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Interplay Between Climate Change and Migration-Induced Population Growth in Konyaaltı, Antalya, Türkiye: Population Growth, Urban Heat Island and Sustainable Development

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Abstract

Throughout the history of civilization, people have always been on the move in search of a better life and often to survive. Growing evidence shows that changing environmental and climatic conditions trigger voluntary or forced displacement. This study explores the complex relationship between climate change and migration-induced population growth in the Konyaaltı district of Antalya, Türkiye. The district's rapidly changing demographic and environmental context makes it a compelling case for examining how migration patterns intersect with regional climate dynamics. The study reveals a significant relationship between rising temperatures and increased population density using statistical analyses, including the Mann-Kendall trend test and correlation analysis. These results underscore the urgent need for integrated policy frameworks that address migration and climate adaptation. These results underscore the urgent need for integrated policy frameworks that address migration and climate adaptation. Such frameworks should prioritize sustainable urban planning measures, such as green infrastructure and resilient resource management, to mitigate environmental stressors while supporting a growing population. This study emphasizes the necessity for interdisciplinary strategies in sustainable development planning by contributing to the evidence linking migration and climate change. The research advocates for a paradigm shift in regional policy-making that integrates migration's impact on local climate variables into long-term sustainability initiatives. It also highlights the importance of longitudinal studies to understand the feedback loops between migration and environmental change, which offer insights critical for anticipating and managing future climate shifts. In sum, this study advances the discourse on migration and climate change in Konyaaltı and suggests that future research focuses on these evolving dynamics to promote resilience in similarly affected regions.

Keywords: Climate Change, Migration, Population Growth, Urban Heat Island, Sustainability, Konyaaltı

İklim Değişikliği ve Göçün Konyaaltı, Antalya, Türkiye'deki Etkileşimi: Nüfus Artışı, Kentsel Isı Adası ve Sürdürülebilir Kalkınma

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Özet

Uygarlık tarihi boyunca, insanlar her zaman daha iyi bir yaşam arayışı içinde ve çoğu zaman sadece hayatta kalmak için hareket halinde olmuştur. Değişen çevre ve iklim koşullarının ister gönüllü ister zorunlu olsun, yerinden edilmeyi tetiklediğine dair kanıtlar gün geçtikçe artmaktadır. Bu çalışma, Antalya'nın Konyaaltı ilçesinde iklim değişikliği ve göç kaynaklı nüfus artışı arasındaki karmaşık ilişkiyi araştırmaktadır. Konyaaltı, hızla değişen demografik ve çevresel bağlamda göç örüntülerinin bölgesel iklim dinamikleri ile nasıl kesiştiğini incelemek için ilgi çekici bir örnektir. Çalışma, Mann-Kendall eğilim testi ve korelasyon analizi de dahil olmak üzere istatistiksel analizler kullanarak artan sıcaklıklar ile artan nüfus yoğunluğu arasında önemli bir ilişki olduğunu ortaya koymaktadır. Bulgular, bölgeye göçmen akınının, özellikle kentsel ısı adası ve artan baskı yoluyla yerel kaynaklar üzerindeki iklim etkisini yoğunlaştırdığını göstermektedir. Bu sonuçlar, göç ve iklim adaptasyonunu ele alan entegre politika çerçevelerine duyulan acil ihtiyacın altını çizmektedir. Bu tür çerçeveler, artan nüfusu desteklerken çevresel stres faktörlerini azaltmak için yeşil altyapı ve dirençli kaynak yönetimi de dahil olmak üzere sürdürülebilir kentsel planlama önlemlerine öncelik vermelidir. Bu çalışma, göç ve iklim değişikliğini birbirine bağlayan kanıtlara katkıda bulunarak sürdürülebilir kalkınma planlamasında disiplinler arası stratejilerin gerekliliğini vurgulamaktadır. Araştırma, göçün yerel iklim değişkenleri üzerindeki etkisini uzun vadeli sürdürülebilirlik girişimlerine entegre ederek bölgesel politika yapımında bir paradigma değişikliğini savunmaktadır. Ayrıca, göç ve çevresel değişim arasındaki geri bildirim döngülerini anlamak için boylamsal çalışmaların önemini vurgulamakta ve gelecekteki iklim değişikliklerini öngörmek ve yönetmek için kritik bilgiler sunmaktadır. Özetle, bu çalışma Konyaaltı'ndaki göç ve iklim değişikliği söylemini geliştirmekte ve gelecekteki araştırmaların benzer şekilde etkilenen bölgelerde, dayanıklılığı teşvik etmek için bu gelişen dinamiklere odaklanmasını önermektedir.

Anahtar Kelimeler: İklim Değişikliği, Göç, Nüfus Artışı, Kentsel Isı Adası, Sürdürülebilirlik, Konyaaltı

1. Introduction

Climate change and population migration are interlinked global phenomena that profoundly impact regional and local environments. As the Earth's climate undergoes accelerated transformations, the repercussions are frequently most intensely manifested at the regional scale. Here, alterations in temperature regimes, precipitation patterns, and the frequency and severity of extreme weather events can significantly disrupt local communities' socio-economic fabric and ecological integrity (Reyes-García et al., 2015; Reyes-García et al., 2019). A pertinent illustration of the intricate nexus between climate change and migration can be observed in the Konyaaltı district in Antalya Province, Türkiye's Mediterranean region.

The relationship between climate change and migration has recently been addressed from an interdisciplinary perspective. While sociological studies examine the social adaptation processes of migrants (De Haas et al., 2019), economic studies analyze the effects of migration on local economies (Kwilinski et al., 2022). Environmental sciences examine the impacts of climate change on natural resources and the pressure of migration on these resources (IPCC, 2023; Han et al., 2024). These studies show that the relationship between climate change and migration is multi-dimensional. Especially in the Mediterranean region, examples such as the Syrian migration reveal how climate change and conflicts trigger migration (Kelley et al., 2015; Selby et al., 2017).

Konyaaltı's geographical positioning and temperate climate have made it desirable for domestic and international migrants. This desirability has led to a substantial population increase in recent years. Such demographic expansion has the potential to amplify the effects of climate change through mechanisms such as increased population density, which can exacerbate the depletion and overutilization of local resources, precipitate alterations in land-use patterns, and intensify urban heat island (UHI) phenomena alongside other environmental stressors (Xu and Khalili, 2020; Sarzynski, 2012). For example, expanding impervious surfaces to accommodate growing populations can lead to elevated surface temperatures and reduced evapotranspiration, contributing to higher ambient temperatures (Strong et al., 2011). Moreover, the strain on water and energy resources may further exacerbate vulnerabilities to climate variability and extreme weather events.

