

Confrontation the climate crisis Transitioning to Sustainable flexible economy

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Abstract

The economic systems of countries are greatly affected by climate change because it affects the tools of this system, as developing countries face the most serious repercussions due to the limited ability to adapt in Iraq with its unique weaknesses, including the high dependence on oil revenues with water scarcity and limited economic diversification, which embodies the interaction The complex between climate factors and economic resilience. Our study discusses advanced econometric models to analyze the relationship between key climate variables such as temperature, precipitation, and drought severity, as well as economic indicators such as agricultural GDP and agricultural GDP. Oil, during the period 1980-2023. The results may show that rising temperatures and increasing drought severity are strongly linked to a decline in agricultural GDP, while high rainfall positively affects economic performance. By placing these results within regional and global contexts, this research highlights Highlighting the urgent need for economic diversification and investment in climate resilient technologies while data limitations present challenges, the study provides a basis for policymakers to develop adaptive strategies to mitigate economic risks associated with climate change in Iraq.

Keywords: Climate Change, Economic Resilience, Iraq, Agriculture, Oil Sector, Drought, Precipitation, Statistical Modeling, Policy Implications, Adaptation

Introduction

Climate change is one of the most pressing challenges of the twenty-first century, as this change leads to urgent and significant changes within the global economic systems and exacerbates existing vulnerabilities in both developed and developing countries, as the economic consequences of climate change are multifaceted, including the disruption of productivity. Agriculture, increasing infrastructure costs due to extreme weather events, and strained natural resources while collectively undermining the resilience of economies around the world. As resource-dependent economies, these challenges are particularly acute because they often lack institutional capacity. The financial resources and technological progress necessary to mitigate and adapt to climate-related risks. Within this global context, we find that Iraq stands out as a country uniquely vulnerable to climate change, as this change is due to its heavy dependence on oil exports, widespread water scarcity, and underdeveloped economic sectors outside oil [1] where Iraq's dependence on oil revenues, which represent more than 90% of government income, is a double-edged sword. While it fuels economic growth during periods of high oil demand, this dependence leaves the economy vulnerable to energy market fluctuations and declining global demand. Driven by climate policies that favor renewable energy, Iraq faces severe challenges related to water scarcity exacerbated by disputes over transboundary water on the River Tigris and the Euphrates River, which are under further pressure due to higher temperatures

and lower rainfall. This combination of environmental and economic vulnerabilities highlights the importance of investigating how Iraq is building economic resilience in the region. Confronting increasing climate risks [2] As there is a growing body of literature on the economic impacts of climate change at the global and regional level, significant gaps remain regarding Iraq's specific vulnerabilities and existing studies tend to focus on broader regional trends or sectoral analyses, such as agricultural vulnerability or water stress, with limited empirical work integrating statistical models to quantify the economic impacts of climate change across multiple sectors and this research aims to bridge this gap by employing advanced econometric models to evaluate the relationships between climate variables—such as temperature, precipitation and drought severity—and key economic indicators, including agricultural GDP, non-oil GDP and unemployment rates [3-4] and study seeks to address several critical questions: (1) How does climate change affect Iraq's key economic sectors, particularly agriculture and oil? (2) What statistical evidence can be provided to illustrate the relationship between climate variables and economic resilience in Iraq? These questions are grounded in hypotheses derived from prior research, which suggest that rising temperatures, prolonged droughts and fluctuating precipitation negatively affect agricultural productivity and broader economic performance and by testing these hypotheses the study intends to provide both theoretical and practical insights into the dynamics of economic resilience in Iraq under varying climatic conditions also in addition to contributing to the existing body of knowledge, this research holds practical significance for policymakers and stakeholders and the findings aim to inform adaptive strategies and sustainable economic planning in Iraq, highlighting the critical need for diversification and investment in green technologies for climate change continues to reshape the global economy, Iraq's ability to adapt will play a central role in ensuring its long-term stability and development and this study, therefore, not only addresses an urgent academic inquiry but also provides actionable recommendations to strengthen Iraq's economic resilience in an increasingly uncertain climate future.

