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Assessment of the Trending Change of Climate Conditions in Relation to the Environmental Degradation: The Case of İzmir and Karaburun Peninsula

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Climate Change, the biggest challenge of our era, has impacts highly variable and uneven across the globe. Confirming this fact, projections suggest that the Mediterranean basin is expected to face significant impacts from climate change, showcasing the region as a critical concern. The climatic changes in the region are characterized by a shift of the Mediterranean climate towards aridity, i.e., 'aridification' that is characterized by an increment in annual average temperature with an associated decrease in annual precipitation. Study area including İzmir and the Karaburun Peninsula located in the western Aegean region of Turkey is undergoing a significant land use and land cover change, a trending increase of annual temperatures, with combined aridity and water scarcity particularly in the peninsula. This study aims to support understanding of the relationship between climatic indicators, namely temperature and precipitation, and environmental degradation characterized by land use land cover change, growth, urbanization, etc. The method includes analysis of long-term climatic records (1970-2020) that are available at four meteorological stations in the study area and the analysis with indicators that spatially represent the characteristics in the close proximity of the stations. First objective of the method is to reveal whether there is a pattern of change in temperature and precipitation in the long term. Second objective is, using GIS capabilities, to explore how the change in local climate is related to the environmental degradation indicators, e.g., land use / land cover, building intensity, population density conducting correlation and regression analyses. The dataset used for the study is primarily sourced from global platforms that serve open data, e.g. Copernicus Programme (land use/land cover, urban atlas, GHS), Landsat imagery (spectral indices) etc. The findings of this study will shed light on the key factors influencing the rise in temperatures and the pattern of precipitation. Based on the empirical evidence, recommendations will be provided on how to intervene and mitigate the impacts of these changes. In the long run, these local interventions are expected to have an impact on our overall efforts in combating climate change and related disasters.

Keywords: *climate change, temperature, precipitation, long term, open data, environmental degradation*

Introduction

Climate change is a pressing challenge across the world. Projections for climate change (CC) indicate an increasing range of climate risks until the end of this century, with significant parts of the world, including semiarid regions, expected to

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struggle with its impacts. The Mediterranean Basin, in particular—characterized by warm summers and scarce precipitation—is considered one of the most vulnerable regions to CC-induced threats such as water stress, drought, and food insecurity. The MedECC Network (Meddecc, 2019) reported a 1.5°C rise in average annual temperature compared to preindustrial levels, which is higher than the global warming trend of 1.1°C. Warmer summers, more frequent heatwaves, and a trend towards erratic or reduced rainfall are expected in the coming decades (Deitch et al., 2017).

The majority of the Mediterranean Basin is dominated by the Csa (hot summer Mediterranean climate) according to the Köppen-Geiger Climate classification (Peel et al., 2007). However, some parts of the Mediterranean Basin are anticipated to shift from Csa to BSh (hot semi-arid climate in the Köppen-Geiger system), indicating a significant change in climate conditions (Barredo et al., 2018). According to the Köppen-Geiger climate classification, which is based on temperature and precipitation data, the C type (e.g., Csa) indicates a temperate climate, while the B type (e.g., BSh) indicates a dry climate (URL-1). This transition suggests a severe level of aridification, not commonly observed in other regions worldwide (Seager et al., 2014).

Projections also suggest that regional and local climate changes will likely be more variable and harder to predict. Many regions, especially Mediterranean territories, are expected to experience increased summer drying due to higher evaporation rates and, in some cases, lower summer precipitation (Jackson et al., 2001).

The study area, İzmir and the Karaburun Peninsula, located in the western Aegean region of Turkey, is characterized by a Mediterranean climate, classified as Csa (Mediterranean dry hot summer). The region has historically experienced semi-arid conditions and is notable for its persistent water scarcity issues (Yüceer et al., 2021). The region's distinctive topographic, hydrogeological, and built environment conditions within the Mediterranean climate form the basis for its vulnerability to various climate change (CC)-induced hazards, such as flash floods, heatwaves, dry spells, and water scarcity (Akgündüz et al., 2021).

This study aims to identify any trends in long-term climatic factors, such as temperature and precipitation, in the study area and to examine whether these climatic factors are related to environmental degradation. Land degradation is defined as changes in land use and land cover driven by growth and urbanization. There is evidence that changes in land cover and landscape degradation impact local climate (Nayak and Mandal, 2019).