Understanding the dynamic interplay between population growth and climate change within Konyaaltı is crucial for formulating robust mitigation and adaptation strategies. Such an understanding necessitates a comprehensive analysis of historical climatic data and demographic trends to elucidate how much population dynamics influence regional climate patterns (Zhao et al., 2019). The present study investigates this relationship by meticulously analyzing historical meteorological data alongside population statistics specific to the Konyaaltı district. The research employs advanced statistical methodologies, including the Mann-Kendall trend test and correlation analysis, to discern significant temporal trends and interdependencies between climatic variables and population metrics.

Preliminary findings from these analyses indicate a discernible increase in average temperatures over the study period, a trend that exhibits a positive correlation with population growth (Maldonado-Chaparro et al., 2018; Lee et al., 2013). This correlation suggests that the burgeoning population may contribute to the intensification of climate change effects within the region, particularly regarding rising temperatures. The urban heat island effect, driven by anthropogenic activities and infrastructural developments associated with population growth, is likely a contributing factor to this temperature escalation (Lu et al., 2024). Additionally, increased vehicular emissions, energy consumption, and waste generation associated with a more extensive population base may compound local climate alterations.

Recent scholarly literature corroborates these findings, highlighting that migration-

induced population changes can substantially influence local climatic and environmental conditions (Hauer et al., 2024; Hirsch et al., 2024). Studies have demonstrated that population influx can lead to enhanced greenhouse gas emissions, altered land use and land cover, and increased vulnerability to climate-related hazards (Wang and Azam, 2024). In the context of Konyaaltı, these dynamics underscore the necessity for integrated urban planning and environmental management approaches that account for population trends and climatic projections.

The implications of this study are manifold. By elucidating the relationship between population growth and climate change in Konyaaltı, the research contributes to a more nuanced understanding of how human migration patterns can drive environmental change at the regional level. Furthermore, the insights derived from this study are instrumental in policymakers and urban planners devising sustainable development strategies that mitigate adverse climatic impacts while accommodating population growth. Such strategies may include implementing green infrastructure to alleviate urban heat island effects, promoting energy-efficient buildings, enhancing public transportation systems to reduce emissions, and prudent management of natural resources to ensure resilience against climatic variability.

In conclusion, the interdependence between climate change and population migration in the Konyaaltı district exemplifies human and environmental systems' complex and reciprocal relationships. Addressing the challenges posed by these intertwined phenomena requires a holistic and interdisciplinary approach, integrating climatological data analysis with demographic studies to inform policy and practice. As global migration trends continue to evolve in response to climate pressures, the findings from Konyaaltı offer valuable lessons for other regions grappling with similar issues, emphasizing the critical need for adaptive and forward-thinking strategies to pursue sustainable and resilient communities.

2. Methodology

This study employs a mixed-methods approach to analyze the complex relationship between climate change and migration-induced population growth in Antalya, Türkiye's Konyaaltı district. By integrating quantitative and qualitative methods, the study aims to capture a multi-faceted understanding of the impacts and perceptions surrounding these phenomena within the district. Similar studies have examined climate change in research areas with high population growth rates (Işınkaralar, 2023; Kaygusuz and Toklu, 2023). This methodological design ensures that statistical trends are contextualized within the experiences of individuals and communities, providing a comprehensive foundation for analysis.

2.1.Data Collection

Quantitative data was drawn from multiple authoritative sources to establish a robust dataset for trend analysis:

Meteorological Data: Historical weather records from the Turkish State Meteorological Service were collected, focusing on temperature, humidity, and precipitation patterns spanning the past three decades. This dataset provides insights into long-term climate changes affecting the region.

Population Data: Demographic statistics from the Turkish Statistical Institute were obtained to document changes in population size, density, and distribution within Konyaaltı over recent years. These data support an understanding of how migration has influenced local demographic structures.

Qualitative data was gathered through semi-structured interviews with key informants, including long-term residents, local policymakers, and environmental specialists. The interview questions explored personal experiences, perceptions of climate change, migration impacts, and community responses. This qualitative component enriches the quantitative findings by providing context-sensitive insights into how individuals and the

community perceive and adapt to climate-induced challenges.

This study obtained quantitative data from the Turkish Statistical Institute (TÜİK) and the General Directorate of Meteorology between 1990 and 2020. Qualitative data were collected through face-to-face interviews, and the participants consisted of 40 people: 20 long-term residents and 20 immigrants living in the Konyaaltı region. Interview questions focused on climate change perceptions, migration experiences, and adaptation processes. Mann-Kendall trend test and Pearson correlation analysis were used to analyze quantitative data, and these analyses were performed with Python software.

The research focused on quantitative data to understand the relationship between climate change and migration. Quantitative analyses were conducted on statistical, demographic population, and meteorological data constituting the study's main backbone. However, qualitative data were also collected and analyzed. However, qualitative data played a limited role in this study and were used to obtain a general impression and provide a context that supports quantitative findings. The findings and analysis results obtained from qualitative data will be discussed more comprehensively in future studies, and more in-depth analysis of qualitative data will be targeted in these studies. This approach will provide the opportunity to evaluate the quantitative and qualitative dimensions of the relationship between climate change and migration.

2.2. Data Analysis

Quantitative data was analyzed through rigorous statistical tests to establish trends and relationships:

Mann-Kendall Trend Test: This non-parametric test detected statistically significant trends in temperature and precipitation data, highlighting any regional directional climate changes.

Correlation Analysis: Pearson correlation coefficients were calculated to examine the relationship between population density and climate variables, such as average temperature, to assess how population growth may influence local climate patterns.

The qualitative data from interviews was systematically analyzed using thematic analysis:

Coding and Theme Identification: Interview transcripts were meticulously coded, with particular attention given to recurring themes and patterns related to climate change impacts, migration-driven demographic shifts, and community-level adaptation strategies.

Synthesis: Identified themes were synthesized to form a coherent narrative of the community's adaptive strategies and challenges, providing a deeper understanding of lived experiences and perceptions.

Quantitative and qualitative findings were integrated to comprehensively understand the interplay between climate change and migration in Konyaaltı. This triangulated approach, combining statistical trends with community perspectives, enhances the validity and depth of the conclusions, presenting a holistic view of how climate and demographic shifts intersect at the local level. The mixed-methods approach thus enables a nuanced perspective that informs sustainable policy recommendations tailored to the region's unique context.

3.Results

Konyaaltı is a district in Antalya province, located in the Mediterranean region of Türkiye. Because of its location, it has recently experienced a high migration rate, and its population has grown significantly. The weather data for Konyaaltı includes various climate metrics (such as solar radiation, humidity, temperature, and rainfall) gathered from the General Directorate of Meteorology (MGM). The population data over the years was obtained from the Turkish Statistical Institute (TURKSTAT). When viewed holistically, mi-

gration and population growth are thought to contribute to regional climate change. Statistical analyses must be performed to investigate this relationship and interpret the results. The findings were interpreted in light of climate change.