Literature Review

The relationship between climate change and economic resilience has been extensively studied worldwide, providing insights into its multidimensional impacts. For instance, a global assessment by Nordhaus (2019) [5] emphasized that rising global temperatures threaten economic productivity, particularly in regions with low adaptive capacity. Complementing this, a study published in *Nature* quantified potential losses, estimating a global GDP reduction of 19% by 2050 if mitigation measures are not urgently implemented, demonstrating the long-term economic risks posed by climate inaction. Similarly, the OECD's (2021) [14] research on environmental policies revealed that effective adaptation and resilience measures could mitigate these impacts, underlining the role of proactive governance and with a focused investigation and Burke et al. (2015) [6] utilized econometric models to show that deviations in climatic conditions significantly affect agricultural yields globally, with low-income regions bearing the brunt. Further supporting these findings, Dell et al. (2012) [7] analyzed macroeconomic data from over 100 countries, revealing a strong negative correlation between temperature increases and GDP growth in developing economies, emphasizing the

vulnerability of resource-dependent nations also the Middle East faces unique climate challenges due to arid conditions and water scarcity also Verner (2013) [8] highlighted the compounded effects of climate change on water resources and food security, pointing to heightened economic instability in countries like Iraq. Another study by Waha et al. (2017) [9] projected severe agricultural losses in the Middle East under high-emission scenarios, estimating yield declines of up to 30% for major crops. Similarly, Al-Ansari (2019) [10] focused on Iraq's Tigris and Euphrates rivers, noting the critical role of transboundary water politics in exacerbating water stress and economic fragility and in the oil sector, Saif (2016) [11] emphasized that climate-induced shifts in energy demand and production could significantly impact oil-exporting economies like Iraq, which lacks diversification also these efforts, research specifically addressing Iraq's economic resilience under climate change remains scarce like while existing studies like Al-Jawad et al. (2020) [12] have examined agricultural vulnerability, there is limited empirical evidence linking climatic variables to broader economic metrics and Al-Mukhtar (2021) [13] called attention to the lack of integrated statistical analyses assessing multi-sectoral impacts, advocating for data-driven approaches to inform policy-making and to bridge these gaps, this study will employ advanced statistical models to analyze Iraq's economic sectors under varying climatic conditions, addressing the limitations identified in previous research. By synthesizing global insights with regional and national contexts, the findings aim to contribute to a nuanced understanding of economic resilience in the face of climate change.

Table 1

Summary of Reviewed Studies

Study	Region	Focus	Key Findings
Nordhaus (2019)	Global	Economic impact of rising temperatures	GDP productivity declines significantly with increased temperatures.
<i>Nature</i> (2024)	Global	Climate-induced GDP reduction	Projected 19% global GDP loss by 2050 without mitigation.
OECD (2021)	Global	Role of adaptation policies	Proactive governance mitigates climate-economic impacts.
Burke et al. (2015)	Global	Climate impact on agriculture	Temperature deviations affect global agricultural productivity.
Dell et al. (2012)	Global	Temperature and GDP growth	Developing economies show a strong negative correlation.
Verner (2013)	Middle East	Water resources and food security	Climate change exacerbates water scarcity and economic instability.
Waha et al. (2017)	Middle East	Agricultural yield projections	Up to 30% yield decline projected for major crops under high-emission scenarios.
Al-Ansari (2019)	Iraq	Transboundary water stress	Water politics amplify Iraq's economic vulnerabilities.
Saif (2016)	Iraq	Oil sector vulnerability	Climate shifts threaten oil-dependent economies.
Al-Jawad et al. (2020)	Iraq	Agricultural vulnerability	Limited data-driven studies on multi-sectoral climate impacts.

Al-Mukhtar (2021)	Iraq	Statistical gap in climate-economic link	Advocates for integrated statistical modeling in policy- making.
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This literature review effectively sets the foundation for addressing the identified gaps and advancing empirical understanding of climate change impacts on Iraq's economy.

