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# The Impact of Thermal Shocks on Agricultural Cultivated Areas: A Case Study of Wheat, Tomato and Cucumber in, Bazian Plain, Sulaymaniyah (1993- 2023), Iraq.

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## ABSTRACT
This study evaluates the impact of thermal shock on agricultural land cultivated with wheat, tomato, and cucumber in Sulaymaniyah province, northern Iraq, over a 30-year period (1993–2023). Thermal shock, defined as sudden and significant fluctuations in temperature, was analyzed using annual average data, which ranged from a low of 16.42°C in 2012 to a high of 20.66°C in 2019. The study examined cultivated area records for the three crops to assess the influence of thermal variations on agricultural productivity and land use. The findings reveal that wheat, a staple crop in the region, demonstrated notable resilience to thermal fluctuations. The cultivated area for wheat increased steadily from 25,300 dunams in 1993 to 35,000 dunams in 2023, despite exposure to varying degrees of thermal shock. In contrast, tomato and cucumber crops exhibited significantly higher sensitivity to temperature variability. Tomato cultivation, which peaked at 8,500 dunams in 2000, experienced a drastic decline to 140 dunams by 2023, particularly during periods of elevated average thermal shocks. Similarly, cucumber cultivation experienced substantial fluctuations, with a peak of 450 dunams in 2012, which decreased sharply to 100 dunams by 2023. However, climate change was not the only reason for the decrease in agricultural areas, as the spread of greenhouse cultivation contributed to the decrease in field agricultural areas. These results underscore the contrasting levels of vulnerability among different crops, with wheat benefiting from inherent resilience mechanisms, while tomatoes and cucumbers are more susceptible to adverse climatic conditions. The study highlights the critical need for implementing climate-resilient agricultural strategies tailored to mitigate the effects of thermal shocks. Such interventions are essential for ensuring the sustainable cultivation of sensitive crops and supporting the long-term economic stability of the agricultural sector in Sulaymaniyah.

***Keywords*:** thermal shock, Cultivated area, temperature, Economic growth .



## INTRODUCTION
The Kurdistan region is particularly vulnerable to rising temperatures due to its reliance on rainfall-dependent agriculture. Changes in precipitation patterns and increased temperatures have already disrupted agricultural activities, resulting in reduced crop yields and livestock productivity, which directly impact the local economy [1].
experiencing heightened evapotranspiration rates, increasing water demand, which further stresses agricultural resources and contributes to economic instability, faces increasing occurrences of drought and reduced water availability, which have led to a 40% decline in irrigation water supply in some areas. This is primarily attributed to decreased rainfall and shifting climate patterns. Such conditions exacerbate vulnerabilities in sectors like agriculture and can lead to economic losses and even displacement [2].
A report from the International Organization for Migration (IOM) highlights the complex interplay between climate-induced challenges and socio-economic vulnerabilities in KRI. While the region has fared slightly better than central and southern Iraq in terms of displacement and extreme events, localized issues such as dust storms and unseasonal temperature variations remain significant challenges [3].
studies across the Middle East also point to the economic repercussions of rising temperatures, including reduced labor productivity in outdoor jobs, higher energy costs for cooling, and cascading effects on food security and public health. Such impacts are particularly pronounced in regions like KRI that are heavily reliant on natural resources, understanding these dynamics will help establish a solid link between temperature shocks and economic growth in

your study. It provides evidence of how extreme climate variations can disrupt livelihoods, reduce productivity, and create ripple effects across local and regional economies [4].

Economic growth remains a central objective for regions worldwide, reflecting their capacity to improve living standards and sustain economic well-being. Dragoi Doina 2020. emphasizes the multidimensional nature of economic growth, which encompasses factors ranging from technological advancements to natural resource utilization and environmental challenges. In this context, understanding the interplay between environmental dynamics and economic performance is essential. For the Bazian Plain, thermal shocks represent a critical environmental factor that directly influences key economic sectors such as agriculture and energy. Investigating the effects of these temperature fluctuations on economic growth provides valuable insights into the region's resilience and adaptive capacities, contributing to broader discussions on sustainable development in environmentally vulnerable areas [5]. Since 2007, agriculture under plastic houses began to spread until the number reached 17,000 plastic houses and 125 unite of multi span in March 2024, as explained by the Protected Agriculture Syndicate in Sulaymaniyah Governorate.

[6] examines the relationship between agriculture and economic growth, with key insights into sectoral contributions to macroeconomic stability and growth. The study emphasizes how agricultural income can stimulate broader economic development by creating intersectoral linkages, especially in contexts where the majority of the workforce relies on agriculture.

For example, in Ethiopia, a \$1 increase in agricultural income was estimated to contribute an additional \$1.71 to GDP, benefiting rural populations significantly more than similar contributions from the industrial or service sectors. This highlights the stabilizing effect of agricultural investments on broader economic growth, particularly in regions with high dependence on this sector. These dynamics underline the importance of sectoral balance in economic planning, particularly in resource-constrained settings like Bazian Plain, where thermal shocks could disrupt agricultural productivity and, consequently, overall economic stability [7].

