Temperature Trends and Ecosystem Resilience in Iran: A Climate-Based Framework for Sustainable Management

Hüseyin Toros[1], Aydin Ulubey (Gulubayov) [2], Mikhail Remizov[3], Mohsen Abbasnia[4]*

[1] Department of Climate Science and Meteorological Engineering, Istanbul Technical University, Maslak Istanbul, Turkey.

[2] Professor of Meteorology, Department of Mechanics and Mathematics, School of Advanced Technologies and Natural Sciences, Western Caspian University, Baku, Azerbaijan,

[3] Professor of Meteorology, Department of Mechanics and Mathematics, School of Advanced Technologies and Natural Sciences, Western Caspian University, Baku, Azerbaijan,

[4] Corresponding Author*: Researcher of Climate Change, Department of Climate Science and Meteorological Engineering, Adana Alparslan Türkeş Science and Technology University, Adana, Turkey.

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Abstract

This study applies the Mann–Kendall trend test to evaluate long-term changes in annual maximum, minimum, and mean temperatures across Iran from 1980 to 2017. Results reveal a consistent upward trend in all temperature parameters nationwide, with spatial variability linked to geographic and topographic factors. Stations in southern regions, such as Bandar-Abbas and Ahvaz, exhibited the lowest positive trends, whereas Kermanshah and Tabriz located in the northeastern mountainous zones, recorded the highest increases in maximum temperature, approximately 2.7 °C and 2.5 °C, respectively. Interestingly, these high-altitude stations showed the smallest rise in minimum temperatures, contrasting with cities like Mashhad, Ahvaz, and Tehran, where minimum temperatures increased more rapidly than maximum values. Among all stations, Mashhad demonstrated the most pronounced warming across all temperature metrics. From a sustainability standpoint, these findings underscore the urgency of region-specific climate adaptation strategies. The accelerated warming in urban and high-latitude areas may intensify energy demands, disrupt agricultural cycles, and strain water resources, particularly in already vulnerable ecosystems.

Keywords: Temperature Trends, Climate Change, Iran, Mann–Kendall Test, Environmental Sustainability, Spatial Analysis

1. Introduction

Climate change has emerged as a defining challenge for environmental sustainability, with rising temperatures threatening the integrity of ecosystems, water resources, and agricultural productivity. In arid and semi-arid regions such as the Middle East, understanding long-term temperature trends is critical for developing adaptive strategies that promote sustainable ecosystem management and climate resilience. Numerous studies have documented significant warming trends across Iran which is located in arid and semi-arid regions. Masoodian (2004) and Ghasemi (2015) identified consistent increases in maximum, minimum, and mean temperatures, while Sabohi and Soltani (2009) highlighted urban vulnerability to climatic shifts in major cities. Abbasnia et al. (2016) projected future temperature changes using HADCM3 and CGCM3 models, reinforcing the urgency of climate-informed planning. Tabari et al. (2012) emphasized the role of autocorrelation in detecting monotonic trends, and Ghasemi and Khalili (2008) explored the influence of large-scale circulation patterns such as the North Sea–Caspian Pattern (NCP) on Iran's winter temperatures.

Recent international assessments further underscore the regional climate risks. The IPCC (2023) reports that the Middle East, including Iran, is warming faster than the global average, with increased heatwaves, reduced snowpack, and heightened threats to water security and agriculture. Daneshvar et al. (2019) project a 2.6 °C rise in mean temperature and a 35% decline in precipitation, noting Iran's high ranking in global greenhouse gas emissions. Ranjbar-Saadatabadi (2025) found that 79% of synoptic stations recorded temperature anomalies during autumn and winter 2024–2025, with November peaking at +2.05 °C above the long-term average and 90% of stations showing reduced precipitation. Nasirian and Naddafi (2025) highlighted the ecological consequences of glacier melt in the Alborz and Zagros ranges, emphasizing the need for community-based adaptation and renewable energy investment. These findings align with global comparative studies, such as Kruger and Shongwe (2004) on South Africa, which demonstrate spatial heterogeneity in warming trends across mid-latitude regions. The statistical foundation for such analyses is grounded in robust methodologies like the Mann–Kendall trend test (Kendall et al., 1983), enabling detection of non-parametric trends in climatological time series.

