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Simulation Models (Scenarios) of Climate Change for Beiji Station in Iraq Until 2051

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Abstract

The reference evapotranspiration and the actual evapotranspiration/transpiration exhibited a general trend toward decline during the wheat crop growth season. Similarly, the seasonal trend indicated a decline during winter and an increase in spring. Future maximum and minimum temperatures, annual, and seasonal levels were all trending upwards, suggesting clear ground warming at the Baiji station in the coming years. Regarding future changes in relative humidity, there was a trend towards decline annually, seasonally, which showed an increase. Regarding future changes in the wind speed component fluctuated between rise and fall, with a trend towards decline in the spring season, indicating a predominant decline. We can do the results with a better understanding of the climate changes we want for farmers and manufacturers and thus choose and choose analyzes in Iraq.

Keywords: Actual Evapotranspiration, Climate Change, Climate Elements, Monitoring Station, Scenario, Trend.

1. Introduction

Wheat production is expected to decline due to climate warming and changes in precipitation (Ainsworth and Long 2021). Increasing evidence from different regions of the world has shown marked phenological changes in response to rising temperatures resulting in an accelerated growth rate and a shorter spring wheat growing season (Hanasaki et al. 2013), due to varying climate change and increased concentrations of carbon dioxide in the atmosphere. The effects of these factors on wheat growth and productivity are complex and diverse (Garrett et al. 2022), leading to weakened wheat production in the future. It is expected that climate change will constitute one of the major challenges facing regional agricultural production worldwide (Juroszek et al. 2022). The average global temperature has risen by about 0.74°C over the past century and is expected to rise further by about 2.0°C to 5.4°C by 2100 (Polanco et al. 2017). Overall, an increase in both maximum and minimum temperature may increase the need for water for both irrigated field crops and may also increase the risk of heat stress during flowering for crops grown during the winter and spring, such as wheat (Vila, et al. 2021). However, global wheat production faces challenges due to global warming, water shortages, and other factors. As a crop that prefers a relatively cool temperature, some wheat-growing areas may see an increase in production, while other regions may witness a decline in production. In recent decades (Vialatte, et al. 2022), there has been great interest in weather forecasts and climate projections, especially after the increase in greenhouse gases and the occurrence of tangible changes in various world environments. Research centers specializing in building global and regional models have emerged (Richard, et al. 2022), with the goal of understanding and extrapolating global climate during the coming decades and its impacts.

These article centers have been concentrated in developed countries, with each center seeking to build its own climate model to continuously evaluate and develop it. Climate models are based on physical principles and are a numerical representation of the climate system based on physical, chemical, and biological characteristics.

They are used as a research tool to study and simulate future climate changes. Climate models begin with a period of observed historical climate used as a reference period, a comparative period that helps verify the model's ability to represent the past and provide a reference basis for comparing future climate change projections. These models simulate climate changes based on a set of scenarios (Stocker et al. 2013), including human radiation influences and scenarios called Representative Concentration Pathways (RCPs), which include a time series of emissions and concentrations of greenhouse gases and aerosols. Four typical concentration pathways were produced (Watanabe 2014). In this study, the Japanese high-altitude model (MIROC5- rcp 85) was chosen to provide a clear picture of the future.

This model is one of the main crop simulation models for the decision support system for the transfer of agricultural technology in many climate change studies, with a radiation effect reaching more than 8.5 watts/m2 after the year 2100. This means that these paths determine possible changes in the radiation effect and interested parties and researchers can use them to verify possible changes. Climate models and their future scenarios are important tools for studying the future and developing plans for water management and adaptation to climate change. The study area enjoys a semi-desert climate with limited precipitation and varying spatial and temporal distribution, making the region vulnerable to climate change.

2. Material and Methods:

Statistical methods have become one of the most important approaches used to illustrate climate change indicators. Therefore, in this chapter, we will rely on the use of the general trend method, the annual rate of change, and the change during the study period to elucidate the changes occurring in the rainfall component in the study area.

Analyzing time series and their behavioral patterns has become a priority for researchers in recent years. The primary goal is to study the behavior and trends of phenomena in the past to obtain a realistic perception and develop an appropriate model that describes the series' pattern. This model is then used to predict its future behavior, i.e., time series forecasting. This process involves predicting the future by understanding the past, and time series forecasting holds great importance in many practical fields such as business, economics, finance, and environmental studies.

Therefore, a time series is statistically defined as a series of random variables within a multivariate probability space, consisting of two variables: one explanatory (time) and the other the response variable (value of the phenomenon studied). It can be expressed mathematically in equation (1) as follows (Al-Shaarawy 2005).

$$Y = f(t) \qquad (1)$$

Where is (Y = Trend, f = phenomena and t = Time)

1- Secular Trend

The general trend in time series is defined as the upward and downward movements in the series level over the long term and is usually known as long-term variations. The general trend is the outcome or result of the influence of a group of independent factors that affected the phenomenon over time.

2- Extract the annual rate of change through the following equation (2) (Abu Zeid, 2010).

$$C = (Pi/Y) * 100 \qquad (2)$$

Where is (C = Annual rate of change, Pi= Direction coefficient and Y= Average).

