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Forecasting some climate parameters of Türkiye using the SSP3-7.0 scenario for the years 2040–2059

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Abstract

This study employs the Coupled Model Inter-comparison Projects (CMIPs) and the Sixth phase of CMIPs (CMIP6) to unravel the multifaceted impacts of global climate change on climate of Türkiye. The CMIP6 data, fundamental to the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, forms the basis for projecting future climate scenarios, specifically under the medium-high reference scenario SSP3-7. Utilizing a suite of global climate models, including the innovative Multi-Model Ensemble (MME) approach, this study combines predictions to enhance the precision climate projections of Türkiye. Historical data spanning from 1951 to 2020 were subjected to rigorous statistical analysis, including descriptive statistics and regression analysis. The findings reveal an unequivocal upward trajectory in Türkiye's annual mean temperature, with an accelerated pace in recent decades. Despite a lack of a significant long-term trend in annual precipitation from 1951 to 2020, the rate of change in precipitation is accelerating, indicating potential future challenges. Projections for 2040-2059 under the SSP3-7.0 scenario indicate a non-uniform increase in mean temperature across Türkiye, with the southern and western regions facing the most significant impact. This warming trend poses imminent threats to agriculture, altering crop yields and increasing the risk of heat stress for livestock. Additionally, the projected decrease in precipitation, alongside a surge in hot days and tropical nights, underscores the urgency for adaptive measures. As Türkiye navigates the complex terrain of climate change, this study provides valuable insights, emphasizing the significance of robust climate modeling for informed decision-making. The results underscore the imminent challenges Türkiye faces and emphasize the critical importance of proactive climate action on both national and global fronts.

Keywords: Drought, Changing climate conditions, Precipitation

INTRODUCTION

The rigorous rise in global temperatures, a hallmark of the ongoing climate crisis, has profound implications for regions worldwide. Temperature increases might have a big impact on Turkey as well, which is particularly vulnerable to the effects of climate change because of its location in the Mediterranean basin. According to Tokuşlu (2022) there is a high probability that the warming in this region will surpass the global average, potentially having negative consequences for the nation's agricultural, water resources, and biodiversity.

Under the medium-high reference scenario, SSP3-7, which envisions sustained economic growth alongside increasing inequality and environmental degradation, Türkiye faces a complex web of challenges. Projected trends, derived from a suite of global climate models, indicate a surge in global population, economic growth, and fossil fuel use, with agriculture and urban development dominating land use. The Multi-Model Ensemble (MME) approach improves the accuracy of future climate predictions by combining predictions from different models.

The study by Acar et al. (2018) examines daily minimum and maximum temperatures from 156 weather stations in order to analyze the long-term changes in temperature extremes in Turkey. The study looks into trends in hot and cold days using Mann-Kendall trend analysis and cluster analysis. It finds that the frequency of hot days is rising while that of cold days is falling. The frequency of extremely hot days has increased since 2000, while the frequency of extremely cold days has decreased since 2005. The warmest year on record was 2010. Analyzing historical data from 1951 to 2020, this current study unveils an unequivocal upward trajectory in Türkiye's annual mean temperature. Paradoxically, annual precipitation exhibits an accelerating rate of change over recent decades, despite an overall lack of a significant long-term trend. This enigma underscores the complexity of climate change impacts on precipitation patterns, hinting at potential future challenges.

The forthcoming projections for 2040-2059 paint a concerning picture. Türkiye anticipates a rise in mean temperature, unevenly distributed across regions, posing imminent threats to agriculture and livestock. The projected decrease in precipitation, coupled with an increase in hot days and tropical nights, particularly in the Aegean and Mediterranean regions, underscores the urgency of adaptive measures.

This study delves into the climate projection data, sourced from the Coupled Model Inter-comparison Projects (CMIPs), to comprehend the impacts of climate change on Türkiye. The CMIP6 data, a pivotal component of the IPCC Assessment Reports, provides a comprehensive foundation for assessing the future climate scenarios (Hoegh-Guldberg et al., 2019). This study aims to understand the potential effects of these changes on Türkiye by examining climate change scenarios between 2040-2059. Moreover, as the world grapples with the consequences of anthropogenic climate change, this study not only sheds light on the impending challenges for Türkiye but also underscores the importance of robust climate modeling for informed decision-making on both national and global scales.

MATERIALS AND METHODS

Data selection for climate projection

Climate projection data is modeled data from the global climate model compilations of the Coupled Model Inter-comparison Projects (CMIPs), overseen by the World Climate Research Program. Data presented is CMIP6, derived from the Sixth phase of the CMIPs. The CMIPs form the data foundation of the IPCC Assessment Reports. CMIP6 supports the IPCC's Sixth Assessment Report. Projection data is presented at a 1.0º x 1.0º (100km x 100km) resolution. The Climate Change Knowledge Portal (CCKP) continues to add new, additional indicators as they are produced and as appropriate.

