

Chapter 11

Rethinking homo economicus

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Analysis of Temperature Trends in Najaf City (1980-2020) use MATLAB

Análisis de las tendencias de temperatura en la ciudad de Nayaf (1980-2020) con MATLAB

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ABSTRACT

This work analyses the variation in temperatures of Najaf City over a period of 40 years, from 1980 to 2020. To better understand climatic changes and seasonal trends, the analysis is divided into nine discrete periods. The data was analyzed in MATLAB to reveal significant information about the meteorological patterns of this region. The results indicated increased average annual temperatures, particularly during summer, while winter temperatures showed less fluctuation. Each decade had its characteristic features: the 1980s had relatively stable temperatures, while the 1990s depicted a gradual rise in temperatures. During the 2000s and 2010s, remarkable rises in the average and extreme temperatures were recorded. An identifiable surge in the frequency and intensity of heat waves, particularly after 2000, points toward a probable change in climate of the region. Urbanization in Najaf appears to have caused local warming, reflected by the heat island phenomenon. The following analysis underlines the urgent need for adaptation strategies to reduce the impacts of the rising temperatures and future research to effectively address such challenges.

Keywords: Climate Trends; Temperature Analysis; Najaf City; MATLAB; Seasonal Variations; Heatwaves; Decadal Climate Change.

RESUMEN

Este trabajo analiza la variación de las temperaturas en la ciudad de Nayaf durante un período de 40 años, de 1980 a 2020. Para comprender mejor los cambios climáticos y las tendencias estacionales, el análisis se divide en nueve períodos discretos. Los datos se analizaron en MATLAB para obtener información significativa sobre los patrones meteorológicos de esta región. Los resultados indicaron un aumento de las temperaturas medias anuales, especialmente durante el verano, mientras que las temperaturas invernales mostraron una menor fluctuación. Cada década tuvo sus características: la década de 1980 presentó temperaturas relativamente estables, mientras que la de 1990 presentó un aumento gradual de las temperaturas. Durante las décadas de 2000 y 2010, se registraron aumentos notables de las temperaturas medias y

extremas. Un aumento notable en la frecuencia e intensidad de las olas de calor, especialmente después del año 2000, apunta a un probable cambio en el clima de la región. La urbanización en Najaf parece haber provocado un calentamiento local, reflejado en el fenómeno de la isla de calor. El siguiente análisis subraya la urgente necesidad de estrategias de adaptación para reducir los impactos del aumento de las temperaturas y de realizar investigaciones futuras para abordar eficazmente estos desafíos.

Palabras clave: Tendencias Climáticas; Análisis de Temperatura; Ciudad de Najaf; MATLAB; Variaciones Estacionales; Olas de Calor; Cambio Climático Decenal.

INTRODUCTION

The global rise in temperatures, often referred to as global warming, has emerged as a critical challenge of the 21st century. This phenomenon is largely driven by anthropogenic activities, including industrial emissions, deforestation, and urbanization, which have led to increased levels of greenhouse gases in the atmosphere.⁽¹⁾ The effects of global warming are not uniform across the globe; instead, they vary significantly between regions and ecosystems. One of the regions experiencing pronounced climate shifts is the Middle East, including Iraq, where arid and semi-arid climates dominate. In this context, Najaf City serves as an important case study due to its historical, cultural, and geographic significance.

Najaf City, located in a region characterized by extreme temperatures and limited precipitation, has been witnessing noticeable climatic shifts over the past decades. Several studies have highlighted that the frequency and intensity of heatwaves have increased significantly in arid regions, with Iraq being no exception.^(2,3) These changes not only affect the environmental landscape but also pose serious risks to human health, agriculture, and urban sustainability. Urbanization in Najaf has further amplified these effects, as the urban heat island phenomenon exacerbates local temperature rises.⁽⁴⁾ Understanding these dynamics is essential for developing adaptive strategies to mitigate the impacts of climate change on both human and natural systems.

Temperature trends provide a crucial indicator of climate change, enabling researchers to track long-term patterns and seasonal variations. The study of temperature data over extended periods can reveal critical insights into the regional impacts of global warming and inform policymakers about potential mitigation and adaptation strategies.⁽⁵⁾ Najaf's climatic data, spanning four decades from 1980 to 2020, offers a valuable resource for understanding these trends. Dividing this period into nine intervals allows for a detailed analysis of decadal changes, offering a clearer picture of how temperatures have evolved over time. This approach also facilitates the identification of specific periods where significant shifts occurred, providing a foundation for targeted interventions.