3. Results:

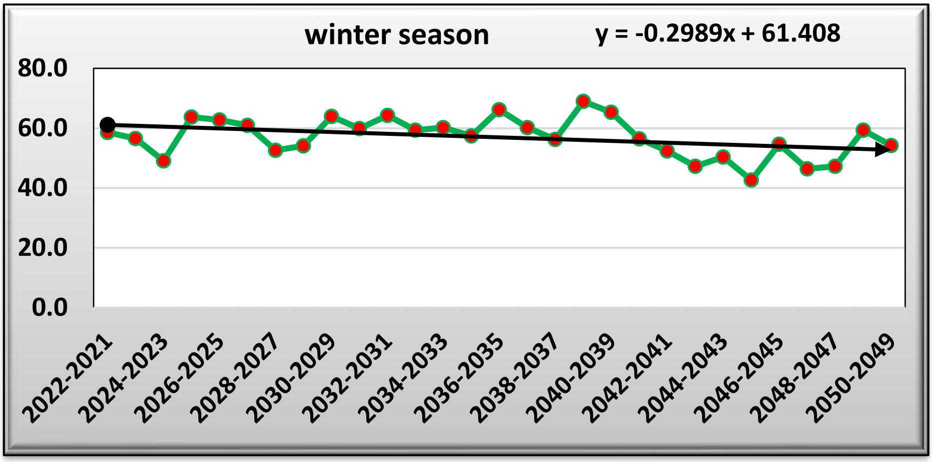
First: Analysis of the Trend, Seasonal and Annual Change of Reference Evaporation/Transpiration:

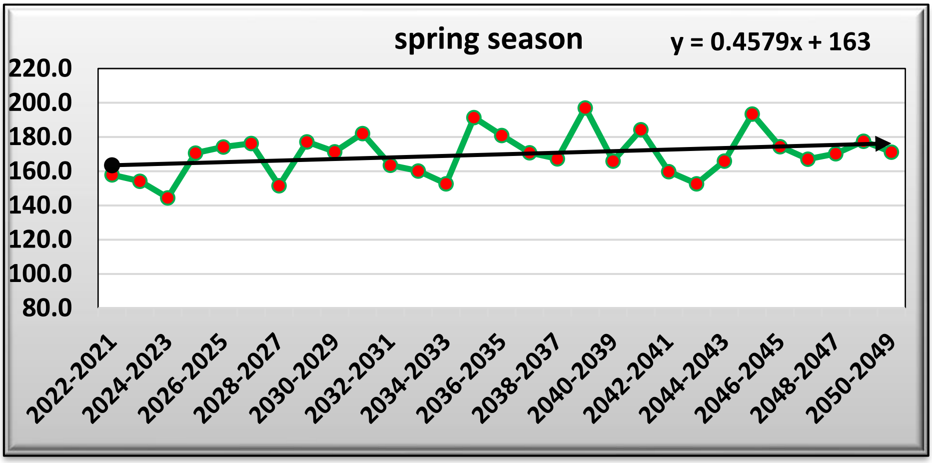
The reference amount of evaporation/transpiration varies seasonally and annually, primarily due to fluctuations in temperature and its impact on this element. This is evident from the analysis of the results presented in table (2) and figure (2). During winter, a notable decrease in the reference amount of evaporation/transpiration was observed, with a trend coefficient of (-0.2989) mm and an annual change coefficient of (-0.0053) mm. Conversely, the spring season exhibited an increase in the reference amount, with a trend coefficient of (0.4579) mm and an annual change of (0.0027) mm, attributed to higher spring rainfall and increased relative humidity. The annual average displayed a trend coefficient of (-0.0143) mm, accompanied by a minimal annual change of (-0.0001) mm.

Table 1: Trend coefficient and seasonal and annual variation of reference evaporation/transpiration (mm) at Baiji station for the period (2021-2050)

Season	Ave.	Trend	Annual change
winter season	56.9	-0.2989	-0.0053
spring season	169.9	0.4579	0.0027
annual rate	110.1	-0.0143	-0.0001

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).





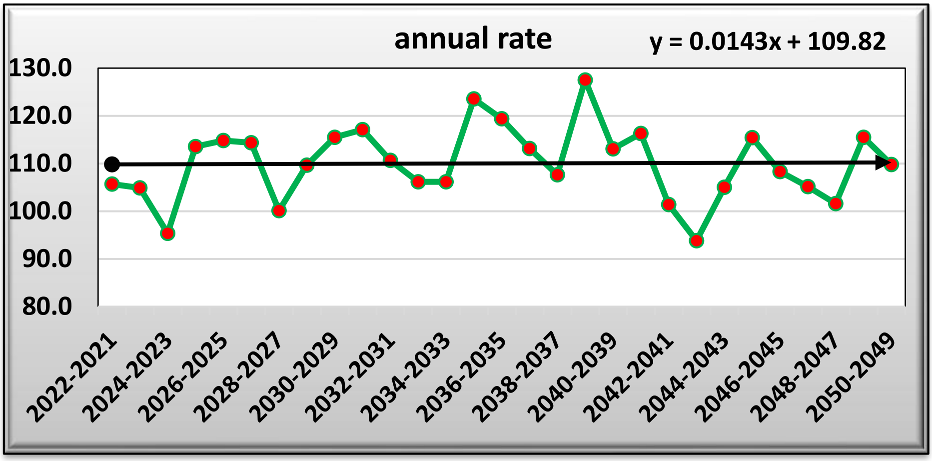


Figure 1: Seasonal and annual trend coefficient of evaporation/transpiration (mm) at Baiji station for the period (2021-2050).