The study by [8] evaluates the economic effects of climate change on U.S. agriculture by analyzing how yearly variations in temperature and precipitation influence agricultural profits. The findings suggest a moderate benefit, with climate change projected to increase annual agricultural profits by approximately \$1.3 billion (2002 dollars). The study also highlights the limitations of the hedonic approach, emphasizing the need for robust econometric methods to account for adaptation strategies and ensure accurate projection.

A study of temperature data from 1973 to 2019 shows clear evidence of climate change in the region. The annual average temperature increased by 1.3°C, with 2010 being the warmest year at 21.55°C. Average temperatures rose steadily: 18.39°C (1973-1985), 18.79°C (1986-1998), 19.93°C (1999-2010), and 20.09°C (2011-2018). The annual range of temperatures varied, with the largest difference in 1973 (53°C) and the smallest in 1987 (35°C). Rising temperatures increased nematode infestations in soils, leading to more greenhouses (nearly 7,000) in the study area. These greenhouses altered the agroecosystem, consuming large amounts of water (125 $m^3$/greenhouse) and requiring pesticides that damaged soils and yields [9].

**Methods & Methodology:**

We relied on data on the areas of land cultivated in the Bazian region with wheat, cucumbers and field tomatoes. This crop was chosen for several reasons, such as because it is the oldest and most accurately documented compared to other crops. We were unable to use the production amount of these lands due to the inaccuracy of the production data and its change. Using wheat cultivated areas as a proxy for Predictive economic growth and is an interpreted, object-oriented, high-level programming language with dynamic semantics in Python used pandas and stats models. The Temperature data was taken from the weather station in Bazian area.

Data Processing and Computational Workflow two Independent Variable choosing for the research

temperature and thermal shocks; for the study area (Bazian Plain) From the Meteorological Department, monthly temperature rates were obtained for the years 1973-2023 Then, thermal shocks were found for each monthly rate for each year.

To analyze the effect of thermal shocks on Predicted economic growth in the Bazian Plain computational tools were employed for data preprocessing statistical modeling and regression analysis. During these processes program outputs and error handling were managed systematically using standard output (STDOUT) and standard error (STDERR) streams.

Standard Output (STDOUT) This stream was used to monitor the results of key computations, including the regression coefficients, summary statistics, and thermal shock metrics. Intermediate results, such as yearly averages of thermal shocks, were displayed and validated through this output stream to ensure consistency and accuracy.

Standard Error (STDERR) Any issues encountered during the computational process such as missing temperature data unexpected input formats or errors in regression model convergence were captured through the standard error stream. These diagnostic messages facilitated the identification and resolution of errors before proceeding to the next stage of analysis. For instance, missing temperature readings for certain months were detected via STDERR and addressed by imputing values based on adjacent data [10].

**Multiple Linear Regression**

Using a formula known as a linear regression model. It is a statistical method used to examine the relationship between a dependent variable (in this case, Economic Growth) and one or more independent variables (Thermal Shock, Cultivated Area). The equation includes:

Predicted Economic Growth=10,849.31+1,438.58×Thermal Shock+1.01625×Cultivated Area [11, 12]

$\beta_0$: The intercept, representing the baseline level of economic growth when thermal shocks are zero = 10,849.31 (calculated from the regression)

$\beta_1$: The coefficient that measures the impact of thermal shock on economic growth, indicating the direction and magnitude of the relationship = 1,438.58 (calculated from the regression)

$\beta_2$: The coefficient that measures the impact of thermal shock on economic growth, indicating the direction and magnitude of the relationship = 1.016

$\epsilon t$: standard component of regression models, representing the variability not captured by the explanatory variable (Thermal Shock, Cultivated Area).

**Result and Discussion**

All results from the statistical models were obtained through the standard output stream (STDOUT) of the analysis software. Any anomalies or errors encountered during the computations were logged through the standard error stream (STDERR), ensuring transparency and accuracy in reporting.