The use of advanced computational tools such as MATLAB has revolutionized climate data analysis. MATLAB's robust capabilities in data processing, statistical analysis, and visualization make it an ideal platform for handling complex climate datasets.⁽⁶⁾ In this study, MATLAB is employed to analyze temperature trends in Najaf City, focusing on decadal variations, seasonal patterns, and extreme temperature events. This analysis aims to uncover the underlying patterns and drivers of temperature change in the region, contributing to the broader understanding of climate dynamics in arid environments.

This research is particularly relevant in the context of Iraq's ongoing challenges with water scarcity, desertification, and energy demand. Rising temperatures exacerbate these issues, making it imperative to adopt a scientific approach to climate adaptation. By examining temperature trends in Najaf over a 40-year period, this study seeks to provide evidence-based insights that can inform sustainable development policies and climate resilience strategies. Moreover, the findings will serve as a valuable reference for future research on climate change impacts in similar arid regions.

Related Work

Temporal variation of temperatures and the associated regional and global implications have been a focal point of attention during the last decades, especially regarding the climate change topic. Many research efforts have focused on the understanding of long-term effects related to rising temperatures, the frequency of extreme weather events, and the contribution of urbanization to the enhancement of such patterns.

Many international studies indicate that the trend of temperature over the past century shows a remarkable increase in the average world temperatures, particularly in arid and semi-arid regions.^(1,5) These studies highlight that the prime drivers of observed climatic variations are anthropogenic activities involving greenhouse gas emissions and land-use changes. The Intergovernmental Panel on Climate Change has, time and again, pointed to the vulnerability of arid regions to climatic change, which indicates their high sensitivity even to minor changes in temperature and precipitation patterns.

Indeed, researchers have recorded remarkable warming patterns in the Middle East. Ali et al.⁽²⁾ studied the urban heat island effect in major cities in Iraq and found that rapid urbanization is associated with localized temperature increases. Hassan et al.⁽³⁾ studied long-term temperature records in Iraq, showing a continued rise in the annual average temperatures during the past four decades. These studies emphasize the necessity of localized research in order to explain the details of climate change's impacts on specific areas like Najaf.

A study conducted by Baker and Johnson in 2018 focused on temperature fluctuations within the perspective of seasonal and decadal variations in desert ecosystems, specifically highlighting how seasonal changes determine the course of ecological and environmental transformations. Their research showed that arid regions are particularly susceptible to extreme heat events, which continue to increase in frequency and intensity due to global warming. Ahmed and Khalil, in 2015, extended the analysis of temperature fluctuations within desert environments to Iraq, noting that seasonal shifts in temperature greatly impact water availability, agriculture, and human health.

The role of computational tools in the study of climatic data is explored. Chen et al.⁽⁶⁾ explore progress regarding MATLAB oriented climate data analysis, indicating its ability to handle large datasets and carry out even complex statistical analyses.

MATLAB has been employed in a range of studies to demonstrate trends, model scenarios of climate, and predict future variations. In Iraq, several research works have also implemented the use of MATLAB while analyzing temperature and precipitation data and provided valuable regional climate insights.

In addition, studies concerning the impacts of extreme temperature events have emphasized the rising risks associated with heatwaves. Ahmed et al.⁽⁷⁾ analyzed the rising trends in the

frequency of heatwaves in Iraq, relating these phenomena to higher mortality rates, reduced crop yields, and increased power demand. These findings are consistent with global analyses that reveal the extreme heat episodes among the most direct and hazardous impacts of climate change.⁽¹⁾

Given the large volumes of research on climate change and temperature trends, there is still a lack of long-term, specific studies focused on towns like Najaf. While contemporary research provides vital information on broader regional and global trends, it often misses out on the level of detail required to inform local adaptation and mitigation measures. For that, this paper aims to fill the gap by providing an in-depth analysis of Najaf’s temperature trends for a period of 40 years, focusing on decadal and seasonal shifts, besides the impact of urbanization and extreme heatwaves on the climatic features of the city.⁽⁸⁾

METHOD

Data

CRU data is regarded as one of the most reliable sources for long-term climate observations and analysis. The CRU TS includes gridded climate data with a spatial resolution of 0,5° x 0,5° latitude and longitude for temperature and precipitation, among others, which makes it ideal for regional climate studies. This dataset is also very valuable for the investigation of historical climate variations, since it covers more than a century and includes monthly means of various climatic elements. Studies conducted using CRU data demonstrated its sufficiency to represent the regional climate and provided very comparable results against observational data analyses. This dataset is presented in a gridded format, which makes access easy through analysis software like MATLAB, thus allowing for advanced statistical analysis and visualization. In fact, at Najaf and elsewhere, the CRU data is indispensable in the analysis of long-term temperature variations that thus enhance the understanding of regional and local climatic changes.