Performing statistical analyses and visualizing the results will explore the relationship between population growth and climate variables. This will help to interpret the findings in the context of climate change by summarizing the population growth and key climate metrics over the years. The annual data have been aggregated, showing the average climate metrics and the maximum yearly population. This will allow us to analyze trends and explore the relationship between population growth and climate variables. The visualization of population growth and climate metrics in Konyaaltı has been successfully created and displayed in Figure 1 and Figure 2. The charts show trends in population, average temperature, and humidity over the years, which will help analyze potential correlations between these variables.

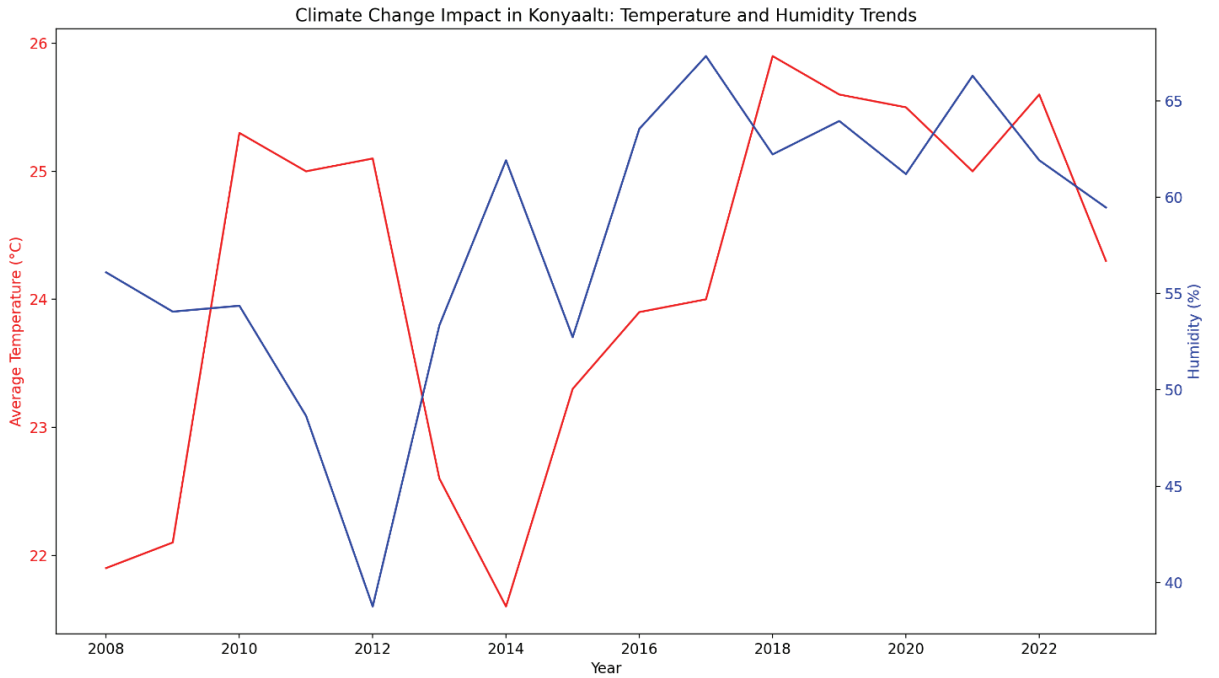

Figure 1. Trends in average temperature and humidity over the years (TSMS, 2023).

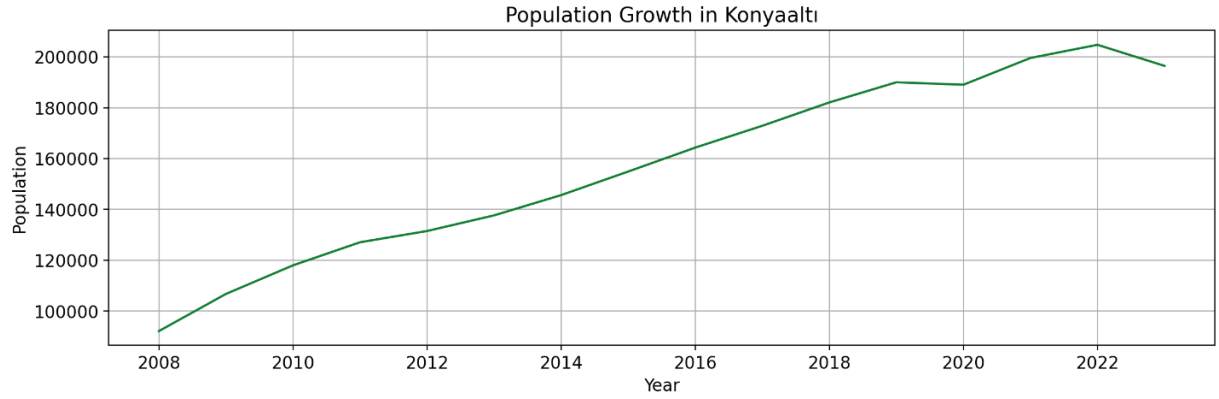

Figure 2. Trends in population over the years (TÜİK, 2023).

3.1.Trend analysis using the Mann-Kendall and Sen's Slope tests

To analyze the impact of population growth on climate change in Konyaaltı, the Mann-Kendall trend test and Sen's Slope estimator were performed on the climate data to investigate the effect of population growth on temperature and humidity trends over the years. This will help to determine whether statistically significant trends could be attributed to population growth and migration. These tests are beneficial since they are non-parametric, meaning that monotonic trends may be found without assuming a particular data distribution. This property makes the tests less susceptible to outliers and appropriate for hydrological data, which frequently show serial correlation. (Hamed, 2008). In the semi-arid regions around Lake Urmia, for instance, studies have demonstrated that the combination of MK and Sen's methods has successfully identified increasing trends in extreme temperature and decreasing trends in rainfall indices (Berhane et al., 2020; Ahmadebrahimpour et al., 2019).

Trend analysis using the non-parametric Mann-Kendall and Sen's Slope Tests through the Eqns. (1)-(5). In the Mann-Kendall Test, the test statistic S is calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \tag{1}$$

Where $sign(x)$ is:

$$sign(x) = \begin{cases} 1 & if\ x > 0 \\ 0 & if\ x = 0 \\ -1 & if\ x < 0 \end{cases} \tag{2}$$

The variance of S is computed as:

$$VAR(S) = \frac{n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)}{18} \tag{3}$$

Where t is the extent of any given tie and $\sum_t$ denotes the summation of all ties.
The test statistic Z is calculated as:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \tag{4}$$

The Sen's slope estimator is the median of all pairwise slopes:

$$Sen's\ slope = median\left(\frac{x_j - x_i}{j - i}\right) \tag{5}$$

for all $i < j$, where x_i and x_j are data values at times i and j, respectively.