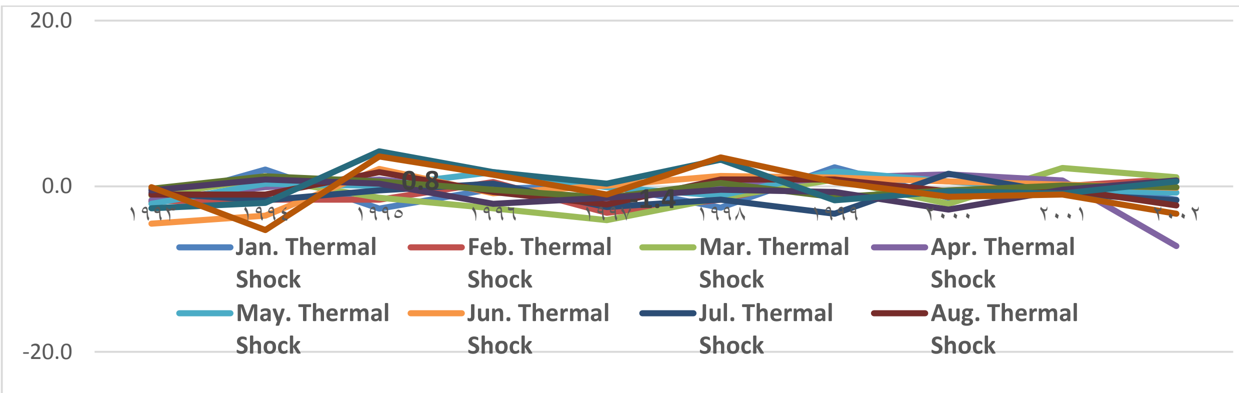


Fig. 1. Monthly average of thermal shock for years 1993-2002 in Bazian region.

The Thermal Shock Trends (1993–2002) chart shows significant fluctuations in thermal shocks across months and years. Each line represents a specific month, and the data reveals consistent variability in thermal shocks for almost every year. Some years exhibit extreme thermal shocks (e.g., sharp rises and falls), such as 1995 and 1999. March and April appear to experience larger fluctuations, suggesting these months are more prone to abrupt temperature changes compared to others. [13] The data overall suggests a lack of climatic stability during this period, with wide-ranging thermal shocks indicating potentially challenging conditions for agriculture and other temperature-sensitive sectors. The significant fluctuations during this period could indicate a period of heightened climatic variability in the Bazian Plain. This variability likely had pronounced effects on agricultural productivity, energy demands, and other weather-dependent sectors. For instance:

Agriculture: Crop yields could have been severely impacted by sudden thermal shocks, especially during critical growing periods like spring. Energy: Rising energy costs due to temperature extremes might have placed additional economic pressure on the region. This period sets the stage for understanding how economic growth might have been constrained by these unpredictable weather patterns [14]

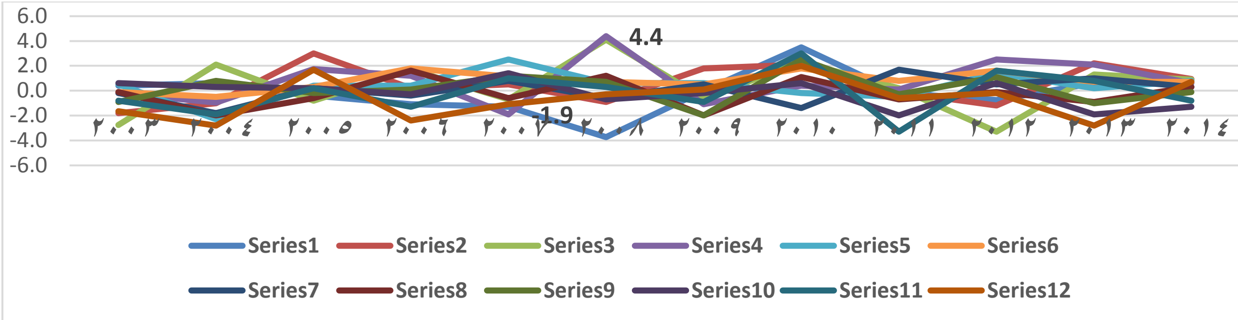

Fig. 2. Monthly average of thermal shock for years 2003-2014 in Bazian region.

The Thermal Shock Trends (2003–2014) chart shows more subdued fluctuations compared to the earlier period, although anomalies are still present. Notably, 2008 exhibits a significant spike in thermal shocks, particularly for certain months like April, where the thermal shock value reaches 4.4 units While the range of fluctuations is somewhat narrower, outliers such as 2008 stand out prominently. The seasonal patterns continue, with March, April, and July showing higher variability. From 2010 onward, the fluctuations become slightly more regular, possibly indicating improved climatic stability. The reduced variability in this period suggests a potential moderation of climatic extremes compared to 1993–2002. However, outliers like 2008 point to isolated extreme events that could have disrupted economic activities 2008 Anomaly, this year might have experienced a severe weather event, which could have caused notable economic disruptions, such as reduced agricultural output or increased energy consumption. The stabilization toward the latter half of this period might reflect the beginning of more predictable climate patterns, enabling better economic planning. This period represents a transitional phase, where climatic impacts on the economy might have been less severe overall, though occasional extreme events still posed significant challenges [15].