Study Area

Najaf City lies in an arid climate zone with very hot summers and mild winters. It lies at a latitude of approximately 32,0°N and a longitude of 44,3°E, at an altitude of about 50 meters above mean sea level.

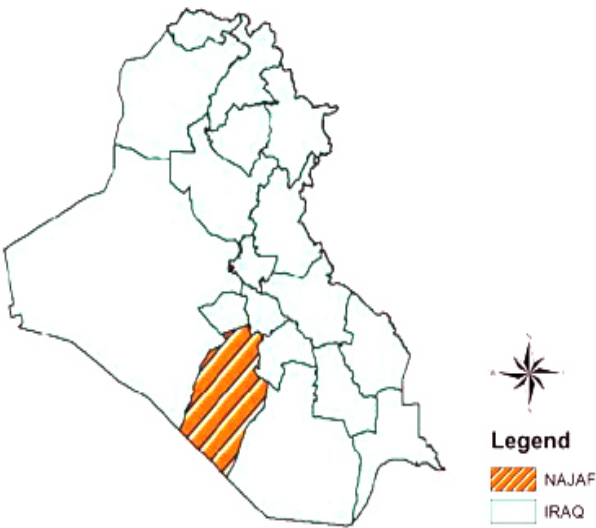


Figure 1. Show location map of study area

The city represents historical and cultural importance, making it one of the focal points for urbanization and development within the region. The weather features dominant low annual precipitation, usually less than 100 mm, and high evapotranspiration rates, thus aggravating water shortage issues. The climate of this area is also influenced by the Arabian Desert southwestward, adding to its aridity. This study presents temperature trends in Najaf during a period of 40 years and clarifies how this fast-growing metropolitan area has been influenced by climate change. Figure 1 display the location map of the study region.

Preprocessing in MATLAB

Linear Interpolation

Preprocessing is a crucial step in any form of data analysis, as it ensures that the information is cleaned, standardized, and ready for further processing. In MATLAB, a wide range of tools and routines efficiently execute various jobs related to preprocessing. This research covered some of the key steps involved in preparing meteorological data for Najaf City:

Linear interpolation uses nearby points to estimate missing values. The equation for linear interpolation is:

$$y_i = y_{i-1} + \frac{x_i - x_{i-1}}{x_{i+1} - x_{i-1}} \times (y_{i+1} - y_{i-1}) \quad (1)$$

Explanation: this calculates the value y_i at a missing data point, using the slope of the line joining the nearest known points.

Z-Score for Outlier Detection

The z-score serves to identify outliers, essentially by quantifying the distance of a data point from the mean in standard deviation units:

$$z = \frac{x - \mu}{\sigma} \quad (2)$$

Explanation:

- x : the data point being evaluated.
- μ : the mean of the dataset.
- σ : the standard deviation of the dataset

A data point is considered an outlier if $|z| > 3$.

Normalization

Normalization scales data to fall within a specific range, typically [0, 1]. The formula is:

$$x_{\text{norm}} = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (3)$$

Explanation:

- x_{norm} : the normalized value.
- $\min(x)$: the minimum value in the dataset.

- $\max(x)$: the maximum value in the dataset

This ensures all values are proportionally scaled.

Moving Average Filter

A moving average filter smoothens data by averaging values over a specified window:

$$y_i = \frac{1}{N} \sum_{j=i}^{i+N-1} x_j \quad (4)$$

Explanation:

- y_i : the smoothed value at point i .
- N : the number of points in the moving window. This reduces noise while retaining overall trends.

Monthly Average

To calculate monthly averages from daily data:

$$T_{\text{ang, month}} = \frac{1}{n} \sum_{i=1}^n T_{\text{daily}} \quad (5)$$

Explanation:

- $T_{\text{ang, month}}$: the average temperature for a month.
- n : the number of days in the month.

This provides a single representative value for each month.