Given Iran's topographic complexity, from low-lying coastal zones to mountainous highlands, temperature trends vary significantly by elevation and latitude. This spatial variability has direct consequences for ecosystem resilience, agricultural planning, and water resource management. Integrating climate trend analysis into national and regional sustainability frameworks can help prioritize adaptation measures tailored to local vulnerabilities. Such measures include adjusting crop calendars, enhancing urban green infrastructure, and protecting biodiversity hotspots. This study contributes to the growing body of climate research by analyzing observed temperature trends across Iran from 1980 to 2017. The results offer actionable insights for ecosystem-based climate adaptation, supporting Iran's transition toward resilient and sustainable environmental governance.

2. Materials and Methods

Iran is geographically located in the mid-latitudes (25°N to 40°N), encompassing a wide range of climatic zones shaped by its complex topography, elevation gradients, and continental positioning. The country spans arid, semi-arid, Mediterranean, and mountainous climates, influenced by the Zagros and Alborz Mountain ranges, interior basins, and salt deserts. These features act as climatic barriers and contribute to significant spatial variability in temperature and precipitation patterns across the country (Raziei, 2022; Roshan et al., 2024; Motavalli-Anbaran et al., 2011).

To represent this diversity, eight synoptic meteorological stations were selected: Bandar-Abbas, Ahvaz, Tehran, Mashhad, Kermanshah, Tabriz, Isfahan, and Shiraz. These stations span coastal lowlands, central plateaus, urban basins, and mountainous regions. For example, Bandar-Abbas experiences a subtropical arid climate, while Ahvaz is characterized by hot desert conditions. Tehran and Shiraz exhibit semi-arid climates, Mashhad and Tabriz reflect cold semi-arid conditions, and Kermanshah shows Mediterranean influences. Isfahan, centrally located, represents an arid steppe climate. This classification aligns with the Köppen-Geiger, Feddema, and UNEP climate frameworks, which confirm that over 98% of Iran's territory falls under arid or semi-arid categories (Raziei, 2022). Next, Monthly maximum, minimum, and mean temperature data from 1980 to 2017 were obtained from the Iranian Meteorological Organization (IRIMO). The dataset was subjected to quality control and homogenization procedures to ensure consistency and reliability across stations and time periods.

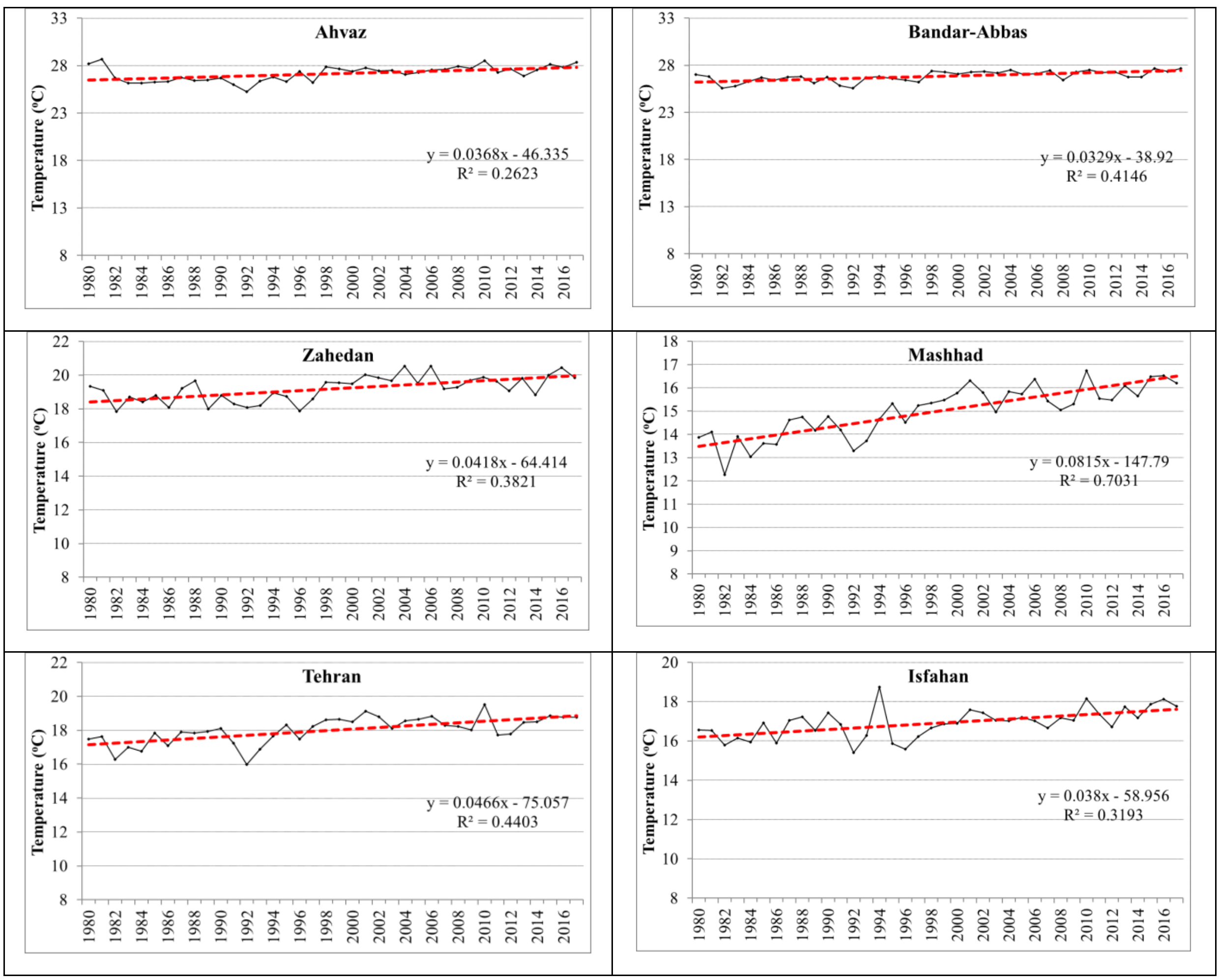
To detect long-term temperature trends, the study applied the Mann–Kendall non-parametric trend test (Kendall, Stuart, & Ord, 1983), a widely accepted method in climatological research for identifying monotonic trends in time series data without assuming a specific distribution. The test was conducted on annual averages of each temperature parameter for all stations.