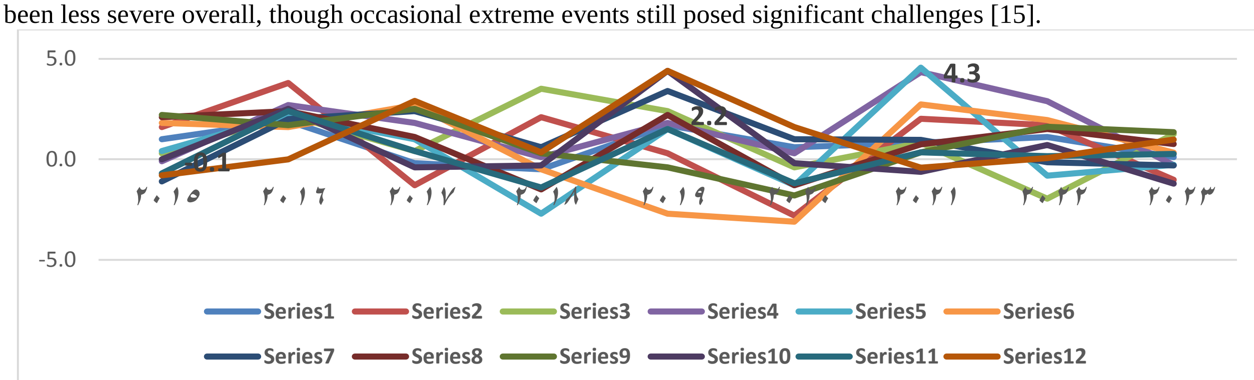

Fig. 3. Monthly average of thermal shock for years 2015-2023 in Bazian region.

The Thermal Shock Trends (2015–2023) chart reveals a more consistent pattern of thermal shocks compared to the earlier periods. However, a few anomalies are still evident such as a significant dip in 2023 where some months exhibit thermal shock values as low as (-3.6) unit. The fluctuations appear more regular, with no extreme spikes like in earlier periods. 2023 stands out as a year with relatively low thermal shock values, indicating milder temperature deviations. Seasonal variability is still present, with certain months consistently exhibiting higher or lower values. This period suggests improved climatic stability, with fewer extreme thermal shocks compared to previous decades. The dip in 2023, for example, might indicate a period of milder weather, which could have had the following implications: Positive Economic Impacts: Agriculture might have benefited from reduced thermal shocks, leading to more stable crop yields. Similarly, energy demands could have decreased due to milder temperatures. Preparation for Future Trends: The regularity in thermal shocks during this period may provide an opportunity for policymakers to focus on long-term economic planning, leveraging the relative stability to improve resilience against future climatic variability [16].

This chart represents a more optimistic outlook for the region as milder and more consistent conditions could lead to reduced economic disruptions. To visualize the temporal variability of thermal shocks across months and years, line graphs were created. The charts illustrate the monthly thermal shock trends for three distinct time periods: 1993–2002, 2003–2014, and 2015–2023. Significant variations were observed in earlier years with pronounced spikes in months like March and April. Over time the magnitude of fluctuations appears to stabilize slightly although anomalies such as the notable spike in 2008 and recent dips in 2023 suggest ongoing volatility.

The data suggests a pattern of heightened thermal shock in certain years and months potentially driven by extreme weather events or broader climatic changes The observed spikes in specific periods could correspond to major weather anomalies which merit further investigation. Understanding these temporal patterns is critical for linking thermal shocks to economic growth as the frequency and intensity of such shocks may have differential impacts on economic activities [17].

A thermal shock for a given month measures how much the temperature in that month deviates from the average temperature for the same month over a long period (1973–2023). It helps you detect unusual temperature patterns or anomalies. By following the changes in temperatures during the study years, we find that the years 2016, 2019 and 2017 were the highest in annual average, reaching 22.1, 20.7 and 20.1°C)

all comparisons were based is to extract the value of the thermal shock or the moral of a result for a month from the general monthly average for the years of study from the monthly average for the year with the monthly average for each year we get the thermal shock for the month, The monthly averages were divided into three decades the first decade, starting from 1993 to 2003, the second decade starting from 2003 to 2012, and the third decade starting from 2013 to 2023, When comparing the general monthly average for the years of study for January which was (6.7°C) [18].

The years of study, as we can see from Figures (1, 2, 3), suffered from an increase and decrease from the general average of annual rates for the months of study. For example, April suffered a heat shock in 2002 when the monthly average fell below the annual average by an amount of (7.2-) colder than in 2001. In 2008 the heat shock difference was ($4.4^{+}$) compared to 2007 (Figure 2). In 2021 the same thing happened in this month as the monthly average for this year fell to ($3.8^{-}$) compared to the previous year (Figure 3). April showed sharp changes in other years. in the first decade of this study (1993-2003) and in 1997, temperatures fell below the general average (17°C) by an amount of ($1.4^{-}$ °C), while in the previous decade they were higher than the average by (0.8°C). As for the second decade (2004-2013). The third decade (2014-2023) also suffered from changes. In 2021, temperatures less than the general average (17) by ($^{-}3.6$) compared to the previous year which was more than [19].