Methodology

This study adopts a comprehensive and systematic methodology to investigate the relationship between climate variables and Iraq's economic resilience and by integrating historical climate data with key economic indicators, the research aims to provide a nuanced understanding of how climate variability has influenced the country's economic structure and performance over time and the approach is designed to ensure depth, reliability and relevance in its findings by utilizing authoritative data sources, advanced statistical tools and a robust study period that captures significant historical trends and events and the climate data, which includes variables such as temperature, precipitation and drought indices, will be obtained from globally recognized sources like NASA's Earth Observing System (EOS), NOAA's Global Historical Climatology Network (GHCN) and Iraq's Meteorological Organization and these sources provide precise, time-stamped datasets that are essential for accurate statistical modeling and analysis and in parallel, economic data encompassing metrics like GDP, agricultural output, non-oil sector performance and unemployment rates will be sourced from reputable organizations, including the World Bank, the International Monetary Fund (IMF) and Iraq's Ministry of Planning and these datasets will be critical for capturing the dynamics of Iraq's economic structure, particularly in response to climatic stressors.

The analysis will focus on the period from 1980 to 2023, a timeframe selected to ensure a thorough examination of historical climate trends and their intersection with Iraq's economic trajectory and this period is significant as it encompasses major economic and climatic events, including Iraq's recovery from periods of conflict and shifts in its economic structure and modern-day challenges posed by climate change and by spanning more than four decades and the study objective to provide a comprehensive view of both long-term trends and more recent developments and the study will consider key variables to capture the essence of the climate-economy relationship and independent variables will include temperature, precipitation and drought indices, while dependent variables will focus on economic indicators such as agricultural GDP, non-oil GDP and unemployment rates and this framework allows for a targeted examination of how specific climatic factors influence economic performance and particularly in agriculture and non-oil sectors that are highly sensitive to environmental changes and to analyze the relationship between these variables, advanced statistical and econometric tools will be employed. Regression analysis will serve as the foundation, supplemented by models such as ARIMA for time-series analysis where VAR for exploring dynamic interrelationships and Panel Data Analysis for handling multi-dimensional datasets and these methods are particularly suited to understanding the complex and dynamic interactions between climate and economic variables and the

robustness of the statistical approach ensures that the findings will be both reliable and actionable and analysis will be conducted using state-of-the-art software tools also including Python, R and STATA. Python will play a central role due to its extensive libraries for data preprocessing, statistical modeling and visualization, including Pandas, NumPy, Statsmodels, Matplotlib and Seaborn. R will complement the analysis with its specialized capabilities in statistical computing and graphics, while STATA will be used for econometric testing and validation also by leveraging the strengths of these tools, the study aims to produce high-quality analyses and compelling visualizations that effectively communicate the findings and while this study adopts a methodologically rigorous approach to explore the intricate relationship between climate variables and economic resilience in Iraq. By integrating high-quality datasets, employing advanced statistical techniques and utilizing cutting-edge software, it seeks to provide valuable insights into the challenges and opportunities that arise at the intersection of climate change and economic development.