3. Results and Discussion

To evaluate long-term temperature behavior across the selected stations, the nonparametric Mann–Kendall trend test was employed to analyze mean annual temperature data. The following results present the identified trends for each station, categorized by maximum, minimum, and mean temperature parameters.

3.1. Mean temperature trends

Over the analyzed period, there is a general increase in annual mean temperature throughout the study area. However, the increase in mean temperature is not observed at the same rate for all stations (Figure 1). Geographic locations of the stations with highest positive trends lie from south to north parts of Iran. There are several reasons for temperature increases at some stations. Pollutions arising from industries have been increased in Mashhad, Kermanshah, and Tabriz, and thereby causing local warming. Population growth and urban development in these cities will made this region warmer, by increasing the local consumption of energy and changing the nature of the land surface (Saboohi and Soltani, 2009). In addition, the mountainous regions located in the higher latitudes are more faced with the risk of rising temperatures compared to the lowland regions of southern parts of Iran (Abbasnia et al., 2016). Therefore, the lowest positive trends have occurred for southern stations such as, Bandar-Abbas, Ahvaz, and Zahedan.



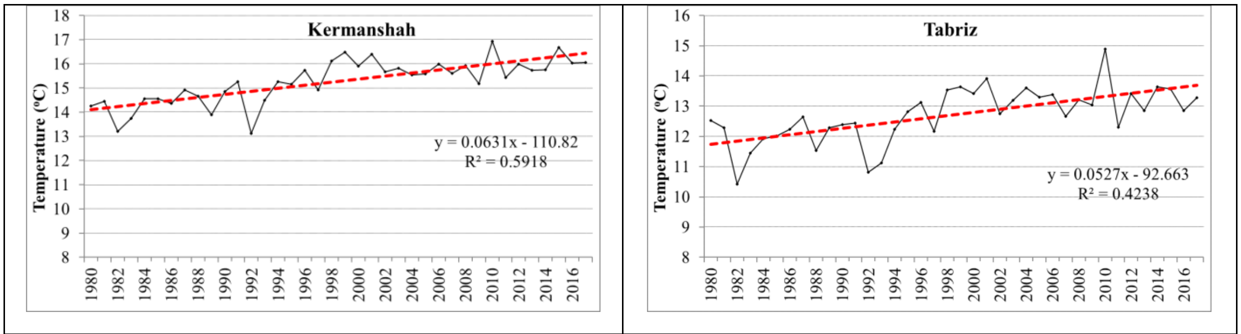
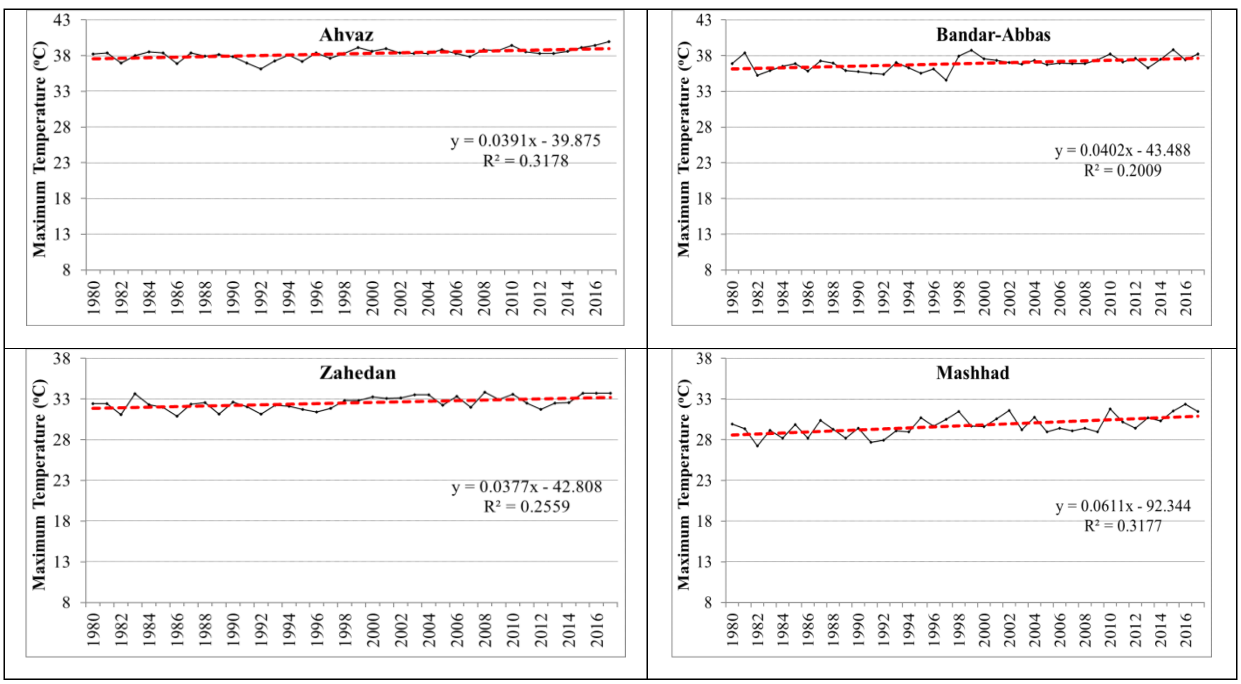


Figure 1- Annual mean temperature trends over selected stations

3.2. Maximum temperature trends

The maximum temperatures in all studied stations have revealed the positive trends during the observational period (Figure 2). In this case, a previously study conducted by Masoodian (2004) indicated that maximum temperature has been increased by about 1.4°C per century in Iran from 1951 to 2000. The highest rising trends in maximum temperatures have obtained for the stations located in mountainous and northern parts of Iran. In this regards, two stations of Kermanshah and Tabriz have had the highest rising trends by about 2.7 and 2.5 °C during the studied period, respectively. In contrast, the lowest rising trends in maximum temperatures have occurred for the southern stations of Zahedan, Ahvaz, and Bandar-Abbas by about 1.36, 1.4, and 1.48 °C during the studied period, respectively. Most of the studied stations have revealed the higher increasing rate for maximum temperatures compared to the mean temperatures.



