of climate change is the instability of precipitation patterns. In Uzbekistan, annual precipitation demonstrates noticeable fluctuations across years.

The analysis of the graph indicates that there is no stable upward trend in precipitation; instead, noticeable interannual fluctuations are observed. This situation increases uncertainty in moisture availability for agriculture. In particular, reduced precipitation in irrigation-dependent areas places additional pressure on water resources.



Source: *Prepared by the World Bank [13].*

Analysis of Seasonal Temperature and Precipitation Distribution in Uzbekistan

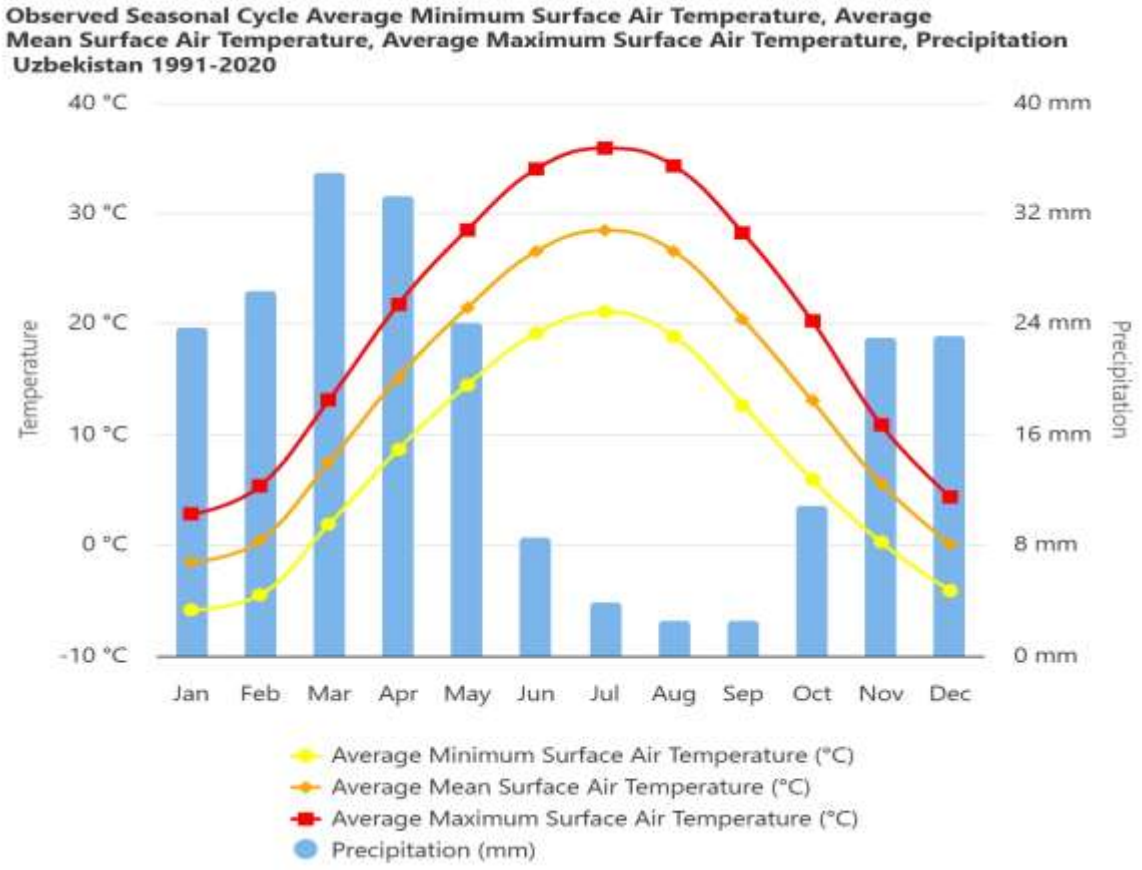
The presented graph shows the distribution of average seasonal temperature (minimum, mean, and maximum) and precipitation throughout the year in Uzbekistan for the period 1991–2020. The analysis clearly demonstrates the sharply continental nature of the country's climate.

First, a significant annual amplitude in air temperature is observed. While average temperatures remain low during the winter months (January–February), maximum temperatures rise sharply in the summer months (June–August). In particular, July records the highest maximum temperatures, indicating a high risk of heat stress during the summer period. This increases the likelihood of heat pressure on crops during the growing season.

Minimum temperatures are also relatively low in winter, indicating potential cold stress risks for certain crops. Thus, agriculture in Uzbekistan must adapt not only to summer heat but also to winter cold fluctuations.

The precipitation analysis shows that the main rainfall occurs in spring (March–April), while precipitation declines sharply during the summer months. In particular, rainfall during

June–August remains very low, confirming the high dependence of agriculture on irrigation during this period. Although precipitation partially recovers in autumn, the overall annual distribution remains uneven.



Source: *Prepared by the World Bank [14].*

This seasonal imbalance creates several risks for agricultural production. First, the combination of high summer temperatures and low precipitation accelerates soil moisture depletion. Second, in conditions where irrigated land occupies a large share, pressure on water resources intensifies. Third, under climate change conditions, the extension of hot periods may negatively affect crop yields.