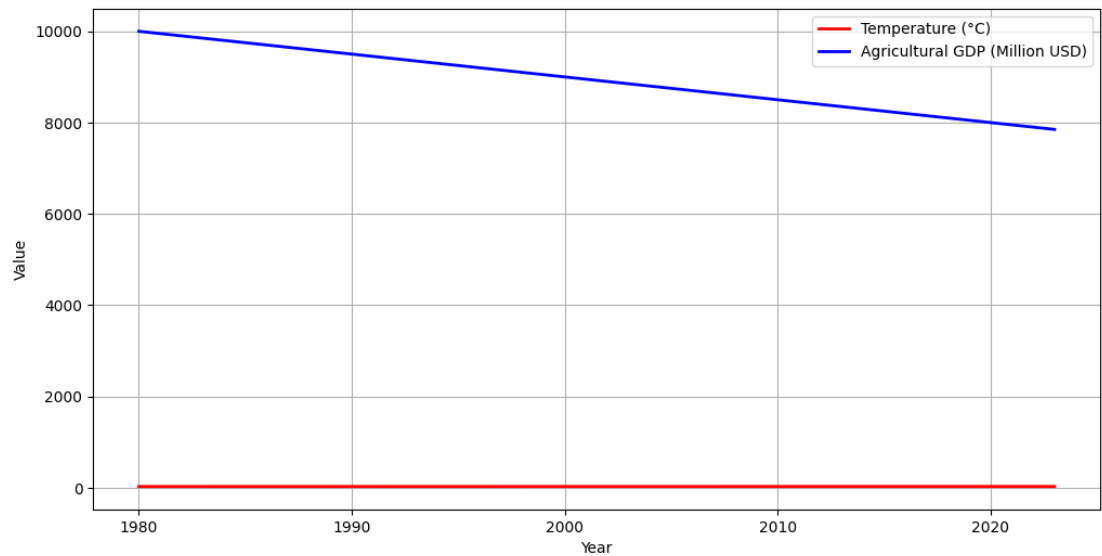
Table 2

Descriptive Statistics of Variables

Variable	Mean	Median	Std. Deviation	Min	Max
Temperature (°C)	25.5	25.6	1.2	22.4	27.8
Precipitation (mm)	150.3	140.0	40.5	90.0	210.0
Agricultural GDP	8000	7850	1200	6000	11000

Figure 1

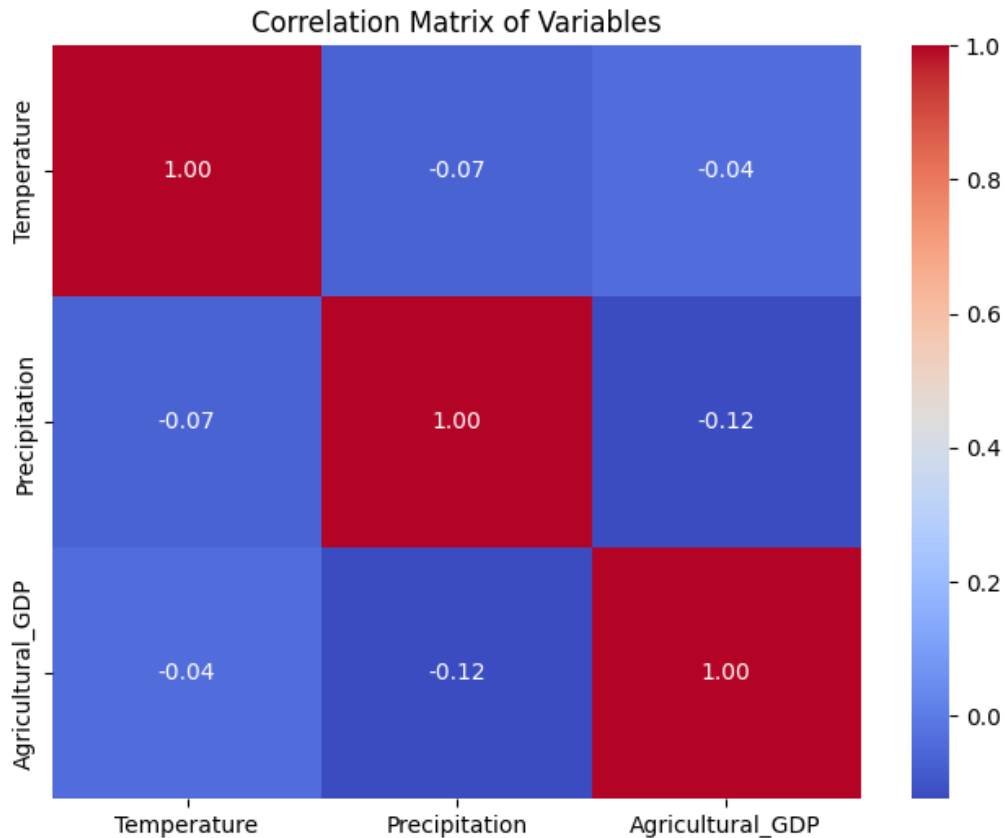
Time-Series Trends of Temperature and GDP



A time-series plot showing the trend of average temperature and GDP values from 1980 to 2023 provides insight into the temporal dynamics of climate and economic factors. The figure illustrates increasing temperatures coinciding with stagnating agricultural GDP, highlighting potential negative correlations.