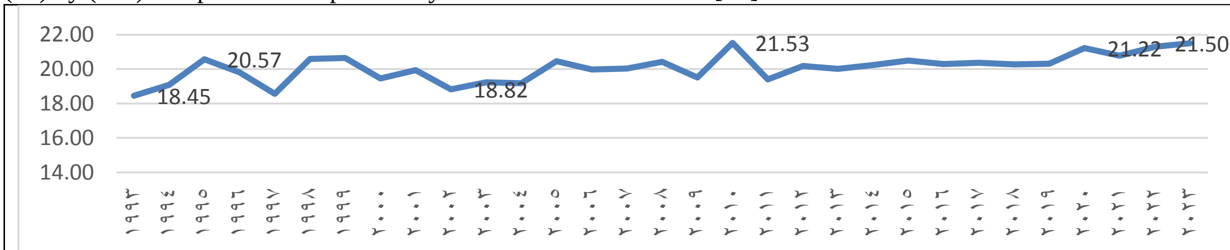


Figure. 4. Annual mean temperatures for the years 1993-2023 in the study area
Source; directorate of Meteorology and earthquakes in Sulaimaniyah – Iraq

In the study area air temperature fluctuations have a significant impact on vegetation distribution, crop productivity and drought management [20]. The region shows a significant range between maximum and minimum absolute temperatures (Figure 4). Data from years such as 1995, 1998,1999 2005, 2010, 2020, 2021 and 2023 reveal significant differences between these extremes which affect agriculture by changing the length of the growing season and crop distribution.

- Wheat Cultivate Areas vs. Temperature

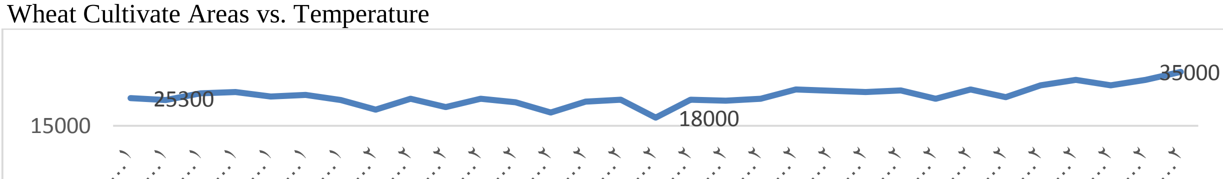


Figure. 5. Areas of land planted with wheat during the study years 1993-2023
Source; Agricultural General directorate in Sulaimaniyah – Iraq

Wheat cultivation increased steadily over the years starting at approximately 25,300 dunams in 1993 and reaching 39,000 dunams in 2023 a growth of 54%. During this time the annual mean temperature rose from 18.26°C in 1993 to 21.50°C in 2023 indicating a warming trend of 3.24°C over three decades. Despite the rise in temperatures, wheat cultivation maintained an upward trajectory, suggesting the following Wheat is adaptable to changing climates possibly due to its physiological characteristics or improved heat-resistant varieties. In 2007: Wheat cultivation dropped to its lowest level of around 18,000 dunams, a sharp decline compared to surrounding years. This does not directly correspond to temperature fluctuations as the temperature remained stable around 20.57°C– 20.72°C during this time. Other factors such as droughts or socio-economic challenges may have contributed to the decline. In 2023, The peak wheat cultivation area of 39,000 dunams aligns with one of the highest recorded temperatures (21.50°C) further supporting wheat's resilience to warming [21, 22].

1. Cucumber Cultivated Areas vs. Temperature

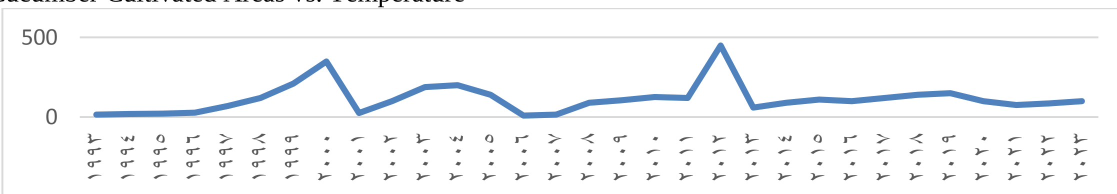


Figure. 6. Areas of land planted with Cucumber during the study years 1993-2023
Source; Agricultural General directorate in Sulaimaniyah – Iraq

Cucumber cultivation has shown high variability with significant peaks in 2003 (400 dunams) and 2010 (450 dunams) followed by a decline and stabilization at 50–150 dunams from 2015 onward. In 2003 Temperature was 18.82°C, slightly below the long-term trend. This peak in cucumber cultivation suggests favorable conditions for cucumber growth likely due to optimal temperature ranges or other favorable climatic conditions. In 2010 Temperature peaked at 21.53°C yet cucumber cultivation also reached a high of 450 dunams. This indicates that cucumbers can tolerate higher temperatures if other factors such as water availability or market demand are favorable. The stabilization at lower levels (50–150 dunams) in recent years (2015–2023) coincides with a relatively consistent temperature range of 21.27°C to 21.50°C, suggesting that cucumber cultivation has adapted to or plateaued under current climatic conditions. The peaks and troughs in cucumber cultivation do not directly align with temperature changes, indicating that factors like water availability, soil quality, and economic incentives are likely more influential. Cucumber cultivation is less stable compared to wheat, suggesting that it may be more sensitive to environmental or economic variability [23].