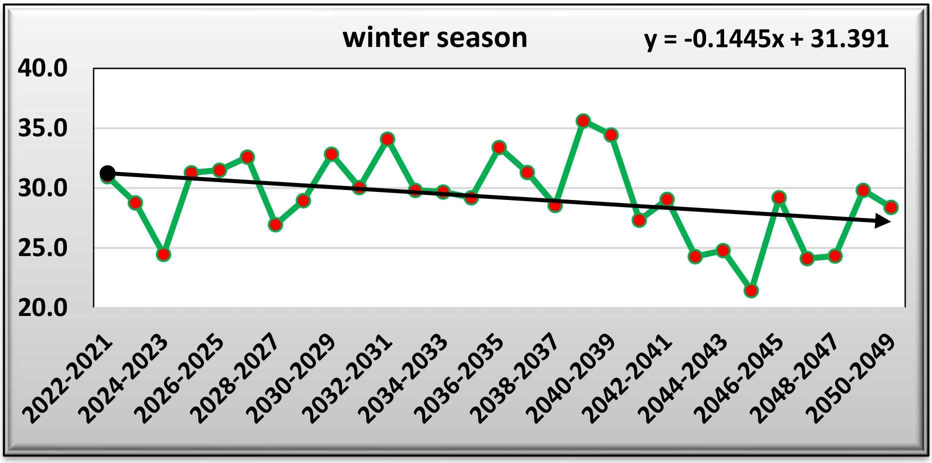
Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

Second: Analysis of the seasonal and annual trend and change of actual evaporation/transpiration

Upon analyzing the results of the change and trend in the amount of actual evaporation/transpiration, both seasonally and annually, it is evident that this variation is due to the difference in temperature and its role in increasing or decreasing that element. This is further supported by the analysis of the results obtained in Table (4) and Figure (4). In the winter, a clear change was recorded towards a decrease in the amount of evapotranspiration/evaporation, with a trend coefficient of (-0.1445) mm and an annual change coefficient of (-0.0049) mm. Then the spring season followed with a positive change towards an increase, with a trend coefficient of (0.4399) mm and an annual change of (0.0026) mm, because of the increase in the amount of spring rain and the rise in relative humidity. The annual average recorded a trend coefficient of (0.1082) mm and a very small annual change of (0.0012) mm.

Table 2: Trend coefficient and seasonal and annual variation of actual evapotranspiration (mm) at Baiji station for the period (2021-2050).

Season	Ave.	Trend	Annual change
winter season	29.2	-0.1445	-0.0049
spring season	170.8	0.4399	0.0026
annual rate	90.2	0.1082	0.0012


winter season
y = -0.1445x + 31.391
40.0
35.0
30.0
25.0
20.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
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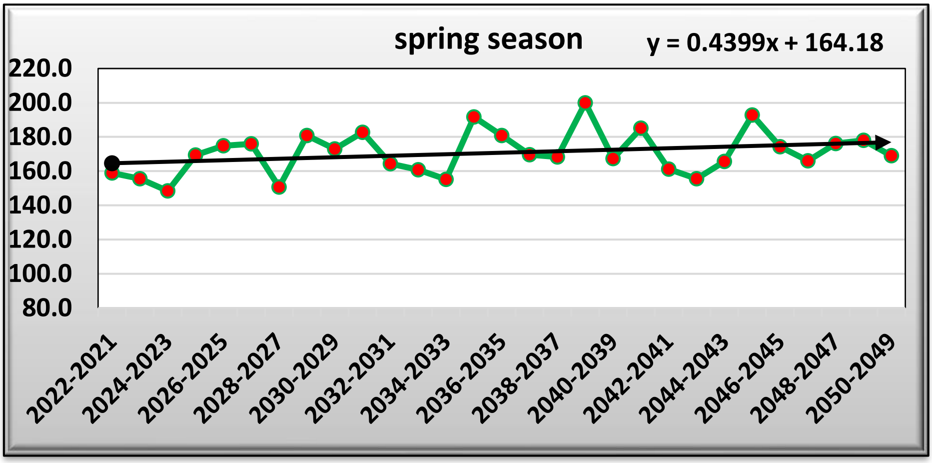
2048-2047
2050-2049


spring season
y = 0.4399x + 164.18
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
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2040-2039
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2048-2047
2050-2049