The Mann-Kendall test result indicates a statistically significant increasing trend in average temperature, while no significant trend is observed in humidity. This suggests that rising temperatures in the region may reflect climate change, potentially influenced by population growth and migration. The following figures illustrate average temperature and humidity trends, while the table summarizes the Mann-Kendall and Sen's Slope test results (See Figure 3 and Table 1).

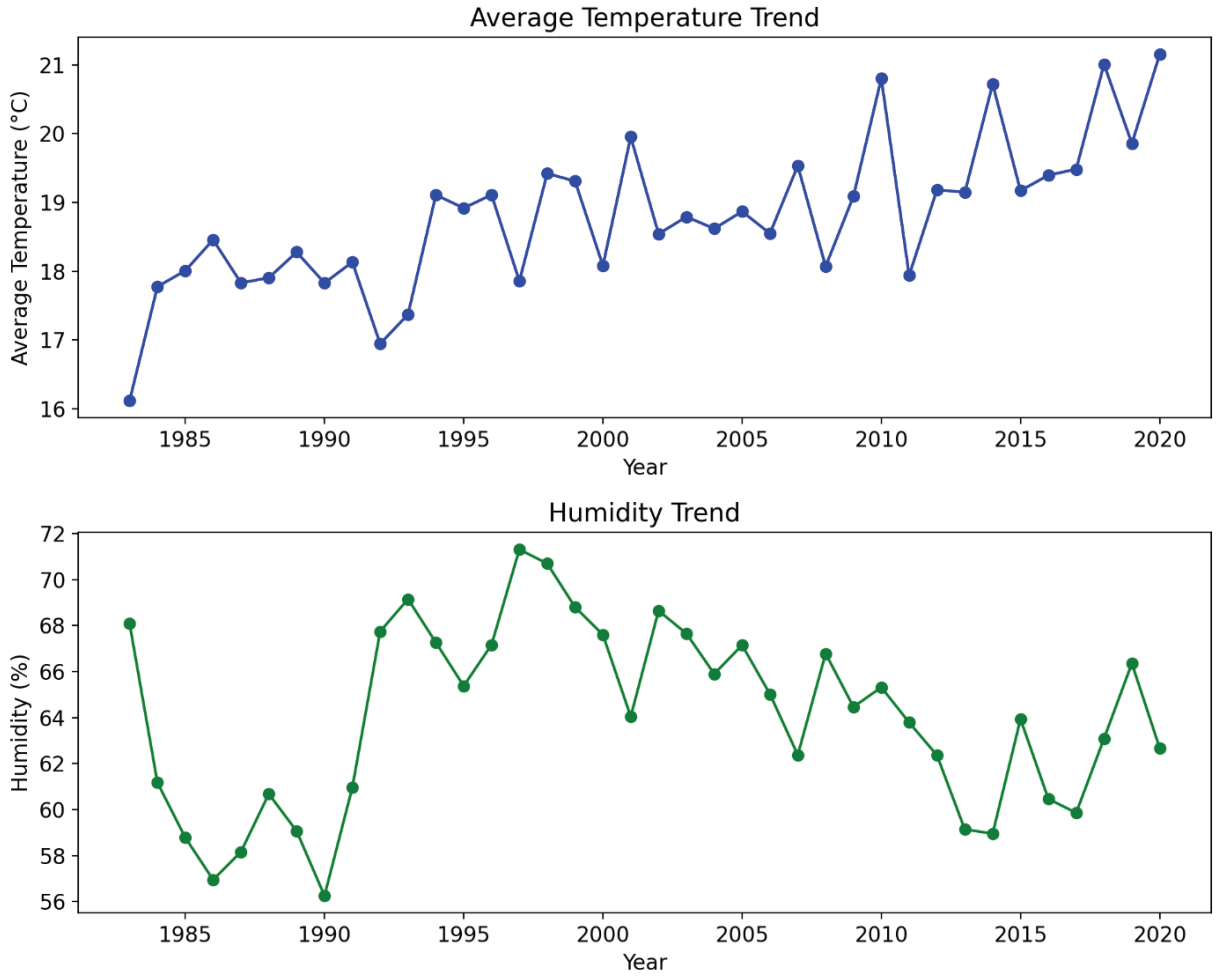

Figure 3. Trends of the average temperature and humidity (TSMS, 2023).

Table 1. Mann-Kendall and Sen's Slope Test Results for Weather Data in Konyaaltı.

Test	Average Temperature	Trend	Humidity	Trend
Mann-Kendall	0.0003627052	increasing	0.0008402455	increasing
Sen Slope	0.0001942661	increasing	0.0000949806	increasing

The Mann-Kendall test indicates an increasing trend in average temperature and humidity, while Sen's Slope provides the rate of change for these variables. This suggests a potential impact of climate change in Konyaaltı. The findings were correlated with population changes to assess the effect of migration on climate change. The visualization in Figure 4 underscores the consistent increase in global population and temperature anomalies over time, reflecting a pattern relevant to understanding long-term environmental impacts. The global population data are based on estimates from the World Bank, while the temperature anomaly data approximates figures from NASA's Goddard Institute for Space Studies (GISS) (NASA/GISS, 2023; World Bank, 2023). Similarly, on the local scale, the scatter plot in Figure 5 illustrates the relationship between population and average temperature.