Selection of scenario

SSP3-7 is a medium-high reference scenario that assumes continued economic growth and technological development, but also increasing inequality and environmental degradation. SSP3-7 is based on a set of assumptions about the future of global population, economic growth, energy use, and land use (Fujimori et al., 2017). These assumptions are used to drive a suite of global climate models to simulate the future climate. The specific assumptions of SSP3-7 are as follows:

- Global population reaches 10.8 billion by 2100.
- Global Gross Domestic Product (GDP) per capita increases by 2.5% per year.
- Fossil fuel use continues to increase, but renewable energy use also increases.
- Land use is dominated by agriculture and urban development.

Model selection

In Multi-Model Ensemble (MME) the predictions of each model are individually calculated and then combined using a variety of methods. The most common method is to simply average the predictions of all models (Kug et al., 2008). The choice of MME method depends on the specific application and the available data.

Historical data selection and Statistical analysis

The historical data used in this study for the period 1951 to 2020 was sourced from the CCKP. This portal provides comprehensive climate data, including temperature and precipitation records, which are critical for our analysis. Utilizing this data, the historical reference period was set from 1995 to 2014 to ensure a robust foundation for accurate regression modeling. The MME approach, incorporating CMIP6 models, was applied to process this data. This included a detailed examination of climate patterns over the years, allowing for nuanced insights into the climatic changes occurring in Türkiye. The regression model used in this study for analyzing climate data is a statistical tool designed to understand and forecast climate trends in Phyton. This model examines the relationship between various climate parameters, such as temperature and precipitation, over time. By incorporating historical data, the model identifies patterns and trends, which are then used to make projections about future climate conditions. The strength of this model lies in its ability to handle large and complex datasets, providing accurate and reliable forecasts. The methodology involves analyzing historical climate data to establish baseline trends, upon which future projections are built. This approach is particularly effective in understanding the impacts of climate change in specific regions like Türkiye. This process involved the following steps:

Data Collection: Historical climate data from 1951 to 2020 was obtained from the CCKP.

Variable Selection: Temperature and precipitation were selected based on their relevance to the study's objectives.

Model Specification: A regression model was formulated to establish relationships between these variables over time.

Data Processing: The collected data was pre-processed for consistency and accuracy before being fed into the model.

Model Fitting: The regression model was fitted to the historical data, allowing for the identification of significant climate trends and patterns.

Projection and Analysis: The model was then used to project future climate scenarios, providing insights into potential changes in Türkiye's climate under various conditions.

RESULTS

Current Datas

Annual Mean Temperature Trends in Türkiye (1951-2020)

The annual mean temperature for the years 1951–2020 and temperature trend lines for different time periods in Türkiye is shown in Figure 1. This graphic depiction has four different trend lines, each of which stands for a different time period:

Average Annual Temperature: This line represents Türkiye's average annual temperature, offering a baseline for comparison with trend lines.

Trend 1951-2020: Trend from 1951 to 2020: This trend covers about 70 years. Over this time period, the average temperature has increased, as indicated by the positive slope. The rate of warming is represented by the slope's magnitude. Global greenhouse gas emissions have increased, there has been a rise in industrial activity, and fossil fuel use has become more intensive between the 1950s and 2020. These factors may have aided in the process of global warming and the rise in mean air temperatures that followed. The trend's slope is roughly 0.0214°C annually, resulting in a 13.11% increase in temperature over the course of the 70 years.

Trend 1971-2020: Trend from 1971 to 2020: This trend, which covers about 50 years, likewise has a positive slope. There's a chance that this period's warming rate will be different from the 1951–2020 period's. The effects of global warming intensified during this period, and scientific research and public awareness of climate change increased. The slope for this time span is roughly 0.0427°C annually, meaning that over a 50-year span, the temperature increased by 18.95%.

Trend 1991-2020: Trend from 1991 to 2020: This trend, which covers the shortest amount of time—roughly 30 years—may point to a quicker rate of global warming than the two periods before it. The acceleration of climate change and the rise in extreme weather events during this time, particularly in the last ten years, make it noteworthy. This period's rapid warming may be directly linked to rising greenhouse gas emissions and atmospheric concentrations of those gases. The slope for this time span is roughly 0.0689°C annually, resulting in an 18.51% rise in temperature over the course of 30 years.

The information shown in Figure 1 clearly shows that Türkiye's annual mean temperature has been rising since 1951. The rate of this warming trend has increased during the past few decades. In particular, the trend line for 1971–2020 indicates a more marked increase at 0.4°C per decade, whereas the trend line for 1951–2020 reveals an annual increase of 0.2°C. The most recent trend line shows the fastest rate of increase, at 0.4°C per decade, and spans the years 1991 to 2020.