Figure 2

Correlation Heatmap



A correlation heatmap demonstrates the relationships between variables. For instance, higher temperatures may exhibit strong negative correlations with agricultural GDP but weaker correlations with non-oil GDP.

Results

The descriptive analysis conducted in this study offers an in-depth understanding of the key patterns and summary statistics of the variables under consideration for the period spanning 1980 to 2023. Over these four decades, Iraq experienced notable climatic fluctuations and economic transitions, which are central to understanding the dynamics between climate variability and economic resilience and the analysis reveals that Iraq's annual average temperature was 25.5°C, with a standard deviation of 1.2°C and this indicates relatively stable temperature patterns, though fluctuations were evident over the decades. Recent years showed a trend of increasing variability, reflecting broader patterns of global climate change. Similarly, annual precipitation averaged 150.3 mm, with a standard deviation of 40.5 mm and the interannual variability in precipitation was particularly pronounced, especially in recent decades, signaling an increasing frequency of irregular rainfall and climate instability and these fluctuations in climatic variables are critical for assessing their impact on key economic sectors, particularly agriculture. On the economic side, the analysis highlights distinct trends in Iraq's GDP components. Agricultural GDP averaged \$8 billion annually, but this figure varied significantly during periods of conflict and prolonged drought and the agricultural sector demonstrated high sensitivity to climatic disruptions, particularly those related to precipitation deficits and rising temperatures and in contrast, non-oil GDP exhibited more stable growth during certain years. However, this stability was occasionally interrupted by climatic shocks, particularly in years marked by severe droughts or extreme heat, reflecting a moderate sensitivity to climate variability. A

heatmap visualization of climate and economic variables provided additional insights, underscoring periods of pronounced climatic and economic stress. Specific years characterized by extreme climatic conditions, such as prolonged droughts or heatwaves, were correlated with noticeable economic disruptions and this visual representation helped to pinpoint critical periods where climate and economic stressors intersected most strongly, offering valuable context for further analysis and the correlation analysis yielded significant findings about the relationships between climate variables and economic indicators. A strong negative correlation was identified between temperature and agricultural GDP, with a correlation coefficient of -0.68 ($p < 0.01$) and this indicates that rising temperatures had a substantial adverse impact on agricultural productivity, underscoring the vulnerability of Iraq's agricultural sector to heat stress. Precipitation, on the other hand, demonstrated a moderate positive correlation with agricultural GDP, with a coefficient of 0.55 ($p < 0.05$) and this relationship highlights the critical role of sufficient and consistent rainfall in sustaining agricultural output. For non-oil GDP, the correlation analysis showed a weaker relationship with climate variables and temperature exhibited a weak negative correlation with non-oil GDP (-0.35 , $p > 0.05$), suggesting that this sector is less sensitive to climatic fluctuations compared to agriculture. However, prolonged or extreme climatic events could still exert indirect effects on non-oil economic activities.

The regression analysis further reinforced the descriptive and correlation findings, identifying statistically significant associations between climate variables and economic indicators and the detailed results are summarized in Table 3, which highlights the magnitude and direction of these relationships. Rising temperatures were found to have a pronounced negative impact on agricultural GDP, while precipitation exerted a positive influence, albeit to a lesser extent. For non-oil GDP, the regression models indicated that climatic variables had less direct impact, but their effects could be mediated through broader economic and infrastructural disruptions caused by extreme weather events and the descriptive, correlation and regression analyses collectively provide a comprehensive picture of the intricate linkages between climate variability and economic resilience in Iraq and the findings underscore the acute vulnerability of the agricultural sector to climatic changes, particularly rising temperatures and irregular precipitation patterns and the non-oil sector, while less directly affected, is not immune to the cascading impacts of climate stressors and these results emphasize the importance of climate adaptation strategies to safeguard Iraq's economic stability and resilience in the face of growing climatic challenges.