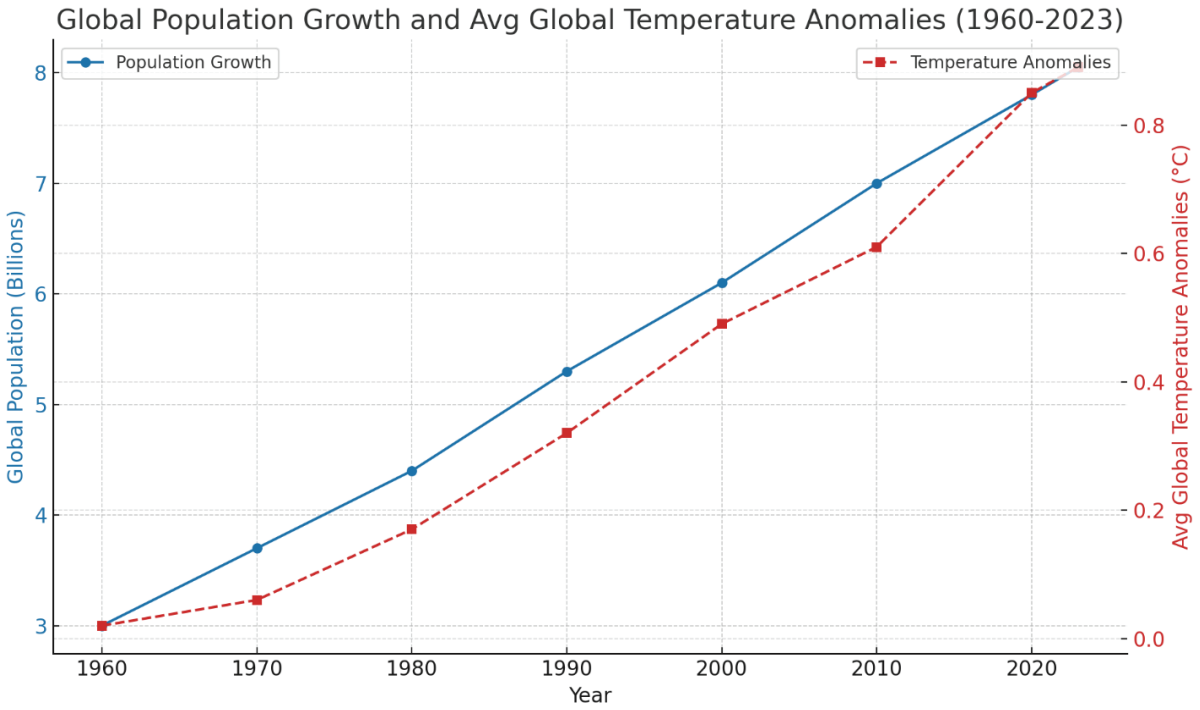

Figure 4. The statistical plot shows the relationship between global population growth and average global temperature anomalies from 1960 to 2023 (NASA/GISS, 2023; World Bank, 2023).

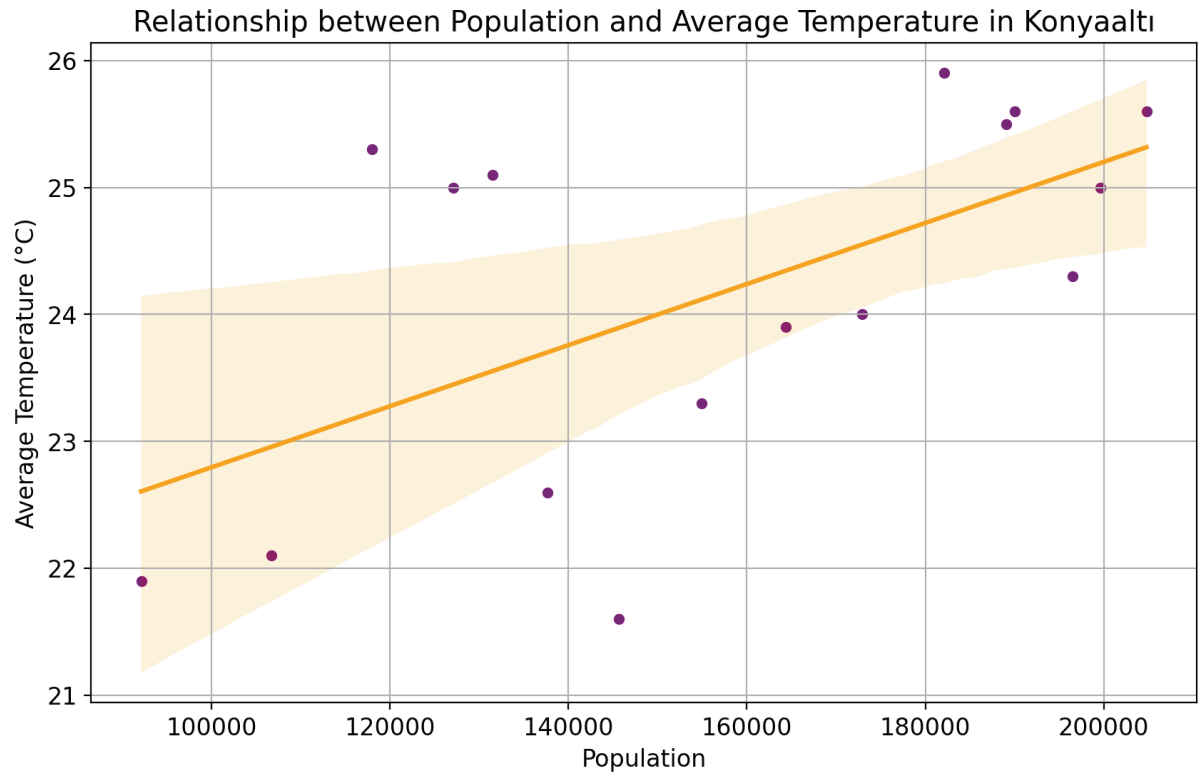

Figure 5. The temporal relationship between the average temperature and the population in Konyaaltı (TSMS, 2023; TÜİK, 2023).

Tablo 2. Statistical metrics for the average temperature by the population scatter plot.

Slope	Intercept	R-squared	P-value	Standard Error
0.0000240492	20.3913753511	0.3465148956	0.0164436132	0.0000088266

The statistical metrics indicate a positive slope of approximately 2.40×10−5, suggesting a slight increase in average temperature with population growth. The R-squared value of roughly 0.35 indicates a moderate correlation, while the P-value of 0.016 suggests that the relationship is statistically significant. This analysis highlights a potential link between population changes and temperature increases that may reflect the impacts of climate change in Konyaaltı.

The metrics indicate varying degrees of correlation between population and different weather parameters, with some showing significant relationships (see Figure 6).