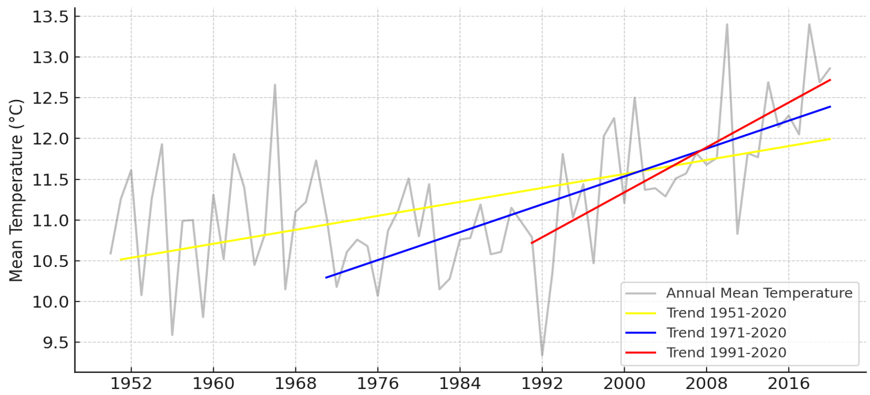

Figure 1. Mean temperature Annual Trends (from 1951 to 2020) with Significance of Trend per Decade, Türkiye.

Annual Precipitation Trends in Türkiye (1951-2020)

Figure 2 presents annual trends in precipitation in Türkiye for the period 1951-2020. The data reveals no significant trend in annual precipitation during this period. However, a noteworthy observation is the acceleration in the rate of change in annual precipitation over recent decades. The trend from 1971-2020 shows a slight decrease, while the trend from 1991-2020 displays a slight increase in annual precipitationIt can be surprising that there isn't a clear long-term trend (1951-2020) considering the predicted influence of climate change on precipitation patterns. However, it is important to note that the trend lines show that the rate of change in annual precipitation has been accelerating in recent decades. This suggests that the effects of climate change on precipitation patterns may become more pronounced in the future. The lack of a significant trend in annual precipitation in Türkiye over the period 1951-2020 does not mean that climate change is not having an impact on precipitation patterns. Climate change is causing changes in the intensity and frequency of precipitation events, as well as the timing of precipitation events. These changes are already being felt in some parts of Türkiye, and they are likely to become more pronounced in the future. For instance, Kara et al. (2016) noted a significant increase in extreme precipitation events for Istanbul, suggesting a future rise in flooding risks. Complementing this, Danandeh Mehr et al. (2020) observed an expected decrease in drought events for Ankara, indicating variations in drought patterns due to changing precipitation regimes. Sen et al. (2012) also highlighted potential increases in temperature and decreases in precipitation, leading to severe drought conditions, particularly in southwestern Türkiye. These findings collectively underscore the ongoing and future challenges posed by climate change to water resource management across different Türkiye regions.

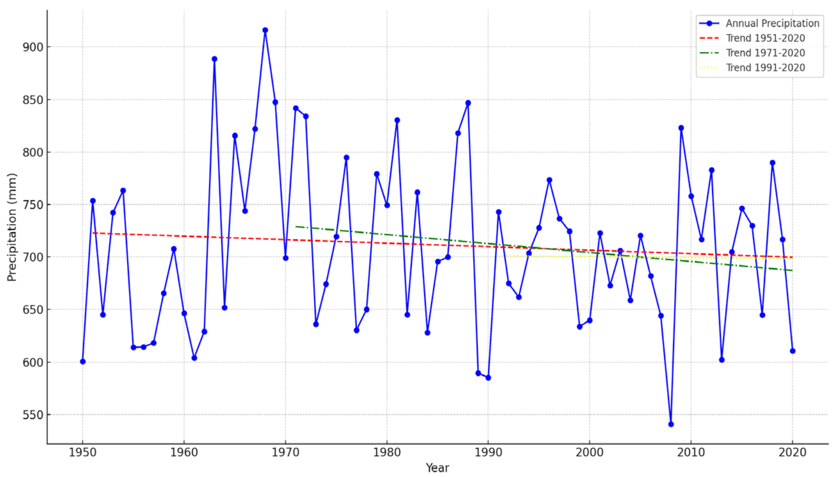

Figure 2. Precipitation Annual Trends (from 1951 to 2020) with Significance of Trend per Decade, Türkiye

Annual Number of Tropical Nights (>20°C) Trends in Türkiye (1951-2020)

Figure 3 shows the annual number of tropical nights (Tmin > 20°C) in Türkiye from 1951 to 2020, along with the significance of the trend per decade. The number of tropical nights has increased significantly over the past 70 years, with an average increase of 1.1 nights per decade. The trend has been particularly pronounced since the 1990s, with an average increase of 2.2 nights per decade.

This increase in tropical nights is likely due to a combination of factors, including climate change, urbanization, and changes in land use. Climate change is causing global temperatures to rise, which is leading to more frequent and intense heat waves. Urbanization also contributes to heat waves, as urban areas tend to be warmer than surrounding rural areas. Changes in land use, such as deforestation, can also contribute to heat waves by reducing the amount of shade and vegetation, which can help to cool the air.