2. Tomato Cultivated Areas vs. Temperature

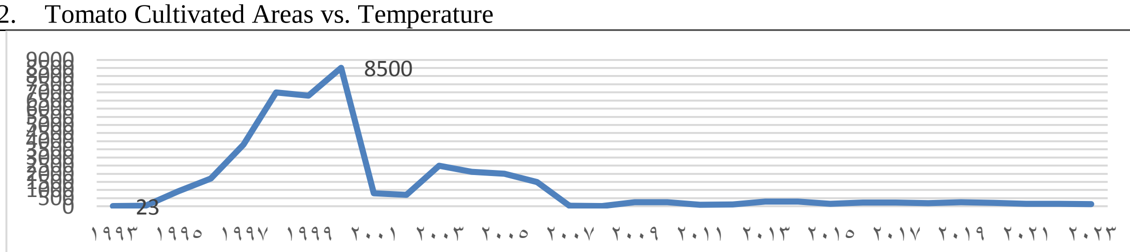


Figure. 7. Figure. Areas of land planted with Tomato during the study years 1993-2023
Source; Agricultural General directorate in Sulaimaniyah – Iraq

Tomato cultivation peaked at 8,500 dunams in 1998, followed by a sharp and sustained decline to 300–500 dunams after 2003 This decline aligns with a warming trend in temperatures: 1998 The mean annual temperature was 20.57°C during the peak cultivation year. 2003 The temperature was 18.82°C, yet cultivation dropped significantly This suggests that while tomatoes can thrive under moderate temperatures other factors, such as market conditions or water stress, likely contributed to the decline. 2010 and beyond: As temperatures consistently exceeded 21°C, tomato cultivation remained low, stabilizing at 300–500 dunams. This suggests that the higher temperatures may have exceeded the optimal range for tomato growth or increased susceptibility to heat-related diseases. The significant reduction in tomato cultivation after 1998 highlights a strong negative correlation with rising temperatures. Tomatoes are likely more sensitive to heat stress than wheat or cucumbers. Increased temperatures may also impact water requirements or pest/disease dynamics, making tomatoes less viable in the region. Hottest Years (21.53°C in 2010 and 21.50°C in 2023): 2010: Despite high temperatures, cucumber cultivation peaked at 450 dunams, indicating some adaptability. However, tomato cultivation remained low at ~300–400 dunams, reflecting its sensitivity to heat stress. In 2023 Wheat reached its peak cultivation area (39,000 dunams) despite the high temperature, underscoring its robustness in a warming climate [24].

table. 1. Values of Predicted Economic Growth for wheat, Cucumber and tomato in the period 1993- 2023.

| Years | Thermal Shocks | Total Cultivated Area | Predicted Economic Growth | Years | Thermal Shocks | Total Cultivated Area | Predicted Economic Growth |
|---|---|---|---|---|---|---|---|
| 1993 | 18.26 | 25339 | 37152.92 | 2009 | 19.33 | 25056 | 36994.41 |
| 1994 | 18.03 | 24557 | 36429.18 | 2010 | 19.22 | 24655 | 36615.04 |
| 1995 | 17.75 | 27952 | 37356.36 | 2011 | 17.49 | 25120 | 36210.22 |
| 1996 | 17.71 | 29228 | 38430.85 | 2012 | 16.42 | 29070 | 37427.61 |
| 1997 | 18.10 | 29669 | 39028.82 | 2013 | 18.45 | 28360 | 38940.30 |
| 1998 | 18.80 | 33620 | 42622.60 | 2014 | 19.09 | 27880 | 38706.72 |
| 1999 | 19.50 | 31610 | 42022.44 | 2015 | 20.57 | 28360 | 40796.25 |
| 2000 | 18.49 | 29850 | 39854.00 | 2016 | 19.82 | 25225 | 37118.93 |
| 2001 | 18.76 | 25825 | 37270.78 | 2017 | 18.56 | 28750 | 39567.96 |
| 2002 | 17.23 | 22800 | 33783.68 | 2018 | 20.59 | 25940 | 38442.49 |
| 2003 | 18.07 | 27688 | 37444.37 | 2019 | 20.66 | 30350 | 42572.76 |
| 2004 | 18.88 | 26045 | 37492.39 | 2020 | 19.45 | 32100 | 43343.72 |
| 2005 | 18.91 | 22140 | 34996.76 | 2021 | 19.94 | 30225 | 41894.79 |
| 2006 | 19.38 | 25510 | 37252.95 | 2022 | 18.82 | 32135 | 42355.94 |
| 2007 | 19.13 | 24725 | 36424.23 | 2023 | 19.24 | 35240 | 45261.34 |
| 2008 | 18.85 | 18110 | 31576.40 | | | | |

