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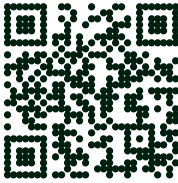
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Research Article

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The State and Problems of Meadow-Pastures in Türkiye in The 100th Anniversary of The Republic



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Abstract

Meadows and pastures are among the most important natural botanic resources in the world in terms of diversity and genetic richness. Although meadows and pastures are often first thought of as agricultural resources and foundational areas for livestock, this perspective is rather narrow. Besides being crucial for both cultural and wildlife animals, meadows and pastures also serve as special ecosystem services that prevent erosion, regulate soil temperature, conserve water resources, support beekeeping, and provide a rich genetic reservoir. There are various types of meadows-pastures represented by various species under different climatic conditions around the world. Due to the country's unique geographical position, Türkiye's meadowlands offer richness characterised by species from three major phytogeographic regions. In this study, which examines the issue of meadows-pastures from the perspective of Agricultural Geography as Türkiye marks its first century, the findings and necessary actions are presented. In this context, the limited literature on the subject has been reviewed, followed by archival studies that have compiled scattered and incomplete statistical data. Following this, over a four-year period, meadow-pasture observations were conducted in various locations (Siirt, Bitlis, Diyarbakır, Tokat, Amasya, Manisa, Tekirdağ, Hatay) through, discussions with technical teams to address past, present, and future conditions. Ultimately, while significant successful studies have been conducted on Türkiye's meadows-pastures with positive outcomes, it has become evident that the country's meadows-pastures need to be rehabilitated through strict policies.

Keywords

Meadows • pastures • animal husbandry • Agricultural Geography • Türkiye



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Introduction

Among natural resources, plant richness is undoubtedly the most important. Although meadows and pastures are initially perceived as merely an element of livestock, they are, in fact, like forests, a plant community unit considered among natural resources. Meadows and pastures are natural resources that contribute directly or indirectly to essential ecosystem services vital for human well-being (Bengtsson et al., 2019: 2; Schils et al., 2022: 1). Due to their multifaceted characteristics, meadows-pastures rank among the most important natural resources, with qualities such as being a source of animal feed, rich biological diversity, soil conservation, and water supply functions. However, when meadows and pastures are mentioned, livestock activities are undoubtedly the first thing that comes to mind among the listed functions. For this reason, meadow-pastures are always considered when planning livestock activities.

Pastures, shrubland, savannas, tundras, and highlands essentially represent similar ecosystems under different geographical conditions. Today, meadows-pastures are one of the largest ecosystems, covering nearly one-third of the world's terrestrial surface (Lemaire et al., 2011; Bengtsson et al., 2019: 2). Despite their importance, meadow-pasture areas are shrinking and degrading both globally and in Türkiye. This degradation and loss of meadow-pastures primarily cause significant problems in the ecosystem and, subsequently, in livestock, which is one of today's key economic activities.

During the establishment and development of the modern Republic of Türkiye, which passed its first century, agricultural activities have always been a priority. Within agricultural activities, livestock farming has been a critical and special place. As previously mentioned, meadows and pastures cannot be separately considered for livestock farming. The main issue here is that the lands on which the modern Republic of Türkiye was established, have been inhabited for thousands of years and constitute a significant portion of the area where the first agricultural activities began. As a result, there is an issue of meadows and pastures in Anatolia, particularly degeneration and degradation. When factors such as long-standing unsuitable grazing practices and the incompatibility between meadow-pasture resources and grazed livestock breeds and species are added to this, an even more bleak picture appears for the state of our meadow-pastures. In recent years, the misuse of land for purposes other than intended has become a significant issue, particularly in meadow-pasture areas. With this in mind, over the past century, highly successful rehabilitation and allocation projects have also been carried out in meadow-

pasture areas in Türkiye. In this study, changes in meadow-pasture areas during the 100th year of the Republic of Türkiye are examined using a holistic approach.