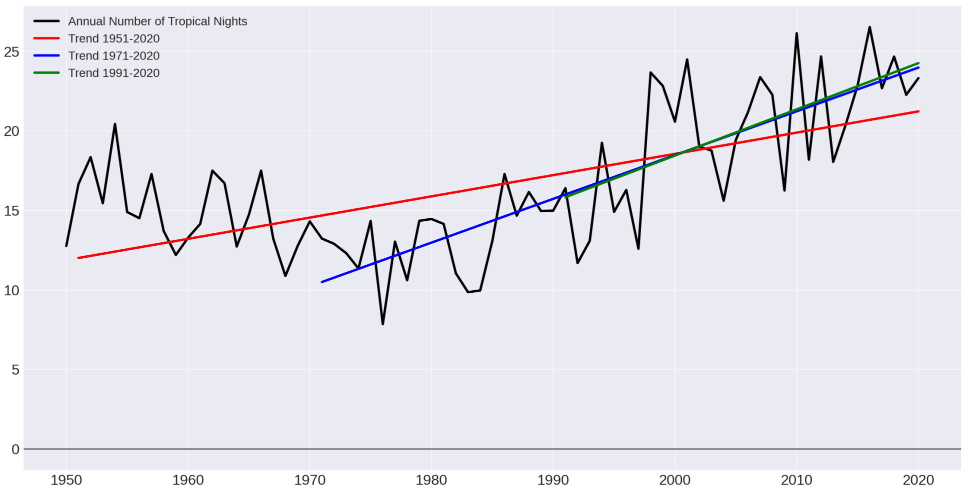

Figure 3. Number of Tropical Nights (Tmin>20°C) Trends (from 1951 to 2020) with Significance of Trend per Decade, Türkiye

Projected Datas

Projected Mean temperature (2040-2059)

The Figure 4 shows the projected mean temperature for Türkiye in the period 2040-2059. The graph is divided into two parts:

(a) Graph: This graph shows the predicted average temperature for Türkiye in general. Black circles line represent historical mean temperature for the period 1995-2014, and the shaded area represents the uncertainty range under the SSP3-7.0 scenario. Red rectangles line represent the average temperature predicted for Türkiye in the 2040-2059 period under the SSP3-7.0 scenario.

(b) Map: This map shows the projected mean temperature for different regions of Türkiye. The colors on the map represent the change in mean temperature, relative to the historical reference period (1995-2014).

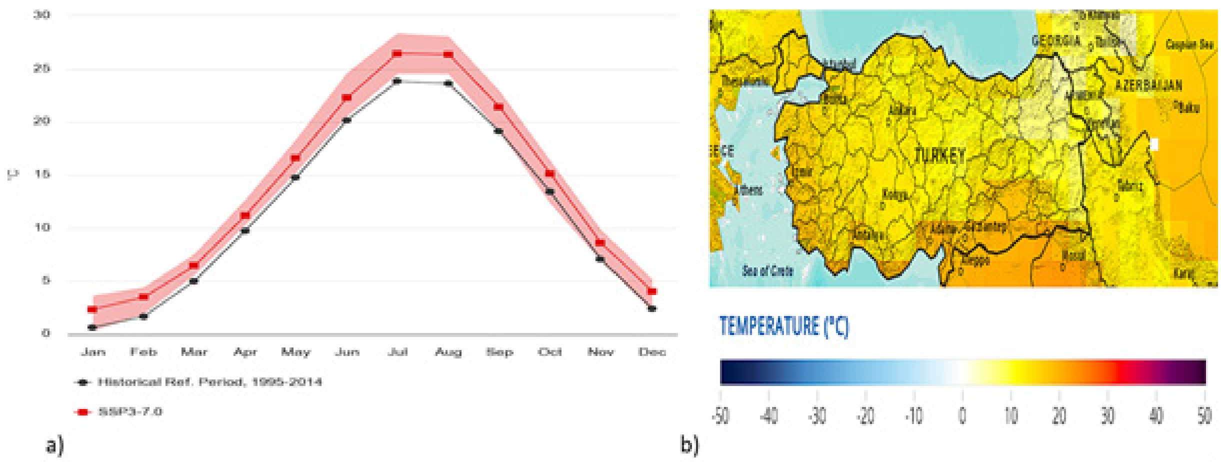

Figure 4. Projected Climatology of Mean-Temperature for 2040-2059 (Annual Türkiye; (Ref. Period: 1995-2014), SSP3-7.0, Multi-Model Ensemble as a graph (a) and regional map (b)

The graph shows that the historical mean temperature for Türkiye is 13.5°C. The range of uncertainty under the historical mean temperatureis from 13.2°C to 13.8°C. The red rectangles line shows that the projected mean temperature for Türkiye in the period 2040-2059 is 15.0°C, which represents an increase of 1.5°C. This is within the range of uncertainty for the historical mean temperature under the SSP3-7.0 scenario.

The map (Figure 4 (b)) shows that the projected increase in mean temperature is not uniform across Türkiye. The southern and western regions are projected to experience the largest increase in mean temperature, with increases of up to 2.0°C. The northeastern and eastern regions are projected to experience a smaller increase, with increases of up to 1.0°C.