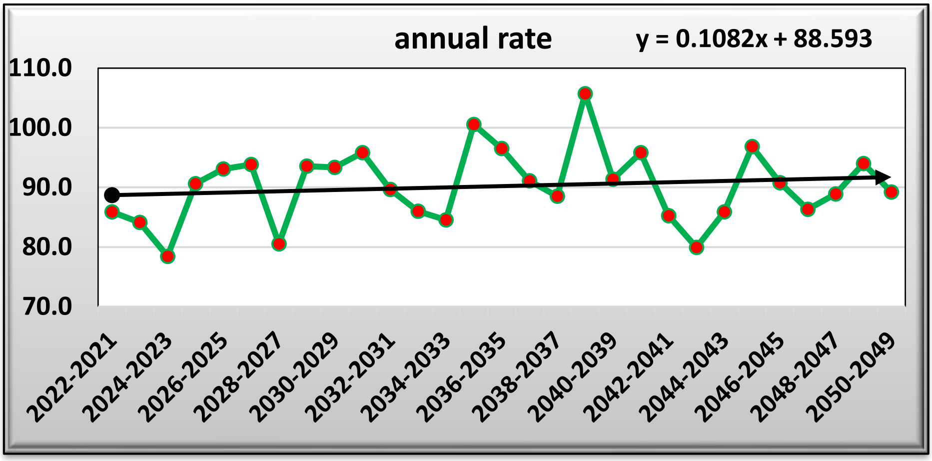


Figure 2: Seasonal and annual trend coefficient of actual evaporation/transpiration (mm) at Baiji station for the period (2021-2050).

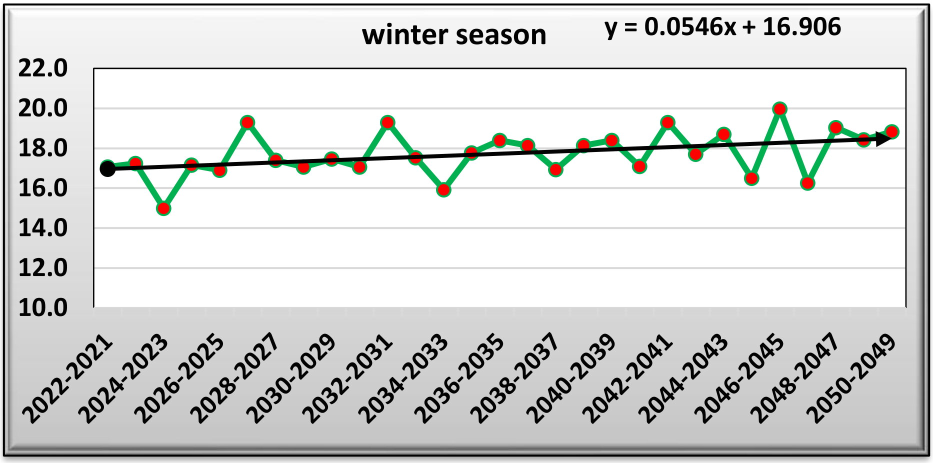
Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

Third: Analysis of the seasonal and annual trend and change of maximum temperature

Upon analyzing the results of the change and trend in maximum temperature, both seasonally and annually, it is evident that there was a general trend towards an increase. This trend is apparent from the analysis of the results obtained in Table (6) and Figure (6). In winter, a clear change was observed towards an increase in maximum temperature, with a trend coefficient of (0.0546) °C and an annual change coefficient of (0.0031) °C. Subsequently, during the spring season, a positive change towards an increase was noted, with a trend coefficient of (0.0807) °C and an annual change of (0.0027) °C. The annual average exhibited a trend coefficient of (0.0722) °C, with an annual change of (0.0030) °C.

Table 3: Trend coefficient and seasonal and annual variation of maximum temperature (ºc) at Baiji station for the period (2021-2050).

Season	Ave.	Trend	Annual change
winter season	17.7	0.0546	0.0031
spring season	29.7	0.0807	0.0027
annual rate	23.9	0.0722	0.0030


winter season
y = 0.0546x + 16.906
22.0
20.0
18.0
16.0
14.0
12.0
10.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
2036-2035
2038-2037
2040-2039
2042-2041
2044-2043
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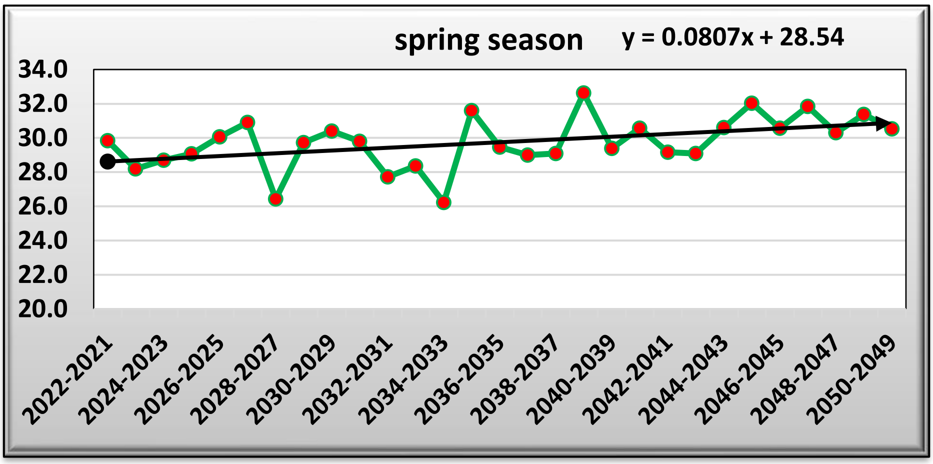
2048-2047
2050-2049