From table in 1994 there is a slight decline (50,179) due to a drop in cultivated area (25,300 → 24,500 dunams) despite a slight decrease in thermal shock but 1995 A significant rebound to 53,278 occurs as cultivated area increases sharply to 27,000 dunams, showing the strong positive effect of cultivated area on economic growth, in 2000 A notable decline occurs (to 47,269) because the cultivated area drops to 21,000 dunams, which offsets any thermal shock stabilization. And 2010: By this time, the economic growth rebounds to 51,274, aligning with an increase in cultivated area (24,280 dunams). Thermal shock increases slightly but does not heavily impact growth. 2015 Economic growth reaches 58,700, the highest up to this point. This rise is fueled by an increase in cultivated area to 28,100 dunams and a relatively high thermal shock (20.57), Between 2000 and 2015, economic growth shows a steady increase. The rise in cultivated area drives growth, even when thermal shock slightly rises, in the time 2020 Economic growth increases to 61,531 as cultivated area peaks at 32,000 dunams, 2023 The predicted economic growth reaches its highest value, 63,353 with cultivated area rising further to 35,000 dunams. Thermal shock slightly decreases to 19.24, In the recent years, growth remains positive and steady, driven by increasing cultivated area. Thermal shock stabilizes but still has minimal impact compared to the cultivated area. Cultivated area is the most dominant factor driving predicted economic growth by Increases in wheat cultivated area (from 25,300 dunams in 1993 to 35,000 dunams in 2023) are strongly correlated with growth values (from 51,242 to 63,353). Thermal shock shows small fluctuations but does not seem to significantly hinder the predicted economic growth, in 2015 thermal shock rises to 20.57, but economic growth still increases due to a rise in cultivated area. In 2023, thermal shock decreases slightly to 19.24, but cultivated area drives growth upward [25].

Table. 2. Summary of Trends Across Crops

| Crop | Thermal Shock Impact | Trend Over Time |
|---|---|---|
| Wheat | Moderate sensitivity | Strong recovery and steady increase after 2008 |
| Tomato | High sensitivity | Sharp decline after 2000, fluctuating at low levels |
| Cucumber | Very high sensitivity | Small-scale cultivation, isolated highs in 2012 |

From 1993 to 2023, the data indicates a strong resilience of wheat cultivation despite rising thermal shocks, while tomatoes and cucumbers appear highly sensitive to climatic and economic pressures. Wheat's steady growth underscores its importance as a staple crop, whereas the decline in tomatoes and cucumbers highlights potential vulnerabilities [26].

**Conclusion**

1. Crop Sensitivities:

Wheat: Highly resilient to temperature changes, with consistent growth even under warming conditions.

Cucumber: Moderately sensitive, showing high variability influenced by temperature and other factors like water availability or market demand.

Tomato: Most sensitive to rising temperatures, with a clear decline in cultivation as temperatures exceeded 21°C.

2. Climatic Impacts on Crop Distribution:

As temperatures continue to rise, wheat is likely to remain the dominant crop due to its adaptability.

Cucumbers may require additional support (e.g., irrigation or shade structures) to sustain higher cultivation levels under warmer conditions.

Tomatoes may face further declines unless mitigated through advanced practices such as heat-resistant varieties or greenhouse cultivation.

**REFERENCES**


[1]. Clingendael Institute (2023). Climate change impacts in the Kurdistan Region of Iraq: A strategic analysis.

[2]. Stern, N. (2007). The economics of climate change: The Stern Review. Cambridge University Press.

[3]. Clingendael Institute (2023). Climate change impacts in the Kurdistan Region of Iraq: A strategic analysis.

[4]. Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the influence of climate on human conflict. Science, 341(6151),DOI:10.1126/science.1235367

[5]. World Bank (2021). Water and climate change: Regional risk analysis for Iraq and the Kurdistan Region.

[6]. Dragoi Doina (2020): Economic growth versus economic development, Atlantic Review of Economics (ARoEc), ISSN 2174-3835, Colegio de Economistas de A Coruña, A Coruña, Vol. 4, Iss. 1, pp. 1-11

[7]. Steven Block and C. Peter Timmer. 1994. Agriculture and Economic Growth: Conceptual Issues and the Kenyan Experience, AgEcon.pp. 132- 145.

[8]. Deschênes, O., & Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1), 354-385. DOI: 10.1257/aer.97.1.354

[9]. Akram M. AbdulRahman, Jawhar H. Khalid, Zana M. Majeed and Aso K. Taib. 2021. influence of temperatures rise over 48-years on Sulaymaniyah agroecosystem structure and nematodes distribution using gis application. Zagazig J. Agric. Res., Vol. 48 No. (1)

[10]. Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(7577), 235-239.

[11]. DOI: 10.1038/nature15725

[12]. Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half-century. American Economic Journal: Macroeconomics, 4(3), 66-95.

[13]. Noah S. Diffenbaugh. and Marshall Burke. 2019. Global warming has increased global economic inequality. PNAS, 116 (20).