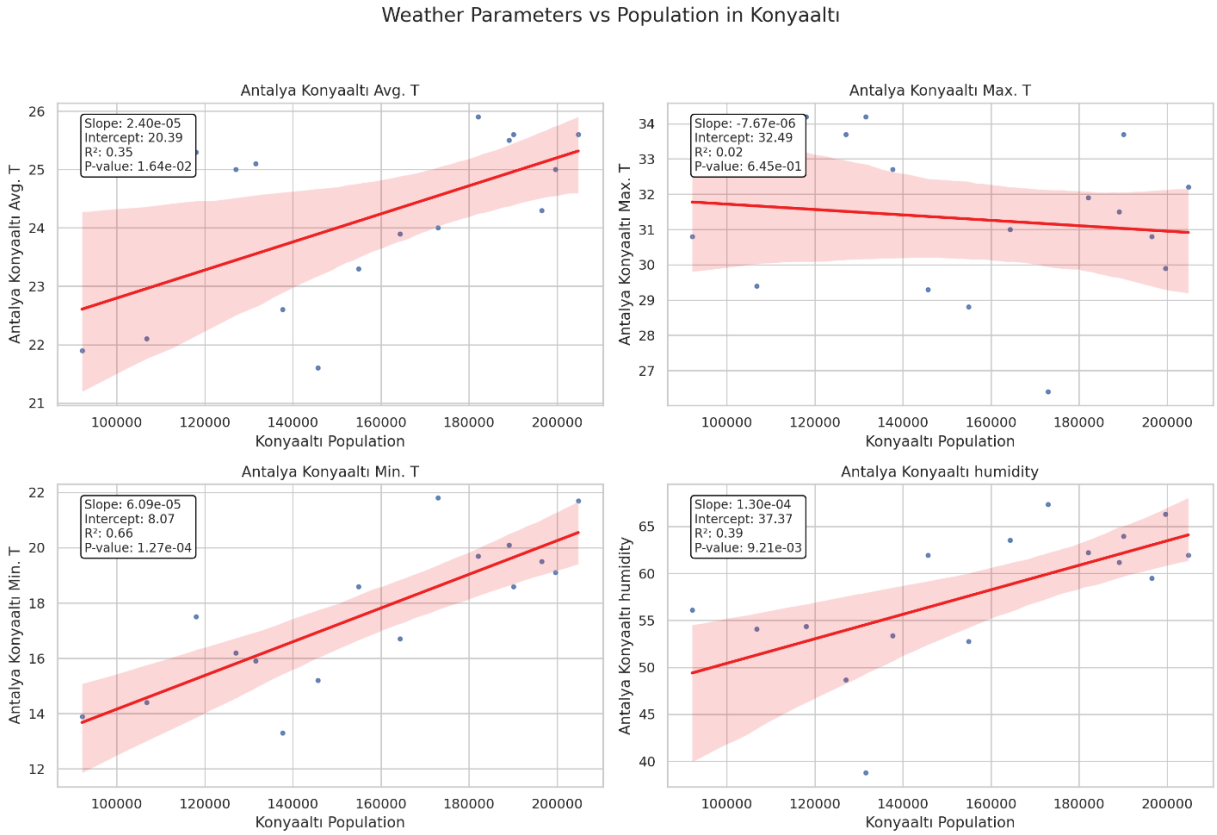

Figure 6. The trends between population changes and weather parameters in Konyaaltı (TSMS, 2023; TÜİK, 2023).

3.2. T-test as an inferential statistical test

Statistical metrics (e.g., slope, R^2, p-value) can indicate whether there is a significant correlation between population growth and changes in weather parameters. However, proving causation would require a more comprehensive analysis, including other factors influencing climate change. Hence, additional statistical tests were conducted to analyze the data. It is typically required to perform statistical tests such as ANOVA and t-tests on the weather parameters against the population data to determine if there are statistically significant differences or correlations. This will help identify potential links between population growth and changes in weather patterns and to evaluate the impact of climate change in Konyaaltı. However, the ANOVA results are unavailable for this dataset because of the number of groups that will perform ANOVA. ANOVA requires at least three groups to compare, but our data is grouped by year.

Nonetheless, the t-test results indicate varying significance levels across different weather parameters in Konyaaltı. The process for the t-tests on the weather parameters against the population data is as follows:

- Prepare the data by grouping it by year and calculating annual averages for weather parameters.
- Perform the t-tests for each weather parameter against the population.
- Create a table with t and P-values for all parameters.
- Analyze the results to determine if there are statistically significant differences or correlations.

The correlation heatmap will help determine whether there are significant differences or correlations between weather parameters and population (see Figure 7). The results for the t-test results and the P-values for the weather parameters are shown in Table 3.

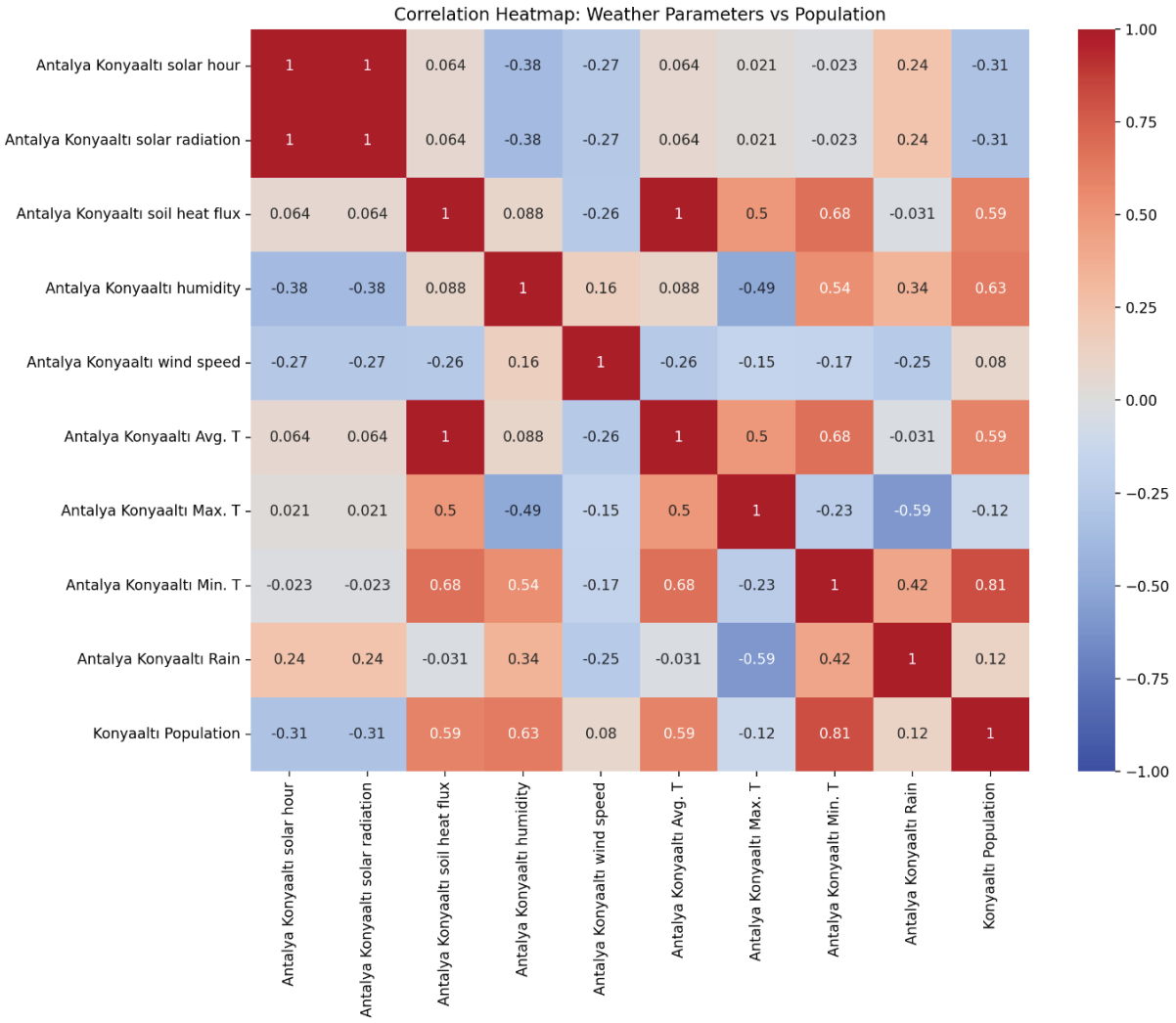

Figure 7. The correlation heatmap for the weather parameters and the population (TSMS, 2023; TÜİK, 2023).