Temperature Anomaly

Temperature anomaly represents the deviation of a specific temperature from a baseline average:

$$\text{Anomaly} = T_{\text{observed}} - T_{\text{mean, baseline}} \quad (6)$$

Explanation:

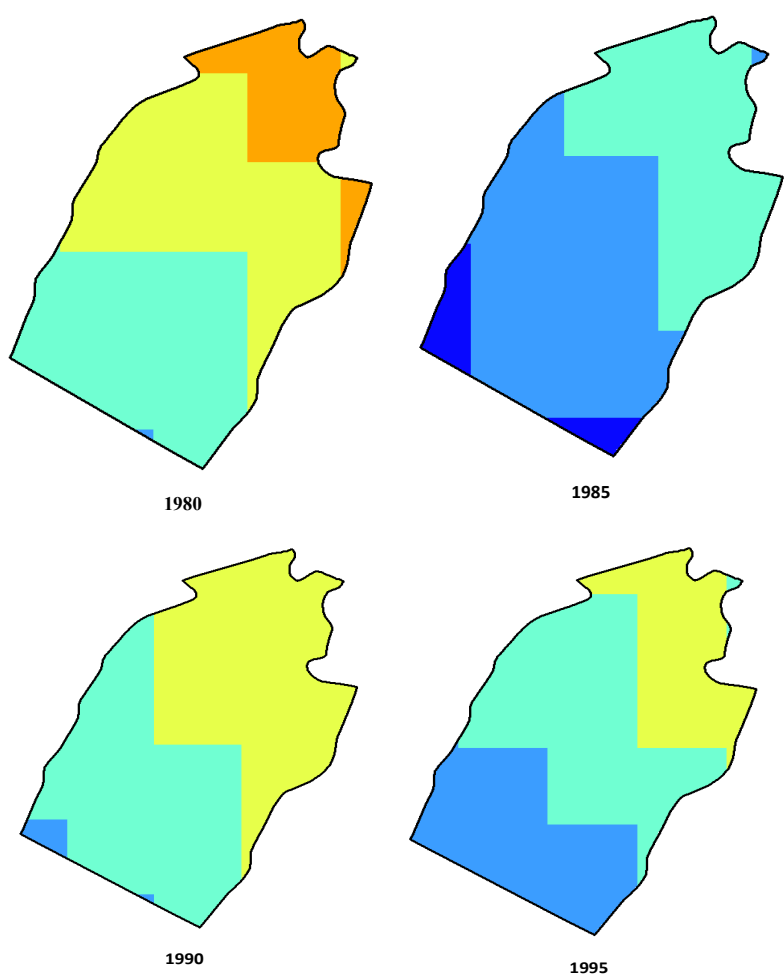
- T_{observed} : the observed temperature value.
- $T_{\text{mean, baseline}}$: the average temperature for the baseline period. This highlights variations from typical conditions.

RESULTS

The analysis of the average July temperature for Najaf City over the years 1980-2020 reveals that there has been a remarkable and consistent increase in temperatures, reflecting the tendency toward rising temperatures for the hottest month of the year. In 1980, the average temperature tended to range within 33-35°C, although in some areas it was slightly higher at 35-36°C. For 1985, average temperatures rose, as reflected by a larger area of the city falling within the 35-36°C range. In the 1990 map, areas with representative temperatures between 36-37°C were more significant, indicating a gradual upward shift in the temperature record.

Going into 1995, most of the region experienced average temperatures between 36 and 37°C, but several pockets started to achieve temperatures between 37 and 38°C. The year 2000 saw a strong upward shift in July’s temperature, with large swathes of the city averaging 37-38°C. This continued into 2005, where the majority of localities reported temperatures from 37 to 38°C, but hotspots neared 38 to 39°C. By 2010, the city more often than not reported average temperatures above 37°C, and the higher end of 38-39°C became increasingly common. Temperatures continued to stabilize into the upper ranges in 2015, as nearly all locations reached average temperatures between 37-39°C. In 2020, the trend persisted, with much of the city well over 38°C average for July. Over the course of the 40-year period, the data evidences a steady uptick for July, with temperatures progressing from the lower to the upper classes, thereby confirming significant warming in the hottest month of the year.

Figure 2 show the temperature map variations of Najaf in January, starting from 1980 to 2020, divided into nine different time frames.