Purpose and Method

In this study, the meadow-pasture resources of the modern Republic of Türkiye, which has completed its first century, were examined in line with principles of agricultural geography. Generally speaking, Türkiye's meadows and pastures have often been addressed in only a few paragraphs within land use studies and have only recently become the subject of independent research as a spatial entity. In addition to Agricultural Engineering, this topic has not received much attention from other disciplines and has generally been largely neglected within the discipline of geography as well. Due to this gap in the agricultural geography literature, there is a need to specifically address meadows and pastures. In this context, the literature review formed the first step of our research, in which previous studies were examined and efforts were made to access official data on the subject from archival records. Unfortunately, it is not possible to speak of reliable statistical data regarding Türkiye's meadow-pasture resources. Statistics on meadow-pasture existence at the national and provincial levels could only be compiled intermittently from the archives of TurkStat (formerly DIE), the Ministry of Agriculture and Forestry, and the Department of Meadows, Pastures, and Forage Crops. Data from MERBİS (Pasture Information System) for 2023 provided, by the Department of Meadows, Pastures, and Forage Crops under the Ministry of Agriculture and Forestry, which contains the most reliable recent data, are used within the scope of the 1998 "Meadow Law". Based on these data, meadow-pasture data for selected years at the provincial level were digitised, and maps were prepared using ArcGIS 10.8. Field studies extending over four years were conducted in Siirt, Bitlis, Diyarbakır, Tokat, Amasya, Manisa, Tekirdağ, and Hatay, focusing on botanical composition and utilisation practices in Türkiye's meadows and pastures. Interviews were conducted with herders (11 individuals) and agricultural engineers (17 individuals) from these various locations, and an attempt was made to derive general conclusions regarding regional and overall issues as well as expectations. Additionally, in areas where successful meadow-pasture rehabilitation has been conducted, selected forage crops and grazing periods were examined as case studies relevant to the topic.

Meadow and Pasture Presence and Geographic Distribution in Türkiye

Before explaining the meadow and pasture presence in Türkiye, it is useful to briefly describe the geographical conditions affecting this natural resource. Türkiye is located in the temperate zone and generally experiences Mediterranean, humid maritime, pontic and continental climates, with occasional transitional climates in some regions. In addition, due to the diversity of the country's topography, Türkiye has a significant number of areas with microclimatic conditions, as well as extensive regions experiencing Mediterranean, continental, and temperate climatic conditions. These changes result in a wide variety of plant species across the country. Elements from the European-Siberian (Oxycoccus and Colchic flora), Iran-Turan, and Mediterranean phytogeographical regions dominate Türkiye. This is why Türkiye is rich in floristic diversity and endemic species. This richness is evident in our meadows and pastures as well although it has dramatically declined because of years of improper livestock grazing systems and incorrect land use. In particular, between 1960 and 1980, conventional agricultural practices involving the use of chemical fertilisers, herbicides, pesticides, and various soil cultivation activities led to the loss of species and varieties in pasture areas or the deterioration of floristic composition (Okuyucu and Okuyucu, 2009: 548). In Türkiye's internal regions of Türkiye, climax vegetation has been destroyed. As a result, heavy and untimely grazing, invasive and unpalatable species to ruminants gradually dominate, which is then followed by a reduction or thinning of these species.

When explaining meadow and pasture resources in Türkiye and their geographical distribution, it should be noted that there are still no definitive data on the subject. This impedes accurate assessment. According to the most recent official data in Türkiye, there are 14.6 million hectares of meadows and pastures. However, under the "National Pasture Use and Management Project", 16.3 million hectares of pasture area have been identified in only 48 provinces (Gökkuş, 2019: 150). Therefore, the actual meadow and pasture area in Türkiye exceeds 20 million hectares. Including approximately 11.5 million hectares of land that could be classified as "Degraded Forest" and considered under "Shrubland", it is possible to say that grazing areas exceed 30 million hectares. Moreover, considering that maquis (scrublands) might also be included in pasture areas, and Türkiye has about 7.5 million hectares of maquis, it can be clearly stated that the meadow and pasture resources are much more extensive and significant. Conversely, with the enactment of the 4342 Law on Pastures in