The study tests two hypotheses related to climate factors: first, whether there is an increasing trend in temperatures and a decreasing trend in precipitation, and second, whether changes in climatic factors are associated with land use/land cover changes. To this end, the study has two objectives: (i) to evaluate the long-term trends in temperature and precipitation in the study area based on weather observations from 1970 to 2020, and (ii) to investigate how variations in local climate are linked to indicators of environmental degradation, such as land cover changes, through image comparisons and correlation analyses.

The data for this research is primarily sourced from global platforms that

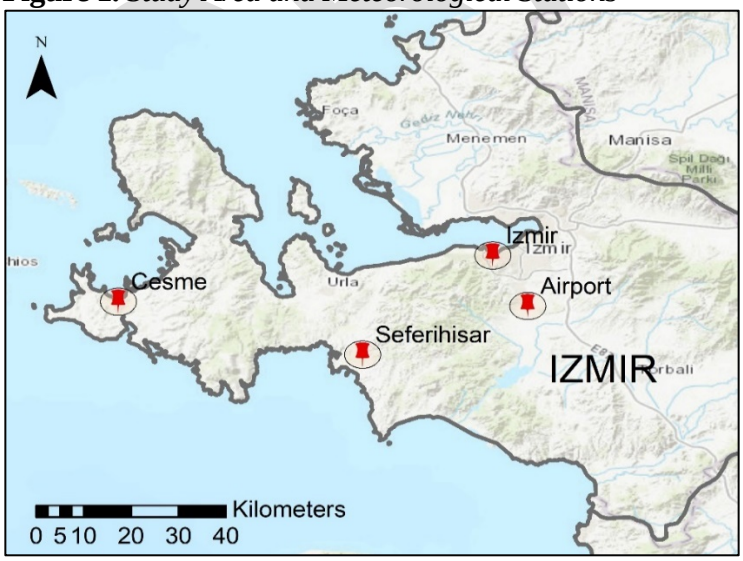
provide open data, such as national meteorological data (URL-2), the Copernicus Program (URL-3), and EarthExplorer (URL-4).

Study Area, Materials and Methods

The study area, İzmir and the Karaburun Peninsula, is located in the western Aegean region of Turkey and lies within the administrative borders of İzmir province. İzmir is the third-largest city in Turkey, known for its developed industry, dense population, services, attractions, favorable lifestyle, and warm climate. Due to its appeal and advantages, the city and its surroundings experience significant migration, extensive population growth, densification, and rapid urbanization. Consequently, the study area is under pressure from development, leading to the conversion of natural and agricultural land into artificial land uses. Since the industrial period, the region has undergone drastic land-use changes, which are believed to affect the local climate.

Climatic factors in the study area are represented by the annual average temperature (°C) and total annual precipitation (mm). To assess trends and variability in the local climate, it is essential to obtain long-term (perennial) measurements. There are about fifteen operational meteorological stations in the study area; however, most of these stations have only been making observations for the last 5-10 years. Among them, only four stations have records spanning more than two decades. This study investigates climatic trends using the long-term meteorological observations of temperature and precipitation from these four stations: İzmir (center), Çeşme, Seferihisar, and İzmir A.D.B. Airport (Figure 1).

Figure 1. *Study Area and Meteorological Stations*



Annual average temperature (°C) and total annual precipitation (mm) data for the years 1970–2020 were obtained from the national meteorological observations database (URL-1). There are some gaps in the Airport station's data, where

temperature measurements are available starting from 1990, and precipitation measurements from 2005. Nevertheless, since the station has been collecting climate data for approximately two decades or more, it was included in the dataset to track potential trends. Scatterplots and trend analyses were conducted to determine if there were any increasing or decreasing trends in the climate data.

Using spatial analysis tools within a GIS environment (ArcMap 10.8.1), an examination of the potential connection between land degradation and local climate was conducted by analyzing vegetation cover in the proximity of four meteorological stations. Vegetation cover includes natural vegetation such as forests, shrubs, maquis, and urban green spaces. The most reliable source of data for monitoring land use and land cover changes is the Landsat mission, which has been providing imagery since the 1970s. The most relevant missions began with Landsat 7 ETM, which introduced more standardized products that continue to be used today. The Landsat 7 ETM mission began in 1999 and continues through the present, as of 2021. The timeframe for the satellite images used in this study is covered by Landsat 7 ETM. This study investigates vegetation cover using images from July 2000, 2010, and 2020, captured by Landsat 7 ETM (URL-3).