Tablo 3. The t-test results for the weather parameters in Konyaaltı, Antalya.

Parameter	T-test t-value	T-test P-value
solar radiation	0.5506495164956735	0.5905530700018222
soil heat flux	-2.6112993453283724	0.02052088080017926
humidity	-4.241140857266308	0.0008221530300184912
wind speed	-0.24518727200057108	0.8098689855137411
Avg. T	-2.611299345328415	0.020520880800177554
Max. T	0.6377635743925517	0.5339203060250982
Min. T	-4.647946338683549	0.0003765481842864683
Rain	-1.0	0.33428194339465733

Table 3 shows the t-test t-values for each weather parameter to the population. The t-test results show significant differences (P-value < 0.05) for soil heat flux (t = -2.61), humidity (t = -4.24), average temperature (t = -2.61), and minimum temperature (t = -4.65). These parameters show statistically significant changes as the population increases. These results reveal a correlation between specific weather parameters, particularly humidity and temperature, and an increase in population. ,

The Mann-Kendall trend test results show that there has been a statistically significant increase in average temperature in the Konyaaltı region between 1990 and 2020 (p < 0.05). This increase is consistent with the temperature increase in Türkiye and reflects global climate change trends. Qualitative findings reveal that migrants' perceptions of climate change differ from those of locals. For example, one participant stated, 'The weather is getting hotter here, but it is more bearable than the drought in my country.'

Figure 8 clearly expresses temperature trends on both global and local scales. Between 1990 and 2020, the average annual temperature increased by 0.2°C per decade worldwide, while in Türkiye, this increase occurred between 0.3°C and 0.4°C per decade. In Antalya and Konyaaltı, the temperature increase is more pronounced, with increases of 0.3°C to 0.5°C per decade. This situation is due to local factors such as rapid urbanization, tourism activities and population growth. The population of Konyaaltı quadrupled from ~50000 in 1990 to ~200000 in 2020. This rapid population growth has accelerated the temperature increase by increasing the urban heat island effect in the region. While a similar temperature increase is generally observed in Antalya, population density and urbanization impact are more pronounced in Konyaaltı (See Table 4). These findings reveal the complex relationship between climate change, rapid population growth, and urbanization.

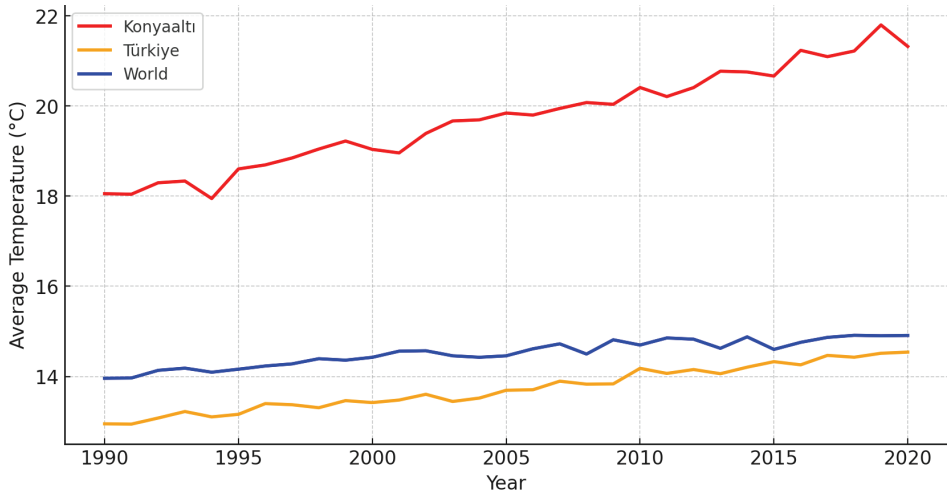

Figure 8. Temperature trends in Konyaaltı, Türkiye, and the world (NASA/GISS, 2023; NOAA, 2023; TSMS, 2023).

Tablo 4. Comparative temperature statistics and population data for Konyaaltı (NASA/GISS, 2023; NOAA, 2023; TSMS, 2023; TÜİK, 2023).

Year	World Avg. Temp. (ºC)	Türkiye Avg. Temp. (ºC)	Konyaaltı Avg. Temp. (ºC)	Konyaaltı Population (Capita)
1990	13.96	12.95	18.05	54231
1991	13.97	12.94	18.04	53942
1992	14.14	13.08	18.30	62222
1993	14.18	13.22	18.33	61548
1994	14.09	13.10	17.95	74920
1995	14.16	13.16	18.60	76779
1996	14.23	13.40	18.69	84588
1997	14.28	13.37	18.85	89086
1998	14.39	13.31	19.04	94323
1999	14.36	13.46	19.22	94638
2000	14.42	13.42	19.04	97693
2001	14.56	13.48	18.96	104611
2002	14.57	13.60	19.39	105189
2003	14.46	13.45	19.67	115426
2004	14.43	13.52	19.69	116309
2005	14.46	13.69	19.84	128031
2006	14.61	13.71	19.80	133265
2007	14.72	13.89	19.94	137014
2008	14.50	13.83	20.07	143150
2009	14.81	13.84	20.04	147779
2010	14.70	14.18	20.41	149070
2011	14.85	14.07	20.21	154804
2012	14.83	14.15	20.41	162577
2013	14.62	14.06	20.77	165943
2014	14.88	14.21	20.75	169029
2015	14.60	14.33	20.66	176462
2016	14.76	14.26	21.23	180323
2017	14.87	14.47	21.09	184651
2018	14.91	14.43	21.22	185087
2019	14.90	14.51	21.80	194854
2020	14.91	14.54	21.32	197093

4. Discussion

The findings of this study highlight a significant relationship between climate change and migration-induced population growth in the Konyaaltı district of Antalya, Türkiye. The statistical analyses conducted, including the Mann-Kendall trend test and correlation analysis, reveal a notable increase in average temperature, which correlates positively with population growth. This suggests that as the population increases, the region may experience exacerbated effects of climate change, particularly in terms of rising temperatures. Recent literature supports these findings, indicating that migration can significantly impact local climates and environmental conditions. For instance, a study by Nagle Alverio et al.