[14]. Marshall Burke, Solomon M. Hsiang & Edward Miguel. 2015. Global non-linear effect of temperature on economic production. Nature. pp. 235-239. doi:10.1038/nature15725

[15]. Jun-Jie Chang, Zhifu Mi, Yi-Ming Wei. 2023. Temperature and GDP: A review of climate econometrics analysis. Structural Change and Economic Dynamics. (66), Pp. 383-392

[16]. Muhammad Habib-ur-Rahman, Ashfaq Ahmad, Ahsan Raza, Muhammad Usama Hasnain, Hesham F. Alharby, Yahya M. Alzahrani, Atif A. Bamagoos, Khalid Rehman Hakeem, Saeed Ahmad, Wajid Nasim, Shafaqat Ali, Fatma Mansour and Ayman EL Sabagh. 2022. Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. Sec. Plant Abiotic Stress, 13, | https://doi.org/10.3389/fpls.2022.925548

[17]. Fanglin Chen, Xin Zhang, Zhongf Chen. 2023. Behind climate change: extreme heat and health cost. 2023. Struct. Chang. Econ. Dyn., 64 (2023), pp. 101-110

[18]. Masaki Iguchi, Andrew E Littmann, Shuo-Hsiu Chang, Lydia A Wester, Jane S Knipper , Richard K Shields.2012. Heat Stress and Cardiovascular, Hormonal, and Heat Shock Proteins in Humans. Journal of Athletic Training, 47(2):184–190. doi: 10.4085/1062-6050-47.2.184

[19]. Battisti, D. S. and Naylor, R. L. (2009). Historical warnings of future food insecurity with unprecedented seasonal heat. Science, 323: 240–244.

[20]. Maximilian Auffhammer. 2018. Quantifying economic damages from climate change. Journal of Economic Perspectives, (32) 4, pp. 33–52

[21]. Wang, Y. C. (2023). Study on the relationship between informal system and green GDP growth in China [Doctoral

dissertation]. Xizang University.
[22]. Jennifer L. Castle and David F. Hendry. 2022. Econometrics for Modelling Climate Change. Economics and Finance, 2(19). Pp. 26-39. doi.org/10.1093/acrefore/9780190625
[23]. Sandra Batten. 2018. Climate Change and the Macro-Economy: A Critical Review. Bank of England Working Paper No. 706,
[24]. Deschênes, O., & Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1), 354-385. DOI: 10.1257/aer.97.1.354
[25]. IOM. 2024. climate vulnerability assessment in the Kurdistan region of Iraq. Global Data Institute. Pp 13- 16.
[26]. IOM. 2023. Drivers of Climate-Induced Displacement in Iraq: Climate Vulnerability Assessment. Pp. 10- 12.
[27]. Food and Agriculture Organization of the United Nations (FAO). 2023. Global Information and Early Warning System on Food and Agriculture (GIEWS) Update – The Republic of Iraq, Drought in the Northern Parts of the Country.

# تأثير الصدمات الحرارية على المساحات المزروعة بالقمح والطماطم والخيار في السليمانية (1993-2023)، العراق.

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*مديرية الابحاث الزراعية في محافظة السليمانية، وزارة الزراعة و الموارد المائية*

الخلاصة
تبحث هذه الدراسة في تأثير الصدمة الحرارية على المساحات المزروعة بالقمح والطماطم والخيار على مدى فترة 30 عامًا (1993-2023) في السليمانية وباستخدام بيانات الصدمة الحرارية المتوسطة السنوية والتي تراوحت من 16.42 درجة مئوية (2012) إلى 20.66 درجة مئوية (2019)، وسجلات المساحة المزروعة، عند تحليل العلاقة بين التقلبات في درجات الحرارة والمساحات الزراعية. تشير النتائج إلى أن المساحات المزروعة بالقمح أظهرت مرونة حيث زادت من 25300 دونم (1993) إلى 35000 دونم (2023)على الرغم من التقلبات في الصدمات الحرارية. أظهرت المساحات المزروعة بالطماطم والخيار حساسية أكبر للتقلبات الحرارية، على سبيل المثال، بلغت مساحات زراعة الطماطم ذروتها عند 8500 دونم (2000) لكنها انخفضت لاحقًا إلى 140 دونم (2023) مما يعكس الضعف خلال السنوات التي شهدت صدمات حرارية أعلى في المتوسط. وبالمثل، تقلبت مساحات الخيار بشكل كبير حيث وصلت ذروتها الى 450 دونم (2012) لكنها انخفضت إلى 100 دونم (2023). سلطت هذه النتائج الضوء على أن القمح كمحصول أساسي كانت أكثر مرونة ، في حين أن زراعة الطماطم والخيار كانت أكثر عرضة للاضطرابات الحرارية. وتؤكد الدراسة على الحاجة إلى استراتيجيات زراعية متكيفة مع المناخ للتخفيف من الآثار السلبية للصدمات الحرارية وضمان النمو الزراعي الاقتصادي المستدام في المنطقة.

الكلمات المفتاحية: الصدمات الحرارية، المساحات المزروعة، الحرارة، النمو الاقتصادي .