Vegetation cover was assessed using a spectral index, specifically the Normalized Difference Vegetation Index (NDVI). The study compared observations from 2000, 2010, and 2020 with the average NDVI values for those respective years within a 3000-meter radius of the meteorological stations, as depicted in Figure 1. NDVI is a widely used spectral index for detecting changes in natural vegetation cover and has been employed in numerous studies, including a few that share similar objectives to this research (Barbosa et al., 2006; Kumar et al., 2022; Chen et al., 2023).

The Normalized Difference Vegetation Index (NDVI) is derived from satellite images using near-infrared (NIR) and red band reflectance values. It is used to assess vegetation health and monitor changes in vegetation cover over time. NDVI values range from -1 to 1, where higher values typically indicate healthier and more abundant vegetation (Jensen, 2000).

NDVI formula: (NIR - Red) / (NIR + Red)

Graphical plots and a correlation analysis were conducted to quantify the relationship between climate trends and land degradation.

Results

The analysis tests two hypotheses: the first pertains to trends in climate factors over a 50-year period, while the second focuses on the relationship between changes in climatic factors and changes in land use/land cover.

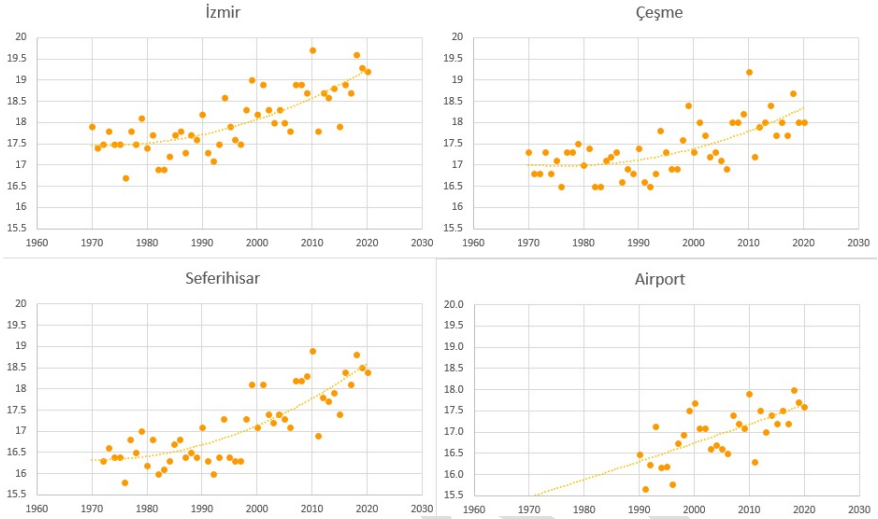
Trends in Climate Factors: Temperature and Precipitation

Based on climatic observations, there is a decrease in temperature and

precipitation from east to west across the study area. Çeşme has a lower long-term average annual temperature (17.40 °C) and precipitation (575 mm) compared to İzmir, which records 18.07 °C and 701 mm, respectively.

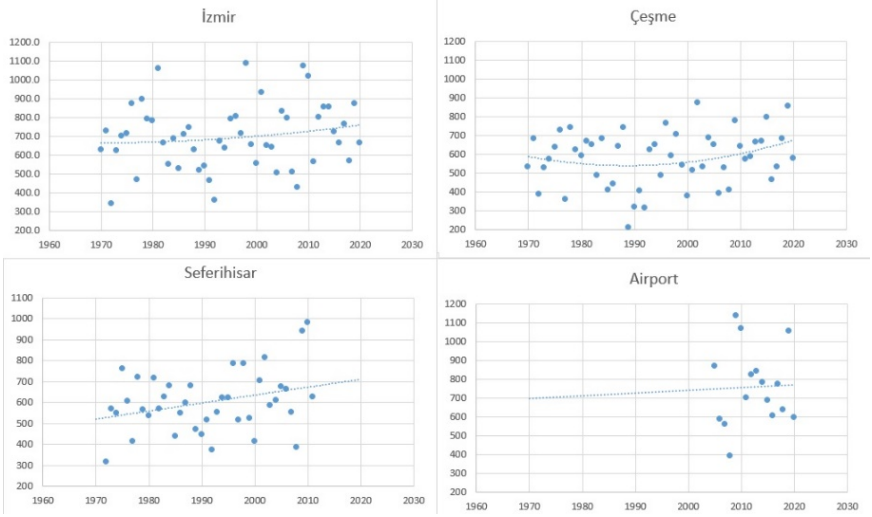
Measurements from the four stations over the years show a trending increase in annual average temperatures (Figure 2). Temperature measurements exhibit a curvilinear trend, with more pronounced increases in recent years..