The projected increase in mean temperature is likely to have a significant impact on agriculture in Türkiye. The warmer temperatures are likely to lead to changes in crop yields, and they are also likely to increase the risk of heat stress for livestock.

Projected Precipitation (2040-2059)

The Figure 5 shows the projected monthly average precipitation for Türkiye in the period 2040-2059, under the SSP3-7.0 scenario. The black circles represent the historical average precipitation for the period 1995-2014, and the shaded area represents the range of uncertainty under the SSP3-7.0 scenario. The red rectangles represent the projected average precipitation for Türkiye in the 2040-2059 period under the SSP3-7.0 scenario.

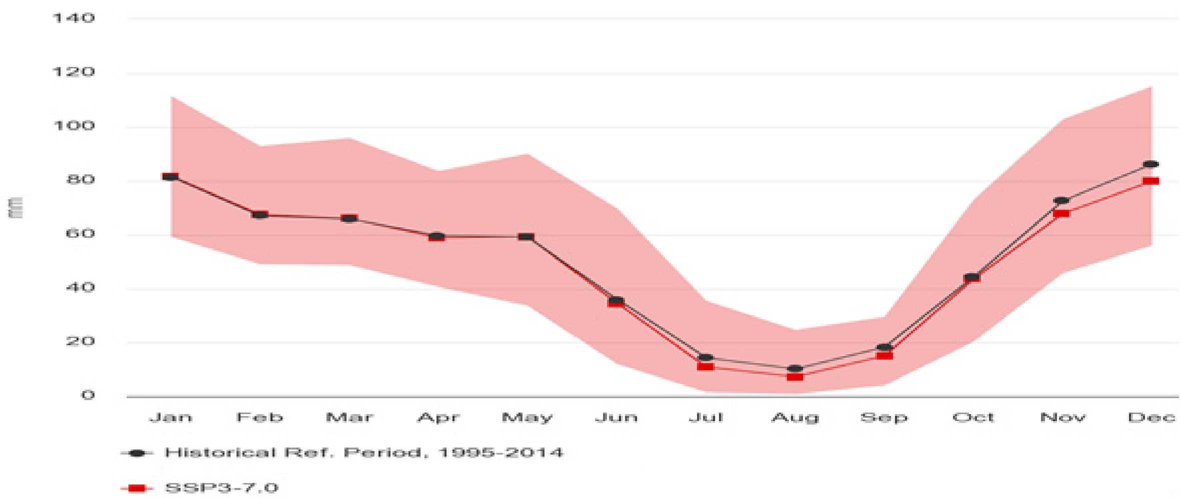

Figure 5. Projected Climatology of Precipitation for 2040-2059 Türkiye; (Reference Period: 1995-2014), SSP 3-7.0, Multi-Model Ensemble

The graph indicate that the projected average precipitation for Türkiye in the 2040-2059 period is significantly lower than the historical average precipitation. The range of uncertainty is from -10% to -20%. This means that there is a high likelihood that Türkiye will experience a significant decrease in precipitation in the coming decades. The projected decrease in precipitation is likely to have a significant impact on agriculture in Türkiye. The aridconditions are likely to lead to changes in crop yields, and they are also likely to increase the risk of droughts.

Number of Projected Hot Days (Tmax>30°C)

The Figure 6 shows a significant increase in the projected number of hot days, from an average of 10.4 days per year in the reference period to an average of 21.6 days per year in the 2040-2059 period. This represents an increase of 107%.

The increase in hot days is expected to be particularly pronounced in the southeastern region (Figure 6b) of Türkiye, where the number of hot days is projected to increase by up to 150%.