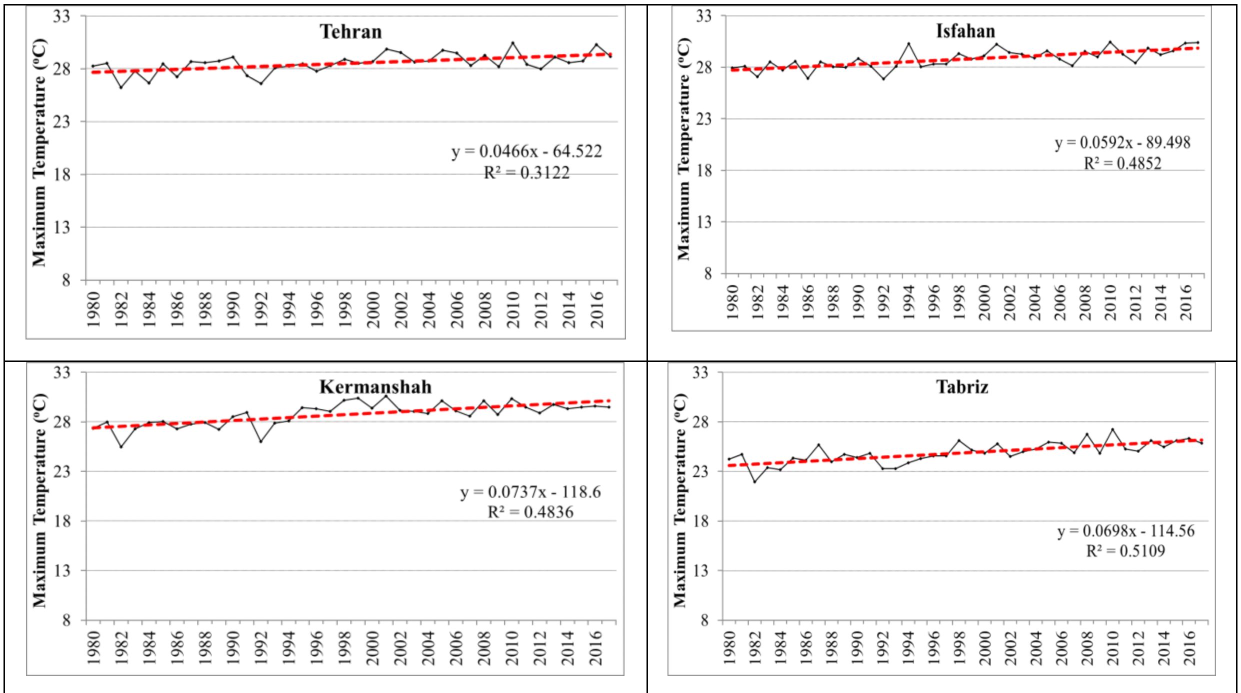


Figure 2- Annual maximum temperature trends over selected stations

3.3. Minimum temperature trends

There were positive trends in the minimum temperatures throughout Iran area (Figure 3). The highest rising trends in minimum temperatures have not showed consistent patterns over Iran. In this case, Mashhad, and Ahvaz have respectively revealed the highest rising trends during the observational period. While, the lowest increasing trends have happened in station scales of Isfahan and Tabriz. What can obtain from surveying the results of minimum temperatures is that two stations of Tabriz and Kermanshah among all studied stations have revealed the lowest positive trends in all of the three parameters of mean, maximum, and minimum temperatures during the studied period. While, the highest positive trends for mountainous and higher latitude stations of Tabriz and Kermanshah have happened in maximum temperature among all parameters of temperature. In addition, the rising trends at station scales of Mashhad, Ahvaz, and Tehran have only had higher rate in minimum temperature than maximum temperature. Moreover, the highest upward trends in all of three temperature parameters have occurred at the station scale of Mashhad among all of studied stations. In the final analysis, the results of warming trends in all of the three parameters of temperature are consistent with previous studies, which showed the last decade of the previous century was substantially warmer than previous decades in global scale (Kruger and Shongwe, 2004).