Figure 2. *Annual Average Temperatures at Four Stations (1970-2020)*



However, a similar pattern of rising temperatures across the four stations is not observed for precipitation. Precipitation follows a more random and variable pattern, making it difficult to identify a clear trend of increase or decrease (Figure 3).

Figure 3. *Annual Total Precipitation at Four Stations (1970-2020)*



The perennial climate data consist of fifty-year (1970 to 2020) records of annual average temperature (°C) and annual total precipitation (mm) from the

stations in İzmir center, Çeşme, Seferihisar, and İzmir A.D.B. Airport, though the Airport station has a shorter data period. Long-term observations from the four meteorological stations demonstrate a clear increase in temperatures, showing a steady upward trend (Figure 4). In contrast, precipitation does not exhibit a long-term trend, though there are well-defined inter-annual variations occurring every four to five years (Figure 5).

Figure 4. *Annual Average Temperature*

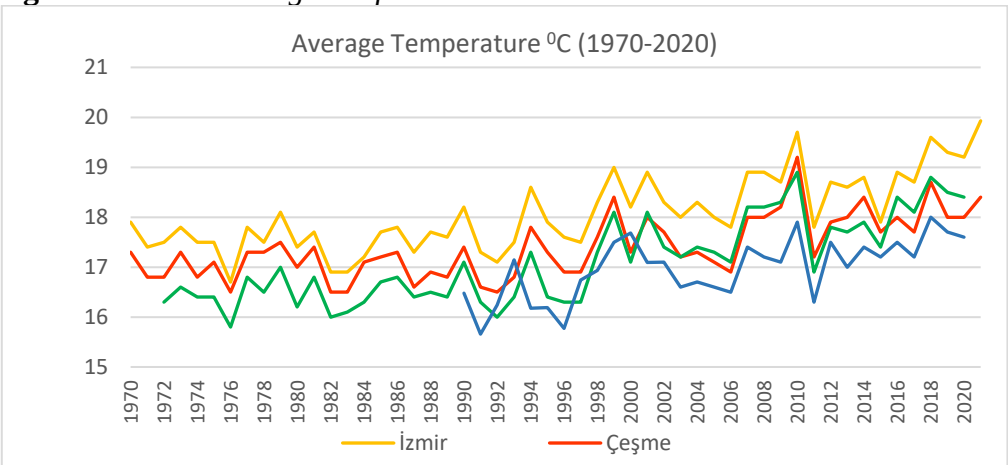
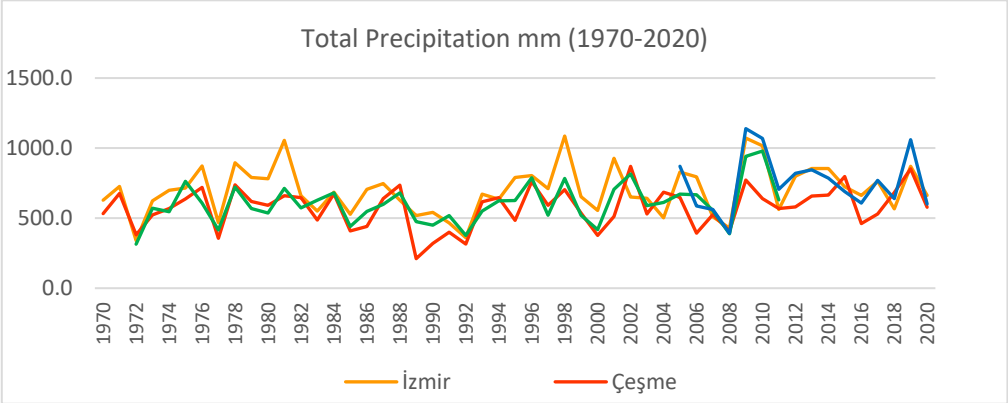