spring season
y = 0.0807x + 28.54
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
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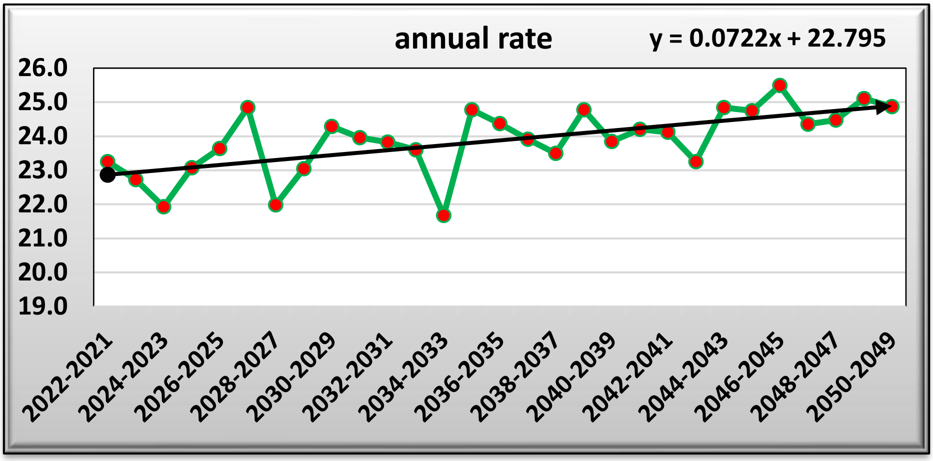
2042-2041
2044-2043
2046-2045
2048-2047
2050-2049



Figures 3: Seasonal and annual trend coefficient of maximum temperature (°c) at Baiji station for the period (2021-2050).

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

Fourth: Analysis of the seasonal and annual trend and change of minimum temperature

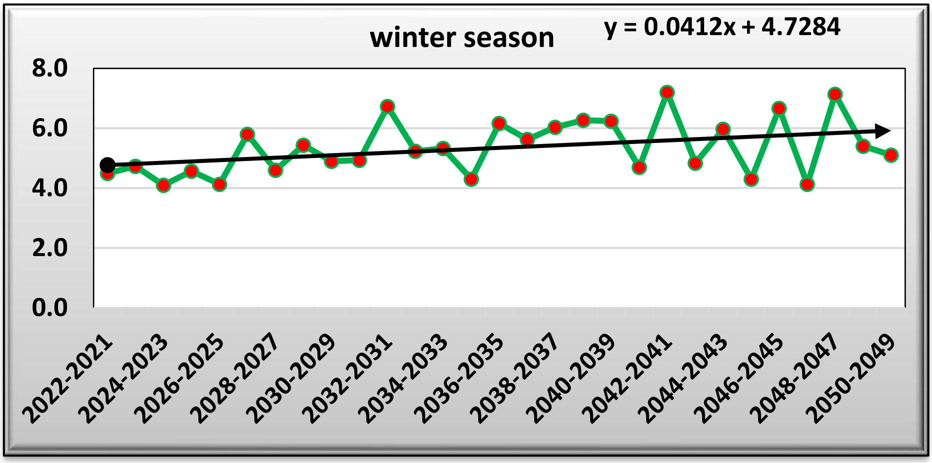
Upon analyzing the results of the change and trend in minimum temperature, both seasonally and annually, it is evident that all the seasonal and annual results exhibited a general trend towards an increase. This trend is illustrated through the analysis of the results presented in Table (8) and Figure (8).

During the winter season, a notable change towards an increase in minimum temperature was recorded, with a trend coefficient of (0.412) °C and an annual change coefficient of (0.0078) °C. Subsequently, the spring season followed suit with a positive change towards a rise, characterized by a trend coefficient of (0.0729) °C and an annual change of (0.0048) °C. The annual average showcased a trend coefficient of (0.0626) °C, with an annual change of (0.0060) °C.

Table 4: Trend coefficient and seasonal and annual change of minimum temperature (°c) at Baiji station for the period (2021-2050)

Season	Ave.	Trend	Annual change
winter season	5.3	0.0412	0.0078
spring season	15.3	0.0729	0.0048
annual rate	10.4	0.0626	0.0060

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).


winter season
y = 0.0412x + 4.7284
8.0
6.0
4.0
2.0
0.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
2036-2035
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2042-2041
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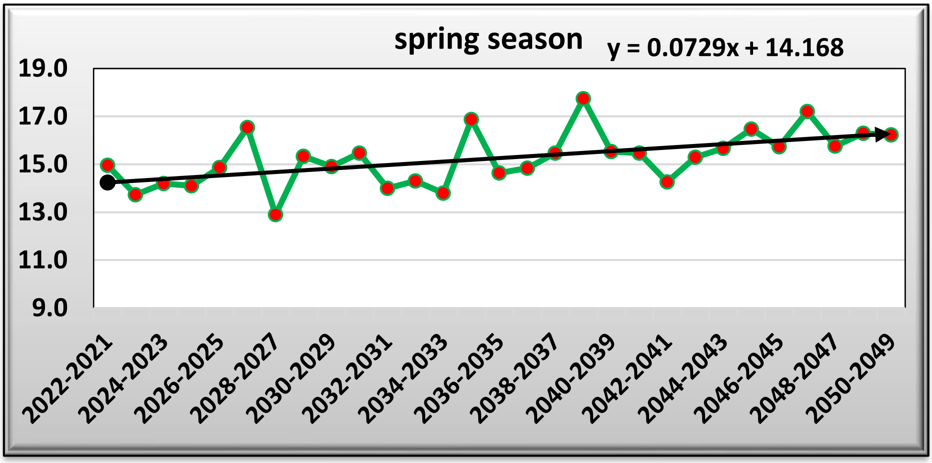
2048-2047
2050-2049