Overall, the graphical analysis indicates that agriculture in Uzbekistan is highly sensitive to climatic factors, particularly summer heat and moisture deficits. This underscores the need to strengthen climate adaptation measures in the agricultural sector, including the

wider adoption of water-saving technologies, expansion of heat-resistant crop varieties, and optimization of agronomic practices.

General discussion

The conducted analyses indicate that agriculture in Uzbekistan is highly sensitive to climatic factors. The sharp seasonal increase in temperature, particularly the rise in maximum temperatures during the summer months, creates additional heat stress during the crop growing period. At the same time, the uneven distribution of precipitation throughout the year limits the potential for natural moisture supply.

Graphical analysis shows that the main precipitation occurs in the spring months, while it declines sharply during summer. This once again confirms the high dependence of Uzbekistan's agriculture on irrigation. As a result, the efficiency of water resource use is becoming a decisive factor in maintaining the stability of agricultural production.

Observations of crop yields indicate that although no sharp decline has been recorded in recent years, certain fluctuations are present. On the one hand, this suggests that agrotechnological development and government support measures are partially compensating for climate pressures. On the other hand, if the warming trend continues, pressure on yields may intensify in the long term.

From this perspective, the adaptation of agriculture to climate change conditions remains a pressing issue. In particular, under conditions of limited water resources, it is important to improve strategies for the integrated and efficient use of land and water resources.

Relationship Between Climate Factors and Crop Yields

According to the Pearson correlation analysis, a moderate positive relationship was identified between average temperature and wheat yield (r = 0.635). This result indicates that thermal conditions are to some extent associated with the efficiency of wheat production.

	Temp	Precip	Wheat	Cotton
Temp	1	-0,29453	0,63547	0,94271
Precip	-0,29453	1	0,323212	-0,31466
Wheat	0,63547	0,323212	1	0,402873
Cotton	0,94271	-0,31466	0,402873	1

Source: *Calculated by the author based on open data from the FAO [15].*

A very strong positive correlation was observed between temperature and cotton yield (r = 0.943). This can be explained by the heat-demanding biological characteristics of the cotton crop. However, given the limited number of observations, this relationship should be interpreted with caution.

The relationship between precipitation and wheat yield was weakly positive (r = 0.323), indicating that the role of natural rainfall is limited under irrigated farming conditions. In contrast, a weak negative relationship was found between precipitation and cotton yield (r = −0.315).

Overall, the results suggest that under the conditions of Uzbekistan, the temperature factor is more closely associated with the yields of certain crops, whereas the effect of precipitation remains relatively limited.

Regression Analysis Results

According to the multiple regression results, average temperature shows a positive association with wheat yield (β = 0.433). This indicates that an increase in temperature is accompanied by a certain increase in yield. However, the coefficient is not statistically significant ($p > 0.05$).

The effect of precipitation was positive but very small (β = 0.0047) and also statistically insignificant. This finding further supports the limited role of natural rainfall under irrigated agricultural conditions.

The model's coefficient of determination was $R^2 = 0.689$, indicating that a substantial share of yield variation is explained by the model variables. At the same time, due to the limited number of observations, the results should be interpreted with caution.

```
Call:
lm(formula = wheat ~ temp + precip, data = data)

Residuals:
       1        2        3        4        5
-0.072939  0.032850 -0.246474  0.007489  0.279075

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -2.295188   3.556626  -0.645    0.585
temp         0.433535   0.223577   1.939    0.192
precip       0.004716   0.003481   1.354    0.308

Residual standard error: 0.2693 on 2 degrees of freedom
Multiple R-squared:  0.6891,    Adjusted R-squared:  0.3781
F-statistic: 2.216 on 2 and 2 DF,  p-value: 0.3109
```

Source: *Calculated by the author based on open data from the FAO [16].*

Conclusion and recommendations

The conducted statistical analyses confirm that agricultural production in Uzbekistan is highly sensitive to climatic factors. Seasonal analysis indicates that the combination of high summer temperatures and low precipitation is forming a primary risk zone for the agricultural sector. Correlation results show that the temperature factor is more strongly associated with the yields of certain crops, particularly cotton, while the effect of precipitation remains limited under irrigated farming conditions.

At the same time, the lack of statistical significance in the regression results is largely attributable to the limited number of observations, indicating the need for more in-depth econometric studies based on longer time series in future research.

Based on the findings, the following practical recommendations are proposed:

— expand the adoption of water-saving irrigation technologies;
— promote the cultivation of heat- and drought-resistant crop varieties;
— digitalize the agroclimatic monitoring system and develop early warning mechanisms;
— conduct differentiated assessments of climate risks at the regional level;
— strengthen policies for the integrated use of land and water resources.

Overall, the sustainable development of agriculture in Uzbekistan under climate change conditions is closely linked to the broad implementation of scientifically grounded adaptation strategies.

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