Figure 5. *Annual Total Precipitation*

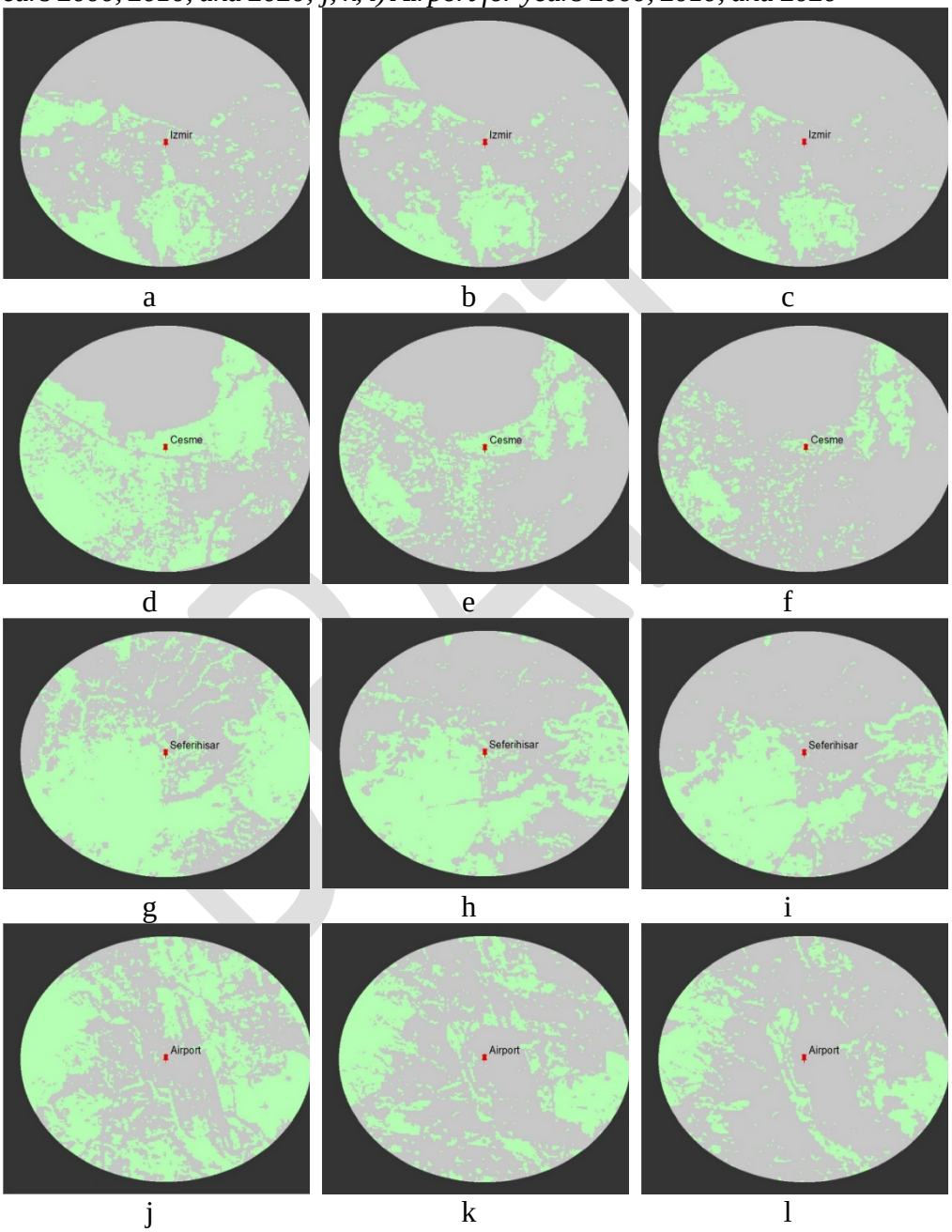


Relation between Landuse/Landcover and Climate Factors

This study investigates land use/land cover change over a 20-year period using the spectral index NDVI for the years 2000, 2010, and 2020, in the proximity of four meteorological stations. Air temperature observations are influenced by their surrounding surfaces and materials. There is a complex but close relationship between land cover composition within a specific buffer area around a location (Yokobori and Ohta, 2009). This buffer can range from 50 meters to several thousand meters (Johnson et al., 2020). For this study, a buffer radius of 3000 meters around the stations was adopted. NDVI rasters were calculated for the years 2000, 2010, and 2020. Figure 6 illustrates the NDVI values, binarized (0, 1) based on a

threshold value of 0.15, for all three years. Green indicates healthy vegetation, while gray represents all other land cover/land use classes, including urban areas, artificial surfaces, sea, etc.