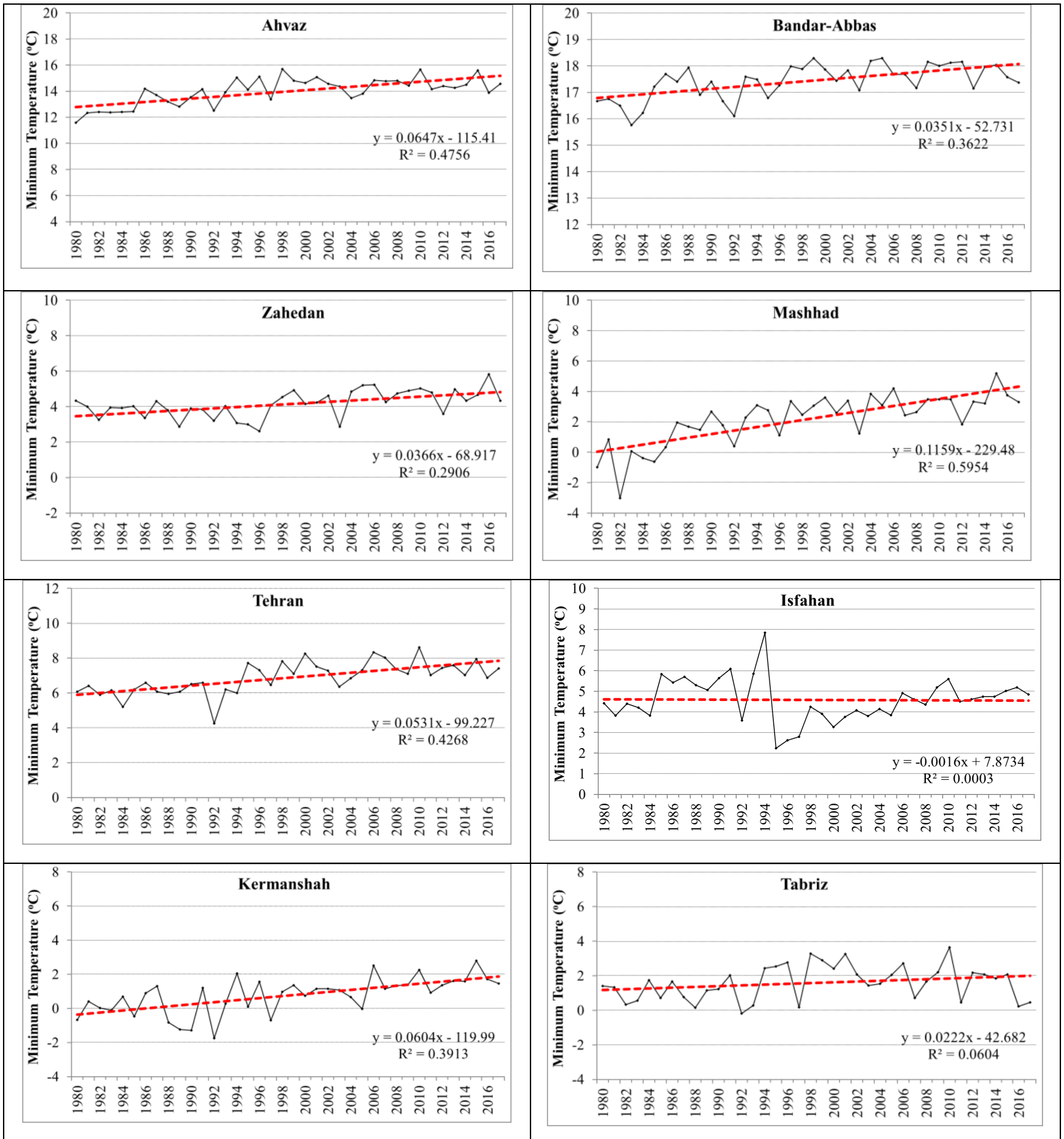


Figure 3- Annual minimum temperature trends over selected stations

4. Conclusion

This study has demonstrated that Iran's temperature regime between 1980 and 2017 has undergone statistically significant warming, with spatial and temporal variability shaped by topography, latitude, and urbanization. While all stations revealed upward trends in maximum, minimum, and mean annual temperatures, the magnitude and consistency of these changes varied across regions. Mountainous and northern stations such as Kermanshah and Tabriz exhibited the most pronounced increases in maximum temperatures, whereas southern lowland stations like Bandar-Abbas and Ahvaz showed more moderate warming. These findings align with broader climatological evidence that the final decades of the 20th century marked a turning point in regional and global temperature acceleration. Importantly, the divergence in warming rates across Iran underscores the need for localized climate adaptation strategies. Urban expansion, energy consumption, and land surface modification have amplified warming in cities such as Mashhad and Tabriz, suggesting that sustainable urban planning, incorporating green infrastructure, energy-efficient design, and pollution mitigation, will be critical in managing future climate risks. Moreover, the vulnerability of high-altitude and semi-arid zones to temperature extremes calls for targeted ecosystem conservation and water resource management.

Given the climatic parallels between Iran and other arid and semi-arid regions of the Middle East, North Africa, and Central Asia, these insights offer transferable value. Policymakers and researchers in similarly exposed regions should prioritize elevation-sensitive climate modeling, integrate temperature trend analysis into long-term planning, and foster regional collaboration to address shared vulnerabilities. Ultimately, the observed warming trends reinforce the urgency of embedding climate resilience into environmental governance, infrastructure development, and transboundary sustainability frameworks.

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