spring season
y = 0.0729x + 14.168
19.0
17.0
15.0
13.0
11.0
9.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
2036-2035
2038-2037
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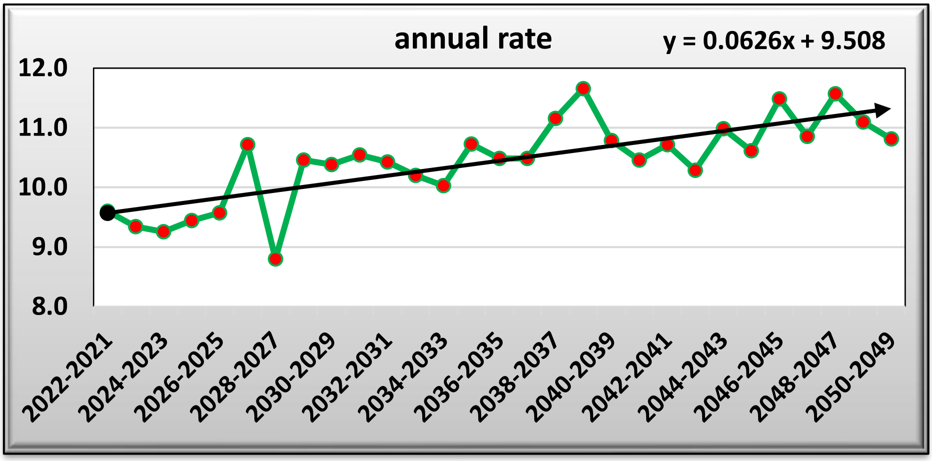
2048-2047
2050-2049



Figures 4: Seasonal and annual trend coefficient of minimum temperature (ºc) at Baiji station for the period (2021-2050)

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

Fifth: Analysis of the seasonal and annual trend and change of relative humidity

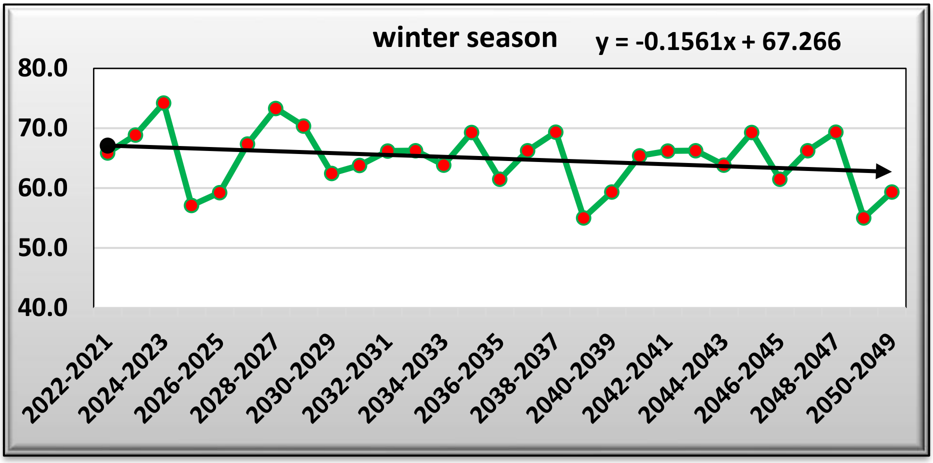
Upon examining the results of the change and trend in relative humidity quarterly and annually, a general trend towards an increase was observed. This trend is evident from the analysis of the results presented in Table (10) and Figure (10), where all the seasons and the annual average exhibited a downward trend.

During the winter season, a clear decrease in relative humidity was recorded, with a trend coefficient of (-0.1561) % and an annual change coefficient of (-0.0024) %. Subsequently, the spring season also witnessed a positive change towards a decrease, with a trend coefficient of (-0.344) %. The annual rate showed a trend coefficient of (-0.2105) % and an annual change of (-0.0040) %.

Table 5: Trend coefficient and seasonal and annual change of relative humidity (%) at Baiji station for the period (2021-2050)

Season	Ave.	Trend	Annual change
winter season	64.9	-0.1561	-0.0024
spring season	42.7	-0.344	-0.0081
annual rate	53.1	-0.2105	-0.0040

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).


winter season
y = -0.1561x + 67.266
80.0
70.0
60.0
50.0
40.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
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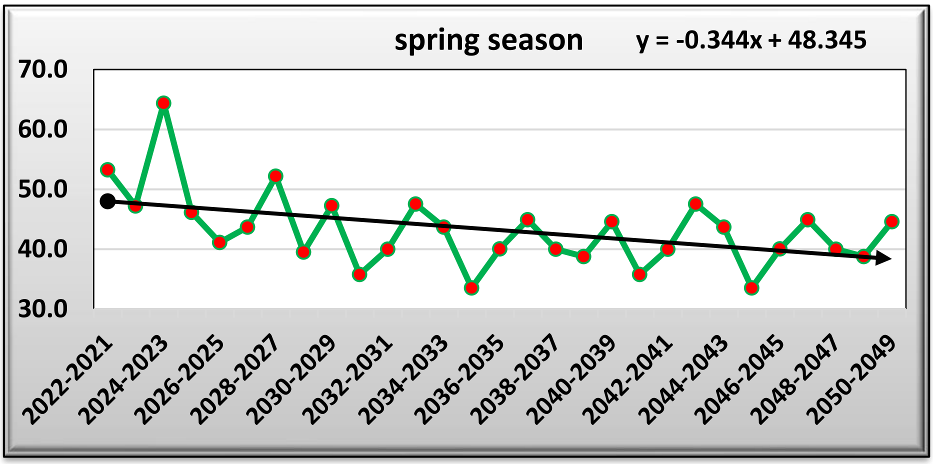
2048-2047
2050-2049