Figure 6. *NDVI (green: healthy vegetation, gray: others) a, b, c) İzmir for years 2000, 2010, and 2020; d, e, f) Çeşme for years 2000, 2010, and 2020; g, h, i) Seferihisar for years 2000, 2010, and 2020; j, k, l) Airport for years 2000, 2010, and 2020*

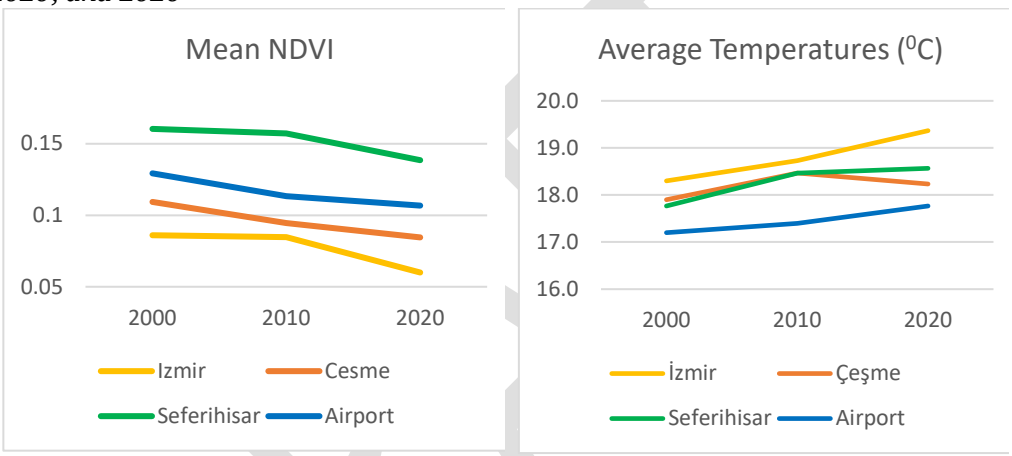


In Figure 6, from left to right, over time, it is evident that vegetation cover degrades. This degradation is particularly pronounced in Çeşme and the vicinity of the Airport. İzmir (center) and Seferihisar have experienced less degradation. The

central district of İzmir has been a highly urbanized area for decades, so the surrounding area has remained largely saturated, with only minor changes occurring. Çeşme, a popular mass tourism destination, has expanded horizontally over the years with intense construction, particularly in the last decade. Seferihisar, characterized by its rural features, has also experienced development, albeit to a lesser extent. İzmir A.D.B. Airport, once located on the periphery of İzmir city, has seen significant development and urbanization in the last decade.

Over the consecutive years (2000, 2010, 2020), a decrease in mean NDVI was noted to correspond with a rise in temperatures across all stations (Figure 7). İzmir station, with the lowest NDVI values, is consistently associated with the highest temperatures.

Figure 7. *Mean NDVI and Average Temperatures for the consecutive years: 2000, 2020, and 2020*



A moderate, statistically significant negative correlation of -0.475 ($p < 0.05$) was calculated between the mean annual NDVI and annual average temperatures across the four stations over three consecutive years. This suggests that as vegetation cover degrades or vegetation health declines, there is a corresponding increase in local temperatures.

Conclusions

The analysis of a 50-year time series dataset on temperature and precipitation trends shows a significant increase in temperature over the years. This rise can be attributed to urbanization, the degradation of natural land and vegetation cover, as highlighted in this study, as well as global warming, which has contributed to elevated average temperatures on a global scale. However, when examining precipitation levels over the same period, no clear trend is detectable.

This variability in precipitation may be influenced by factors such as regional climate patterns, natural climate variability, and local weather events. The absence of a consistent trend in precipitation underscores the complexity and variability of climate systems, highlighting the importance of considering multiple factors when

assessing long-term climate trends.

Over the 20-year period investigated through satellite imagery, a notable correlation was identified between the decrease in the mean Normalized Difference Vegetation Index (NDVI) and the rise in average annual temperatures. The data suggest that as NDVI values decrease, there is a corresponding increase in temperatures, indicating a causal relationship in which reduced or fragmented vegetation cover leads to higher temperatures. This finding underscores the value of NDVI as a reliable metric for assessing environmental conditions, as changes in vegetation cover and health appear to directly influence local climate dynamics.