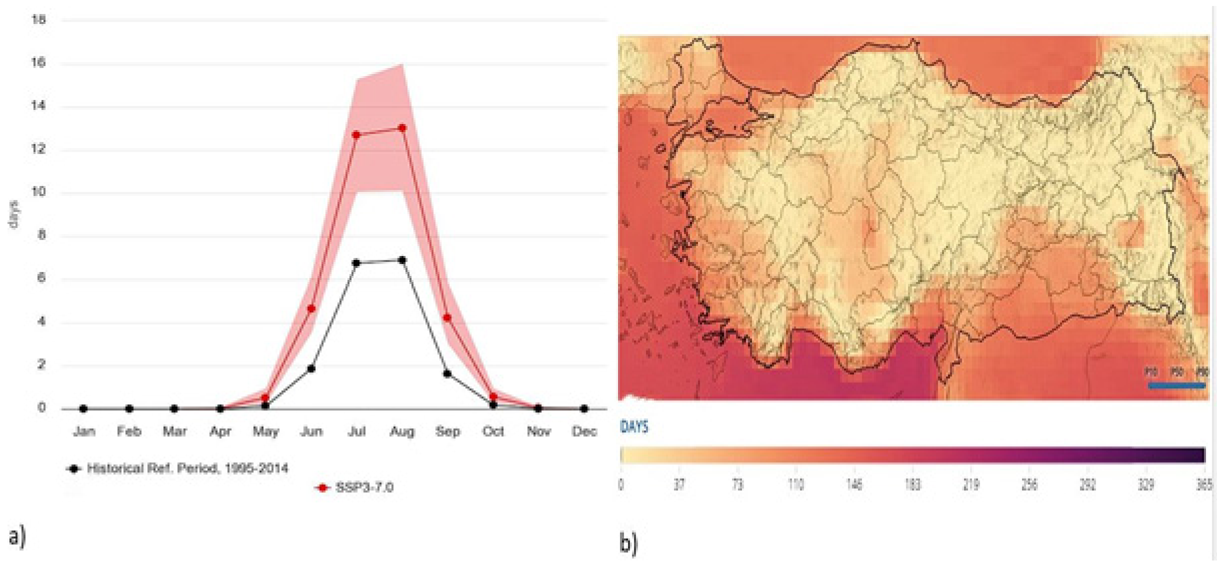

Figure 6. Projected Number of Hot Days with monthly graph (a) and map (b) (tmax>30oC) for 2040-2059 Türkiye; (Reference Period: 1995-2014), SSP 3-7.0, Multi-Model Ensemble

Number of Tropical Nights (Tmin>20°C)

The Figure 7 (a) shows the projected monthly number of tropical nights (Tmax>30°C) for 2040-2059 under SSP 3-7.0, Multi-Model Ensemble. The Figure 7 (b) shows the spatial distribution of the projected increase in the number of tropical nights.

According to the graph, the projected number of tropical nights is expected to increase by 10-20 nights per year by 2040-2059. The increase is expected to be most pronounced in the Aegean and Mediterranean regions.

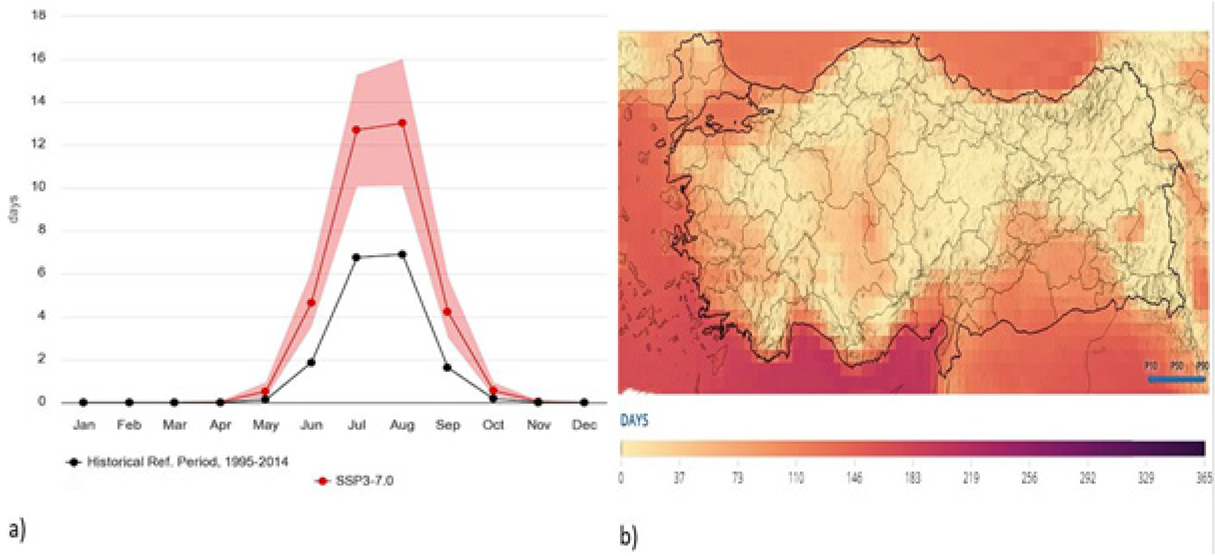

Figure 7. Projected Number of Tropical Nights with monthly graph (a) and map (b) (tmax>30°C) for 2040-2059 Türkiye; (Reference Period: 1995-2014), SSP 3-7.0, Multi-Model Ensemble

DISCUSSION

Our study's conclusions are consistent with the current state of knowledge regarding the various effects of climate change in Turkey. The impacts of climate change on agricultural productivity and water resources in various regions of Turkey are described in detail in studies conducted by Acar et al. (2018) and Bağçaci et al. (2021). More precisely, Bektaş and Sakarya (2023) emphasize the expected rise in fluctuations in temperatures and the frequency of extreme weather events. The adverse impacts of climate change on water resources and agricultural incomes are documented in the works of Demircan et al. (2017) and Pilevneli et al. (2023). Similarly, the impacts on Türkiye's water resources are the main focus of Rustem and Goknar (2022). These studies emphasize how crucial it is to create strategies and policies to comprehend and prepare for the regional and global effects of climate change. In this regard, our research advances our knowledge of the detailed and complex effects of climate change in Turkey and enhances the discussion currently taking place in this area.