(2024) found that urbanization due to migration leads to increased heat retention in cities, further contributing to local temperature rises.

Similarly, Palginõmm et al. (2024) emphasized the role of population density in amplifying climate change effects, particularly in coastal regions. The implications of these findings are profound, as they underscore the need for integrated policies that address migration and climate change. Policymakers should consider the interplay between these factors when developing sustainable urban planning and environmental management strategies.

Furthermore, the significant differences observed in climate variables such as soil heat flux and humidity as population increases indicate that targeted interventions may be necessary to mitigate these impacts. Future research should focus on longitudinal studies that track the long-term effects of migration on climate variables and the socio-economic consequences of these changes. Understanding the feedback loops between migration and climate change will be crucial for developing effective adaptation strategies (Arshad et al., 2022; Uddin et al., 2022). As a result, this study contributes to the growing body of evidence linking migration and climate change, highlighting the urgent need for comprehensive approaches to address these interconnected challenges.

Meanwhile, this study presents significant implications for architecture and urban planning. Research indicates that rising temperatures correlate with increased population density, aggravating urban heat island effects and straining local resources. This scenario necessitates re-evaluating urban planning strategies to effectively incorporate climate resilience and sustainability principles. Urban planning must prioritize integrating green infrastructure to mitigate the impacts of climate change. For instance, the development of parks and open spaces can serve as heat outlets, reducing urban heat island effects and enhancing the ecological footprint of urban areas (Feizi, 2021). Moreover, sustainable housing models incorporating resilience characteristics are fundamental in addressing the risks of climate change (Ruíz and Mack-Vergara, 2023). The need for adaptive urban governance frameworks is underscored by the findings, suggesting that planners should adopt a multi-faceted approach that considers both the environmental and social dimensions of urban resilience (Tyler and Moench, 2012).

The findings of this study are consistent with other studies in the literature. For example, Nagle Shen et al. (2020) stated that migration increases the urban heat island effect. However, this study is one of the first to examine the relationship between climate change and migration in a tourism region like Konyaaltı. The limitations of the study include data deficiencies and time constraints. In future studies, it is recommended that a broader period and more qualitative data be collected.

Furthermore, the study advocates for interdisciplinary strategies in sustainable development planning, emphasizing the importance of longitudinal studies to understand the feedback loops between migration and environmental change. This aligns with the broader discourse on urban resilience, highlighting the necessity of addressing urban inequalities and vulnerabilities in climate change responses (Broto and Bulkeley, 2013). Integrating geoscience information and disaster resilience strategies can also enhance urban planning efforts, ensuring that cities are better equipped to handle the dual challenges of migration and climate change (Affandi et al., 2023). Consequently, the findings from the study call for a paradigm shift in urban planning, where climate adaptation and migration are viewed as interconnected challenges. By prioritizing sustainable urban development and resilience frameworks, cities can better manage the impacts of climate change while accommodating growing populations. This holistic approach is essential for fostering resilient urban environments capable of withstanding future climate shifts.

4.1. Limitations

While offering valuable insights into the relationship between climate change and migration in the Konyaaltı district, this study faces several limitations that must be recognized.

First, data availability poses a significant constraint. The research relies heavily on historical data, which may not encompass all relevant variables affecting migration and climate change. Data gaps can lead to analyses and conclusions that may be incomplete, limiting the study findings, especially on causality among the variables of climate and population. Another limitation is generalizability. The findings are specific to the Konyaaltı district and may not apply to regions with differing socio-economic and environmental conditions. This specificity restricts the broader applicability of the results, as regional variations in climate, migration patterns, and policy contexts can affect outcomes differently. The study's temporal scope also limits its comprehensiveness. By focusing on a particular time frame, the research may overlook broader, long-term climate and migration patterns trends. Future studies would benefit from a more extended temporal analysis to better capture evolving dynamics.

Additionally, subjectivity in qualitative data presents challenges. The qualitative data gathered through interviews may reflect individual biases and personal perceptions, which could influence the findings. Although thematic analysis mitigates this somewhat, subjectivity cannot be entirely removed. Finally, the complex interactions between climate change and migration add further difficulty. This relationship is shaped by various economic, political, and social factors that this study may not fully account for, potentially simplifying a complex interplay. In conclusion, while this research advances understanding of the climate-migration nexus in Konyaaltı, these limitations should be considered when interpreting its findings and implications.

4.2. Recommendations for future research

The findings of this study show that the relationship between climate change and migration in the Konyaaltı region has a complex structure. Policymakers should design programs that support the adaptation processes of migrants while developing sustainable urban planning strategies. In addition, green infrastructure projects and energy efficiency measures can play an essential role in reducing the effects of climate change. Future research should focus on qualitative studies examining the adaptation processes of migrants to climate change. Quotes from the participants' statements will support the qualitative findings obtained and provide a richer and more multi-dimensional presentation of the effects of climate change and migration on individuals and communities. This approach will allow a more in-depth analysis of the impacts of climate change and migration interaction on human behavior and motivations, especially in the Konyaaltı region.

5. Conclusions

This study has elucidated the complex interplay between climate change and migration-driven population growth in the Konyaaltı district of Antalya, Türkiye, offering crucial insights into how these intertwined phenomena affect local environments and resources. The analysis revealed a substantial correlation between rising temperatures and increased population density, underscoring the compounded challenges of climate change and rapid urbanization. As the Konyaaltı region continues to attract migrants drawn by its favorable climate and economic prospects, the environmental implications of this influx are particularly significant.

The findings indicate that population growth intensifies the impacts of climate change through mechanisms such as urban heat retention and heightened resource demands. This dynamic accentuates the need for integrated policy frameworks that address migration management and climate adaptation.

Effective strategies must recognize the reciprocal influences between population dynamics and environmental stressors to create resilient urban planning approaches that accommodate and regulate population growth while minimizing ecological impacts. Additionally, the study highlights the value of longitudinal research for tracking and understanding the lasting effects of migration on climate variables at the regional scale. Such longitudinal analyses are essential for developing effective adaptation measures that enhance resilience to the continuous pressures of climate change. Monitoring these changes over time will deepen our understanding of how migration reshapes environmental patterns, informing more targeted and sustainable adaptation practices. In conclusion, this research contributes to a growing body of knowledge on the links between migration and climate change, emphasizing the importance of comprehensive strategies that address the shared challenges posed by these interconnected issues. Future research should aim to explore the feedback loops between human migration and environmental shifts further, ultimately providing insights that can guide sustainable development in regions increasingly vulnerable to the compounded effects of climate change and urbanization.

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