The findings emphasize the importance of monitoring NDVI trends as an indicator of environmental changes and their impact on temperature trends, showcasing the interconnectedness of vegetation health and ambient temperatures in the study area over the analyzed 20-year timeframe. However, further research is crucial to explore other potential underlying mechanisms driving this correlation.

Understanding the implications of maintaining a balance in land use and land cover is essential for sustainable urban planning and effective environmental management strategies. Several approaches can be implemented to increase vegetation cover and mitigate temperature rises that may lead to environmental and heat-related problems. One approach is to promote urban greening initiatives, such as planting trees and creating green spaces, as well as implementing green infrastructure—such as green roofs and walls—that can reduce the urban heat island effect and minimize heat absorption by buildings. Encouraging sustainable land use practices, such as preserving green spaces and establishing urban forests, can also contribute to increasing vegetation cover. Finally, raising awareness about the benefits of vegetation in reducing heat can foster community involvement in planting and maintaining green spaces. By implementing these strategies, we can work towards creating a more sustainable and healthier environment for all.

References

Akgündüz S, Odabaşı E, Kılıç G, Çamalan G, Erkan MA, Soydam M, Güser Y (2021) *Türkiye Meteorolojik Afetler Değerlendirmesi* (2010-2021).

Barbosa HA, Huete AR, Baethgen WE (2006) A 20-year study of NDVI variability over the Northeast Region of Brazil, *Journal of Arid Environments*, Volume 67, Issue 2, 288-307

Barredo JI, Mauri A, Caudullo G, Dosio A (2018) Assessing Shifts of Mediterranean and Arid Climates Under RCP4.5 and RCP8.5 *Climate Projections in Europe, Pure and Applied Geophysics* 175 (2018), 3955-3971

Chen X, Wang Y, Chen Y, Fu S, Zhou N (2023) *NDVI-Based Assessment of Land Degradation Trends in Balochistan, Pakistan, and Analysis of the Drivers*, Remote Sensing, 15, 2388.

Deitch MJ, Sapundjieff MJ, Feirer ST (2017) Characterizing Precipitation Variability and Trends in the World's Mediterranean-Climate Areas, *Water*, 9(4):259, 1-20

Jackson RB, Carpenter SR, Dahm CN et al. (2001) Issues in Ecology: *Technical Report Ecological Applications* 11(4), 1027-1045.

Jensen J (2000) *Remote Sensing of the Environment: An Earth Resource Perspective*. Prentice Hall, New Jersey.

Johnson S, Ross Z, Kheirbek I, Ito K (2020) *Characterization of intra-urban spatial variation in observed summer ambient temperature from the New York City Community Air Survey*. Urban Clim. 2020, 31.

Kumar BP, Babu KR, Anusha BN, Rajasekhar M (2022) Geo-environmental monitoring and assessment of land degradation and desertification in the semi-arid regions using Landsat 8 OLI / TIRS, LST, and NDVI approach, *Environmental Challenges*, 8, 100578

Mediterranean Experts on Climate and Environmental Change (MedECC) (2019). *Risks Associated to Climate and Environmental Changes in the Mediterranean Region: preliminary assessment* by the MedECC Networ Science-policy interface-2019

Nayak S, Mandal M (2019) Impact of land use and land cover changes on temperature trends over India, *Land Use Policy*, 89, 104238

Seager R et al. (2014) Causes of Increasing Aridification of the Mediterranean Region in Response to Rising Greenhouse Gases, *Journal of Climate*, 27 (12), 4655–4676

Yokobori T, Ohta S (2009) Effect of land cover on air temperatures involved in the development of an intra-urban heat island. *Clim. Res.* 2009, 39, 61–73

Yüceer H, Baba A, Gönülal YÖ., Uştuk O, Gerçek D, Güler S, Uzelli T (2021) Valuing Groundwater Heritage: The Historic Wells of Kadıovacık. *Geoheritage* 13, 97

URL-1: https://climateknowledgeportal.worldbank.org/country/turkiye

URL-2: https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace

URL-3: https://www.copernicus.eu/en

URL-4: https://earthexplorer.usgs.gov/