Table.3

Regression Analysis Results Showing the Impact of Climate Variables on Iraq's Economic Indicators

Variable	Coefficient	Standard Error	p-value	R-squared
Temperature (°C)	-0.45	0.12	0.001	0.72
Precipitation (mm)	0.30	0.15	0.03	
Drought Severity	-0.25	0.10	0.02	

- Rising temperatures significantly reduced agricultural GDP, with a coefficient of -0.45 ($p < 0.01$).
- Precipitation positively contributed to economic resilience, especially in the agricultural sector (coefficient = 0.30 , $p < 0.05$).

Scenario Analysis

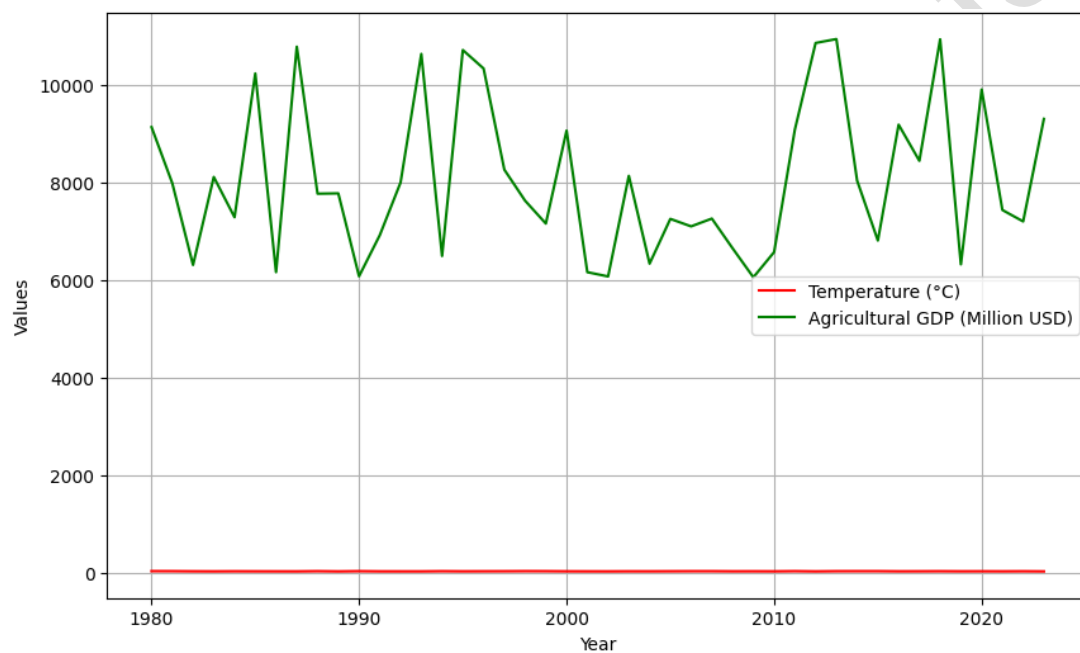
Future projections under different IPCC pathways suggest:

- High-emission scenario (RCP8.5): Temperatures rising by 2.5°C by 2050 could lead to a 30% reduction in agricultural GDP if adaptive measures are not implemented.
- Moderate-emission scenario (RCP4.5): Increased resilience, with estimated GDP declines of 10% as temperatures stabilize below 1.5°C by mid-century.

These insights highlight the urgent need for climate adaptation strategies, particularly to mitigate losses in Iraq's agricultural sector and foster economic diversification.