spring season
y = -0.344x + 48.345
70.0
60.0
50.0
40.0
30.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
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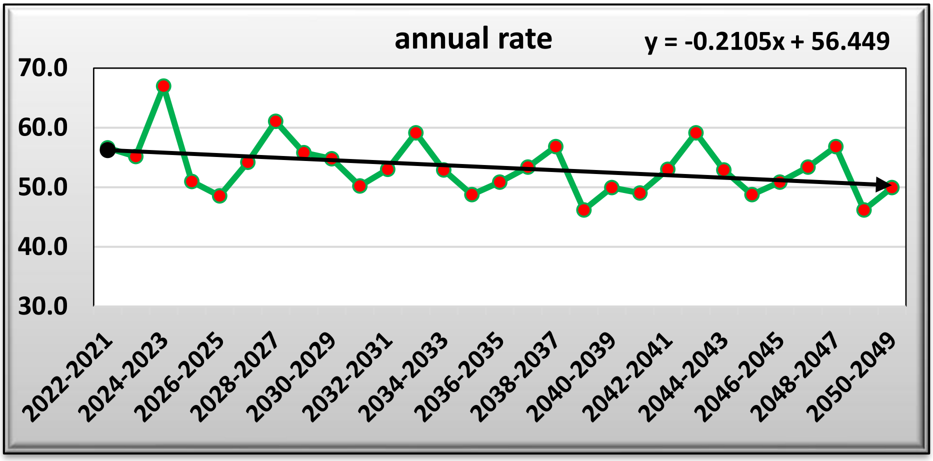
2048-2047
2050-2049



Figures 5: Seasonal and annual trend coefficient of relative humidity (%) at Baiji station for the period (2021-2050).

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

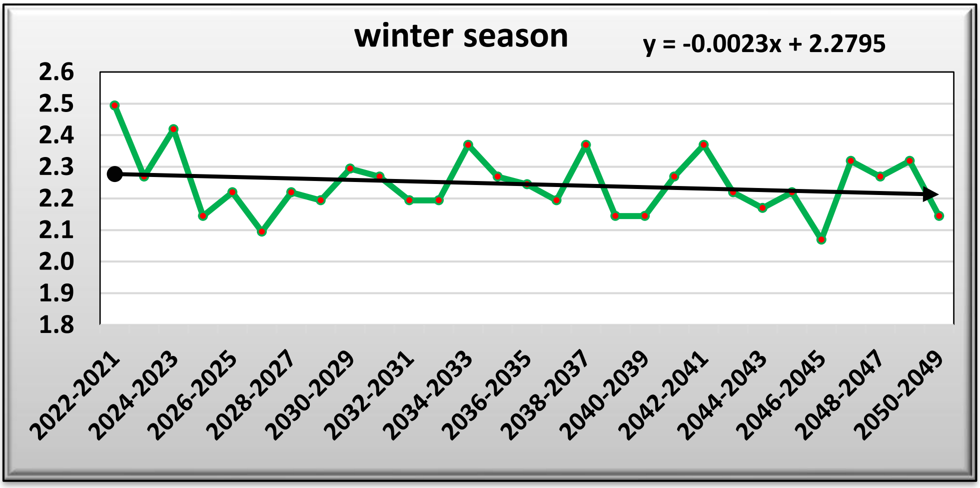
Sixth: Analysis of the seasonal and annual trend and change of wind speed

A general mining the results of the change and trend in seasonal and annual wind speed, a general trend towards an increase was observed, except for the winter season. This trend is evident from the analysis presented in Table (12) and Figure (12). During the winter season, a clear decrease in wind speed was recorded, with a trend coefficient of (-0.0023) m/s and an annual change coefficient of (-0.0010) m/s. Subsequently, the spring season witnessed a positive change towards an increase, with a trend coefficient of (0.0075) m/s and an annual change of (0.0028) m/s. The annual rate recorded a trend coefficient of (0.0028) m/s and an annual change of (0.0012) m/s.