The observed temperature rise aligns with the global phenomenon of climate change, supported by the Intergovernmental Panel on Climate Change's assertion that human activities contribute significantly to the increase in global mean surface temperature (Masih, 2018). Bozoglu et al. (2019) argue that climate change is already having a significant impact on agriculture in Türkiye. They cite evidence of increased crop yields in some regions, but also of decreased yields in other regions due to drought, heat stress, and pests. Pilevneli et al. (2023) investigate the impact of climate change on agricultural production and incomes in 25 river basins in Türkiye. They find that climate change is likely to lead to a decrease in agricultural production and incomes in most river basins, with the most severe impacts being felt in the southeastern region of the country. These studies suggests that while global trends are evident, local variations are significant and should be considered in policy and adaptation strategies.

Some recent studies, also, project a 1.4°C average temperature increase in Türkiye (Tokuslu, 2022), with anticipated rises up to 2-3°C (Rustem and Günal, 2022). These changes have direct implications for extreme weather events, such as droughts, floods, and heatwaves (Bektaş and Sakarya, 2023). As for projected temperature increase estimates for Türkiye, the projected increase of 1.5°C aligns with findings from Oruc et al., (2019), which investigates the impact of climate change on extreme precipitation in Türkiye. They emphasizes the consequences of non-stationary climate patterns and the potential intensification of extreme weather events due to climate change. Every single one of these projections is in line with the current study. This agreement emphasizes how urgent it is to address the effects of climate change, particularly with regard to anticipating and reducing extreme weather events.

Climate models indicate a general decrease in annual precipitation in Türkiye, exacerbating water resource challenges. To address these issues, proactive measures like green initiatives and resilient infrastructure are crucial (Demircan et al., 2017). The projected decrease in precipitation aligns with findings from Andrade et al., (2021), which focuses on climate change projections of aridity conditions. Andrade's research emphasizes the likelihood of significant impacts due to arid conditions in certain regions. The projected range of -10% to -20% in precipitation is consistent with these concerns. Moreover, the projected reduction in yearly precipitation, as suggested by climate models and the study conducted by Andrade et al. (2021), enhances the difficulties related to water resources in Turkey. In line with these concerns, the anticipated range of -10% to -20% in precipitation requires comprehensive management of water resources that takes socioeconomic and climatic factors into account. In order to proactively address these new challenges, it is crucial that green initiatives and resilient infrastructure be prioritized, as stressed by Demircan et al. (2017).The results of other studies are in line with the anticipated rise in the number of tropical nights in Turkey. The observed increase in the number of tropical nights corresponds with findings from previous studies on climate change projections in Türkiye. Demircan et al., (2017) highlights a significant rise in mean temperatures, which is consistent with the increase in tropical nights projected here. This aligns with the broader understanding of climate change leading to more extreme temperature conditions in the region. The projected increase of 10-20 tropical nights per year is most pronounced in the Aegean and Mediterranean regions. These regions are known for their warm climate, and this increase is expected to exacerbate the already warm conditions. To continue in greater detail, it is clear that adaptation and mitigation strategies for climate change in Türkiye must be customized to the unique regional characteristics of the phenomenon. As our study has shown, there are serious concerns regarding the rise in tropical nights for human health, agriculture, and ecosystems especially in the warmer regions of the Mediterranean and Aegean. Sen et al. (2012) and Tayanc et al. (2009) findings are consistent with the larger understanding of climate change causing more extreme temperature conditions in the region. A targeted strategy is required to address the particular challenges posed by higher nighttime temperatures because of the predicted increase of 10–20 tropical nights annually, which will be most noticeable in these regions.

CONCLUSION

The comprehensive analysis of current and projected climate data for Türkiye underscores the imminent challenges posed by climate change. The observed upward trajectory in annual mean temperatures, especially the accelerated increase since the 1990s, aligns with global climate change patterns. This temperature rise, supported by multiple studies, is anticipated to have significant implications for agriculture, with potential changes in crop yields and heightened risks of heat stress for livestock.

Contrastingly, the analysis of annual precipitation trends reveals a paradoxical lack of a significant long-term trend (1951-2020) in Türkiye. Despite this, the acceleration in the rate of change in recent decades suggests that the effects of climate change on precipitation patterns may intensify in the future. Projections indicate a significant decrease in average precipitation for the period 2040-2059, with a range of uncertainty from -10% to -20%. This projected decrease poses substantial risks to agriculture, leading to potential changes in crop yields and an increased risk of droughts.

The projections for the number of hot days (Tmax>30°C) and tropical nights (Tmin>20°C) further emphasize the intensification of extreme weather events. The substantial increase in hot days, particularly in the southeastern region, aligns with the broader understanding of climate change-induced heatwaves. The rise in tropical nights, concentrated in the Aegean and Mediterranean regions, poses additional challenges to human health, agriculture, and ecosystems.

In conclusion, the synthesis of current and projected data accentuates the urgency for comprehensive strategies and proactive measures in Türkiye. Addressing the impacts on agriculture, water resources, and human well-being necessitates green initiatives, resilient infrastructure, and concerted efforts to mitigate and adapt to the evolving climate patterns.