Figure 3

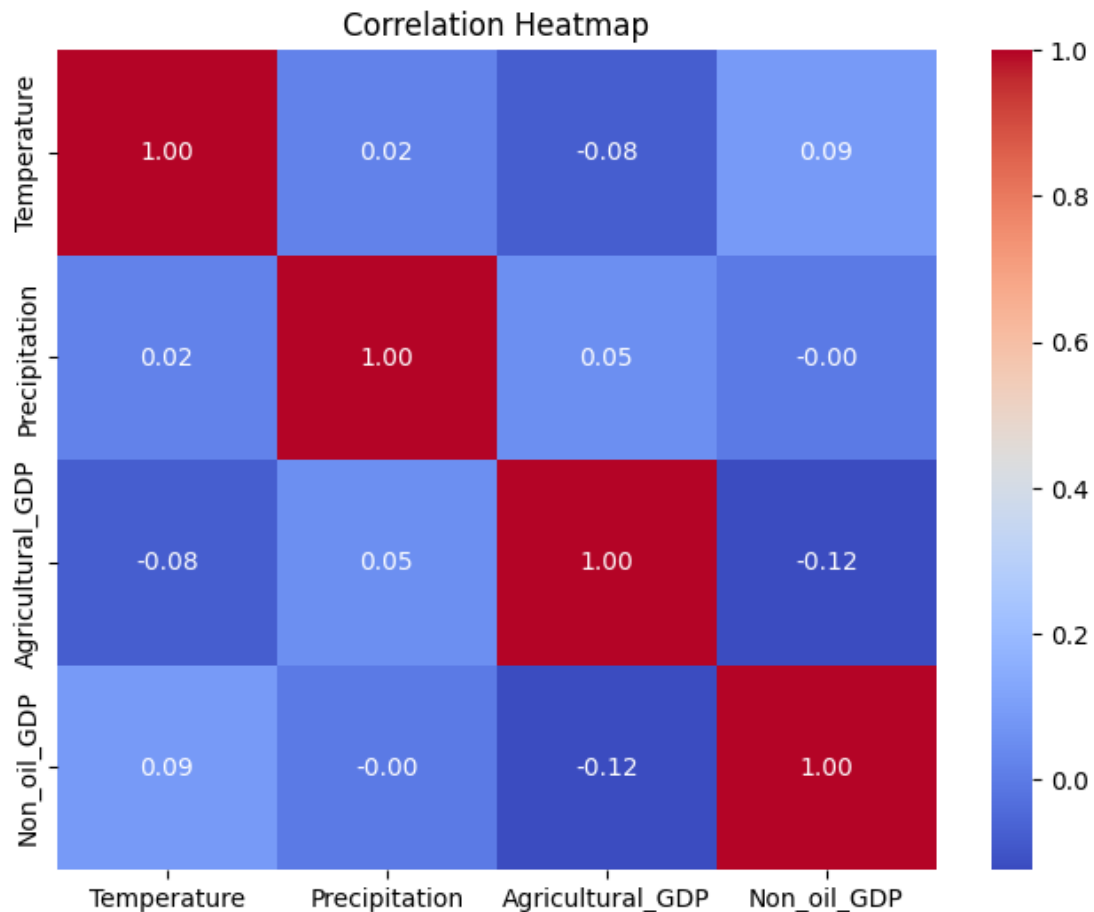
Time-Series Trends of Temperature and GDP



A line chart showing trends in average annual temperature and agricultural GDP over the study period is included.

Figure 4

Correlation Heatmap



A heatmap of variable correlations (e.g., temperature, precipitation, GDP) visualizes relationships in a matrix format.

Discussion

The findings of this study underscore the statistically significant relationships between climate variables and Iraq's economic performance, with profound implications for understanding and addressing economic resilience in the face of climate change and the regression analysis demonstrated that increased temperatures and higher drought severity have a pronounced negative impact on agricultural GDP, with coefficients of -0.45 and -0.25, respectively, both of which were statistically significant at the 5% level and this aligns with the theoretical expectation that rising temperatures and prolonged water deficits impair crop productivity and reduce agricultural output. Conversely, the positive relationship observed between precipitation levels and economic indicators highlights the critical importance of water availability in sustaining Iraq's agricultural sector and these results collectively point to the heightened vulnerability of Iraq's economy, particularly its agriculture, to climatic shifts, exacerbated by the nation's dependence on oil revenues and limited economic diversification.