Table 6: Trend coefficient and seasonal and annual change in wind speed (m/s) at Baiji station for the period (2021-2050)

Season	Ave.	Trend	Annual change
winter season	2.2	-0.0023	-0.0010
spring season	2.7	0.0075	0.0028
annual rate	2.4	0.0028	0.0012

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).


winter season
y = -0.0023x + 2.2795
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
2036-2035
2038-2037
2040-2039
2042-2041
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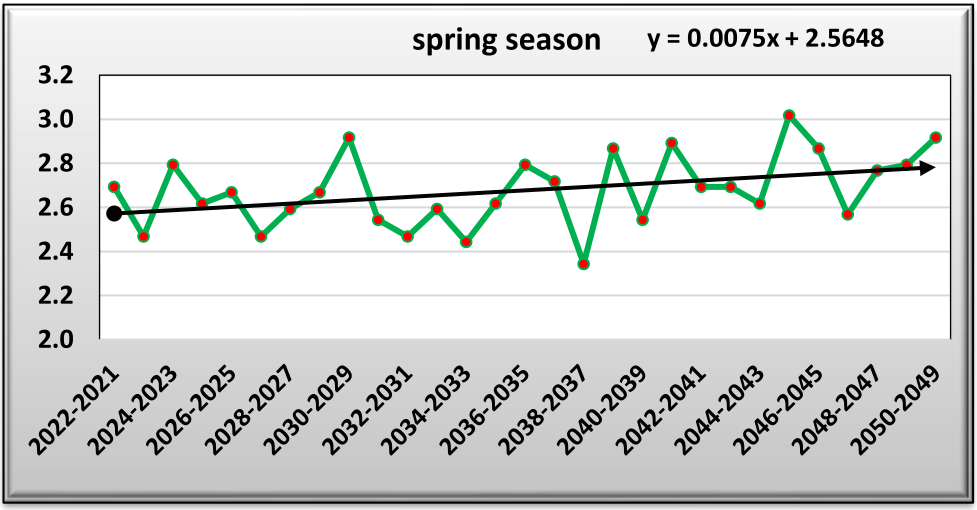
2050-2049


spring season
y = 0.0075x + 2.5648
3.2
3.0
2.8
2.6
2.4
2.2
2.0
2022-2021
2024-2023
2026-2025
2028-2027
2030-2029
2032-2031
2034-2033
2036-2035
2038-2037
2040-2039
2042-2041
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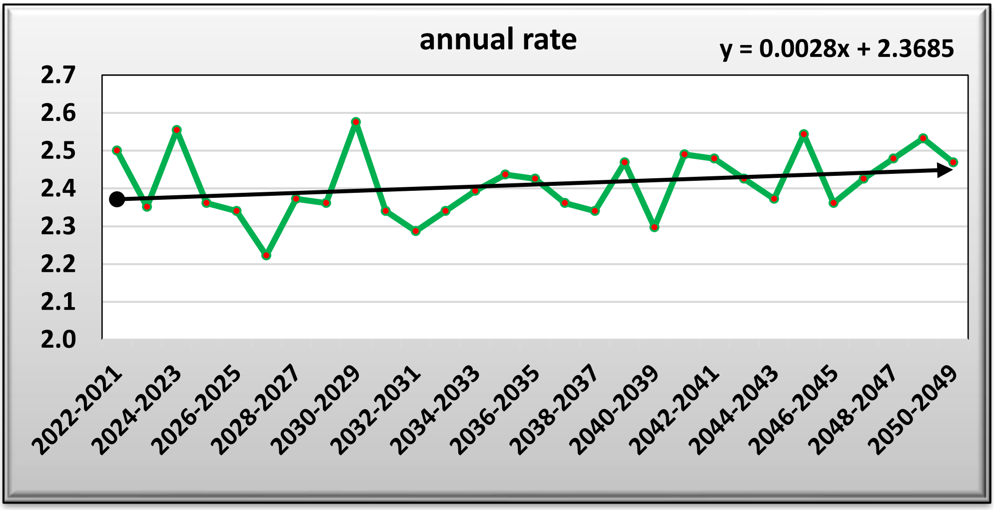
2048-2047
2050-2049



Figures 6: Seasonal and annual trend coefficient of wind speed (m/s) at Baiji station

For the period (2021-2050).

Source: The researcher relies on: https://esgf-node.ipsl.upmc.fr/search/cordex-ipsl/, then it was processed using these programs: (Fortran, Java, Notepad++, read_data, notepad panoply and excel).

4. Conclusions

We evaluated the trend and anticipated changes in climatic elements affecting wheat crop water consumption using the Japanese high model scenario (MIROC5-rcp85) for the period (2021-2050) as follows:

1. Both reference evapotranspiration and actual evapotranspiration are projected to decrease during the wheat crop growth season Similarly, seasonal trends indicate a decline during winter and an increase in spring.

2. Future changes in maximum and minimum temperatures are expected to rise, potentially facilitating the spread of harmful insects like the sun pest. This pest damages wheat by feeding on leaves, stems, and ears, leading to economic losses. Moreover, increased temperatures may promote the spread of fungal diseases such as rust, further impacting wheat yield. With a growing population in the study area, policymakers must take preventive measures to avert potential food shortages.

3. Relative humidity is anticipated to decline annually, quarterly.

4. Wheat crop growth season saw decreasing evapotranspiration, Seasonal trends showed declining evapotranspiration in winter and increasing in spring.

5. Future temperatures are expected to rise, indicating warming at Baiji station. Relative humidity is decreasing annually and seasonally. Wind speed fluctuates, mostly declining in winter and spring.

6. Wind speed trends are variable, showing fluctuations between rise and fall. While some months and the spring season indicate a declining trend, overall, the trend leans towards an increase. High temperatures, low wind speeds, and reduced relative humidity may exacerbate drought conditions at Baiji station, potentially reducing cultivated wheat areas.

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