COMPLIANCE WITH ETHICAL STANDARDS

Peer-review

Externally peer-reviewed.

Conflict of interest

No conflict of interest exists.

Author contribution

Each process in the article was conducted by Eser Celiktopuz (EC).

Ethics committee approval

Ethics committee approval is not required.

Funding

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Data availability

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Consent for publication to the manuscript should be specified in this section

REFERENCES

Acar, Z., Gönençgil, B., Korucu Gümüşoğlu, N. (2018). Long-Term Changes in Hot and Cold Extremes in Turkey. Coğrafya Dergisi (37), 57-67.

Andrade, C., Contente, J., Santos, J. A. (2021). Climate Change Projections of Aridity Conditions in the Iberian Peninsula. Water 2021, 13, 2035. https://doi.org/10.3390/w13152035

Bağçaci, S. Ç., Yucel, I., Duzenli, E., Yilmaz, M. T. (2021). Intercomparison of the expected change in the temperature and the precipitation retrieved from CMIP6 and CMIP5 climate projections: A Mediterranean hot spot case, Turkey. Atmospheric Research, 256, 105576. https://doi.org/10.1016/j.atmosres.2021.105576

Bektaş, Y., Sakarya, A. (2023). The Relationship between the Built Environment and Climate Change: The Case of Turkish Provinces. Sustainability, 15(2), 1659. https://doi.org/10.3390/su15021659

Bozoglu, M., Başer, U., Alhas Eroglu, N., Kılıc Topuz, B. (2019). Impacts of Climate Change on Turkish Agriculture . Journal of International Environmental Application and Science, 14 (3) , 97-103. Retrieved from https://dergipark.org.tr/en/pub/jieas/issue/48886/560710

Demircan, M., Gürkan, H., Eskioğlu, O., Arabacı, H., Coşkun, M. (2017). Climate change projections for Turkey: three models and two scenarios. Turkish Journal of Water Science and Management, 1(1), 22-43. https://doi.org/10.31807/tjwsm.297183

Fujimori, S., Hasegawa, T., Masui, T., Takahashi, K., Herran, D., Dai, H., Hijioka, Y., Kainuma, M. (2017). SSP3: AIM implementation of Shared Socioeconomic Pathways. Global Environmental Change-human and Policy Dimensions, 42, 268-283. https://doi.org/10.1016/J.GLOENVCHA.2016.06.009.

Hoegh-Guldberg, O., Bindi, M., Allen, M. (2019). 3. Chapter 3: Impacts of 1.5 ºC global warming on natural and human systems 2. Global warming of, 1.

Kara, F., Yucel, I., Akyurek, Z. (2016). Climate change impacts on extreme precipitation of water supply area in Istanbul: use of ensemble climate modelling and geo-statistical downscaling, Hydrological Sciences Journal, 61:14, 2481-2495, DOI: 10.1080/02626667.2015.1133911

Kug, J., Lee, J., Kang, I., Wang, B., Park, C. (2008). Optimal Multi-model Ensemble Method in Seasonal Climate Prediction. Asia-pacific Journal of Atmospheric Sciences, 44, 259-267.

Masih, A. (2018). An Enhanced Seismic Activity Observed Due To Climate Change: Preliminary Results from Alaska. IOP Conference Series: Earth and Environmental Science, 167. https://doi.org/10.1088/1755-1315/167/1/012018.

Mehr, D. A., Sorman, A. U., Kahya, E., Hesami Afshar, M. (2020). Climate change impacts on meteorological drought using SPI and SPEI: case study of Ankara, Turkey. Hydrological Sciences Journal, 65(2), 254-268.

Oruc, S., Yücel, İ., Yilmaz, A. (2019). Investigation of the Effect of Climate Change on Extreme Precipitation: Capital Ankara Case. Teknik Dergi, 33(2), 11749-11778. https://doi.org/10.18400/tekderg.714980

Pilevneli, T., Capar, G., Sanchez-Cerda, C. (2023). Investigation of climate change impacts on agricultural production in Turkey using volumetric water footprint approach. Sustainable Production and Consumption, 35, 605-623. https://doi.org/10.1016/j.spc.2022.12.013

Rustem, J., Günal, M. (2022). Review on impacts of climate change on water resources in Turkey. Advanced Engineering Days (AED), 5, 91-93.

Sen, B., Topcu, S., Türkeş, M., Sen, B., Warner, J. F. (2012). Projecting climate change, drought conditions and crop productivity in Turkey. Climate Research, 52, 175-191.

Tayanç, M., İm, U., Doğruel, M., Karaca, M. (2009). Climate change in Turkey for the last half century. Climatic change, 94(3-4), 483-502. Doi10.1007/s10584-008-9511-0

Tokuşlu, A. (2022). Assessing the Impact of Climate Change on Turkish Basins. International Journal of Environment and Geoinformatics, 9(4), 102-112. https://doi.org/10.30897/ijegeo.1066840