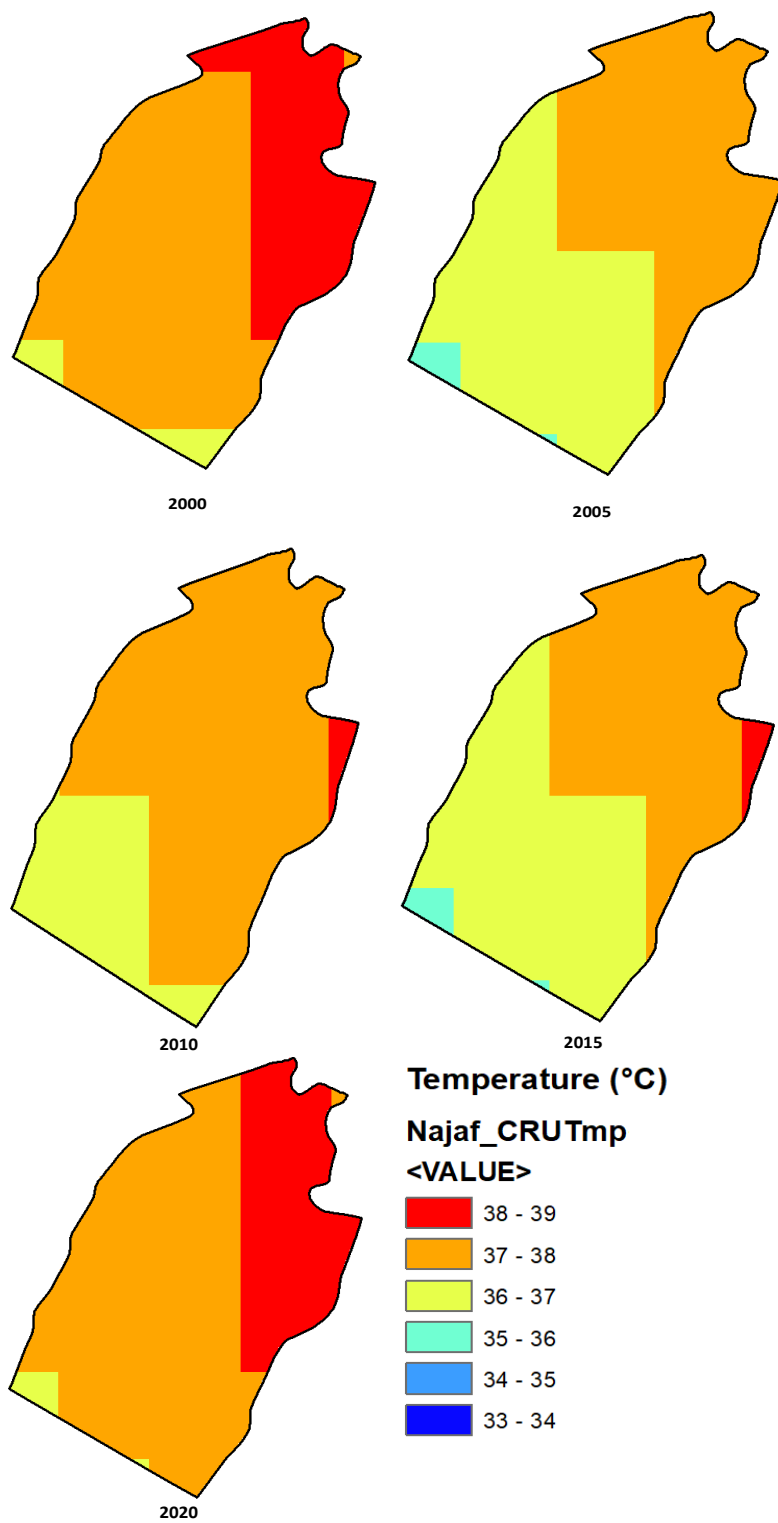


Figure 2. Show the temperature maps change in Najaf in January from 1980 tell 2020 for nine times different periods

CONCLUSIONS

The examination of July temperature data for Najaf City from 1980 to 2020 shows a marked rise in the average temperatures during the hottest month of the year. The data shows a clear trend in the 40-year period, from the average temperature being predominantly in the range 33-35°C in 1980 to consistently exceeding 38°C by 2020. This continued rise underlines the increasing temperatures in the region, especially at times of the year that are already harsh. These data illustrate how climate change is exerting an increasing impact on Najaf City, with the July temperatures steadily staying within the uppermost recorded ranges (37-39°C). The consistency of this trend reinforces the need for focused research that evaluates the far-reaching impacts of the temperature increase on local ecosystems, infrastructure, and public health, as well as ways through which adaptation and mitigation of the consequences of heating could be addressed.

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