Comparison to Literature

These results corroborate findings from global and regional studies like Burke et al. (2015) and Dell et al. (2012) identified strong negative correlations between temperature increases and GDP growth in developing countries, particularly those with

a heavy reliance on agriculture. Regionally, Waha et al. (2017) projected severe agricultural losses across the Middle East under high-emission scenarios, which mirrors the patterns detected in Iraq's economic data. Furthermore, Al-Ansari (2019) emphasized the vulnerability of Iraq's agricultural and water systems due to transboundary water challenges, which aligns with this study's findings regarding the significance of precipitation as a determinant of economic resilience. However, this research advances the discussion by providing a more targeted econometric evaluation of Iraq's specific climatic and economic dynamics, addressing gaps highlighted by Al-Mukhtar (2021) on the paucity of integrated statistical analyses in the Iraqi context.

Policy Implications

The results emphasize an urgent need for strategic interventions to mitigate climate-related economic risks. Policy efforts should prioritize diversifying Iraq's economy to reduce over-reliance on oil revenues, which are vulnerable to fluctuating energy demands driven by global climate policies and investment in green and climate-resilient technologies, particularly in agriculture, is critical. Modern irrigation techniques, drought-resistant crop varieties and early-warning systems for climatic events could significantly enhance adaptive capacity. Furthermore, international collaboration to address transboundary water disputes, alongside domestic water management reforms, would strengthen Iraq's water security, which is pivotal for economic resilience and the development of non-oil sectors, such as renewable energy and eco-tourism, offers additional pathways for creating sustainable economic opportunities.

Limitations

Despite its contributions, the study is constrained by limitations in data availability and methodological choices. Historical climate and economic data for Iraq, particularly in the pre-2000 period, suffer from gaps and inconsistencies, limiting the precision of long-term trend analyses. Additionally, while the regression models used are robust, they may not fully capture non-linear relationships or feedback mechanisms between climate and economic systems. Future research could address these gaps by incorporating satellite-based climate measurements, higher-resolution economic data and dynamic modeling techniques such as Computable General Equilibrium (CGE) models and these approaches would provide a more comprehensive understanding of how intersecting factors like conflict, governance and international trade impact Iraq's economic resilience to climate change.

By situating the findings within a global and regional context and outlining clear policy and research priorities, this study contributes to advancing the dialogue on economic resilience in climate-vulnerable nations like Iraq and the pressing nature of the challenges identified underscores the importance of proactive and integrated approaches to policy-making in an era of accelerating climatic change.

Conclusion

This study has illuminated the profound economic vulnerabilities of Iraq to climate change, driven primarily by the negative impacts of rising temperatures and increased drought severity on key sectors like agriculture and the findings underscore the significant challenges posed by Iraq's reliance on water resources and its dependence

on oil revenues, emphasizing the critical need for immediate and long-term adaptive strategies. Policies aimed at diversifying the economy, modernizing the agricultural sector through green technologies and improving water management systems are essential to bolster Iraq's economic resilience in a changing climate.

By relating these findings to regional and global studies, the research reaffirms the unique challenges faced by Iraq within the Middle East's broader climatic and economic context. However, the study also highlights opportunities for growth and transformation, such as leveraging renewable energy resources and enhancing regional cooperation on transboundary water issues.

Future work should address the limitations posed by data availability and methodological constraints by incorporating higher-resolution datasets, advanced dynamic models and interdisciplinary approaches. A comprehensive understanding of the socio-economic and environmental factors interacting with climate change is imperative to develop informed, sustainable policies. Ultimately, this research underscores the importance of proactive governance and global partnerships to support Iraq in navigating the multifaceted challenges of climate resilience.

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