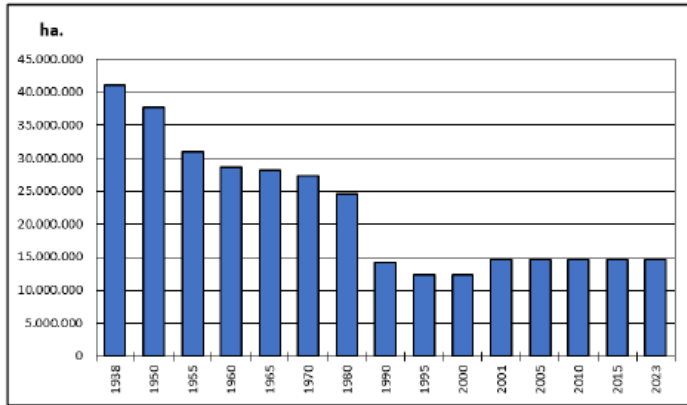
1998, more accurate data began to be collected following the start of identification and assignment efforts. As a result, since 2001, official data for Türkiye indicate 14.6 million hectares of meadows and pastures, with 13.2 million hectares identified by 2023 (Ministry of Agriculture and Forestry, Directorate of Meadows, Pastures, and Fodder Plants, 2024). However, historical data for Türkiye and provincial scales are based on the Turkish Statistical Institute data and generally the "General Agricultural Censuses" conducted every 10 years in the past.

When evaluating the 100-year period in Türkiye as a whole, it is observed that there have been significant initial declines meadow-pasture areas. While the total meadow-pasture area in Türkiye was over 40 million hectares in 1938, it decreased to 37.8 million ha. in the 1950s, 28.6 million ha. in 1960, 27.3 million ha. in 1970, 14.2 million ha. in 1990, and 14.6 million ha. as of 2023 (Figure 1). Accordingly, meadows-pastures, which had a large share of 54% of the national surface area in 1938, declined to 40% in 1955, 36% in 1965 (Cillov, 1972: 208), and finally to 18.9% in 2023. As shown in Figure 1, some of the dramatic declines in some years are due to sudden changes resulting from the alteration of the status of the pastures. For example, the "Law on Land Allocation for Farmers" enacted on June 11, 1945, led to a significant reduction in the number of pastures. This was influenced by the fact that the lands allocated to farmers were generally pasture lands, resulting in a notable decline in meadow-pasture areas by the 1950s. Accordingly, it is possible to say that a significant amount of pasture lands were converted into agricultural lands. Of course, this situation further increased livestock pressure on shrinking meadow-pasture areas. Nevertheless, according to the data on land holdings from *Zirai Bünye* and *İstihsal Bülteni* for 1949, meadow-pastures still represented the largest share with 50% in the land distribution (Bayar, 2004: 42). Later, with the establishment of the Ministry of Forestry on August 11, 1969, a notable second decline in meadow-pasture areas occurred when 7.5 million hectares of scrubland, classified as "Degraded Forest / Scrubland", were transferred to the jurisdiction of the newly established ministry. Indeed, the forested area in Türkiye, which was 10.6 million ha. in 1965, increased to 18.3 million hectares by 1969 (TurkStat, 2013). Lastly, with the change in land classification in 1980, a third decline occurred, and the status of some areas was altered. The conversion of pasture lands into agricultural areas and the change in their status also played a significant role in the reduction of these areas. For instance, from 2006 to 2012, a significant portion of pasture areas whose status changed, about 72%, was converted into dry and irrigated agricultural lands (Bayar, 2018: 196). As a result, meadow-pasture areas in

Türkiye decreased from 21.7 million ha. to 14.6 million hectares. Of this, 13.2 million hectares are pastures, whereas 1.4 million hectares are meadows.

Figure 1

Changes in Türkiye's Meadow-Pasture Areas over Selected Years



Source: TurkStat (Previously DiE) data (Agricultural Statistics Summaries, General Agricultural Censuses 1991, 2001); Cillov, 1972: 208

When examining the geographical distribution of meadows-pastures in Türkiye, as seen in Figure 2, these natural resources are concentrated in the country's interior regions. Generally, the availability of meadows-pastures decreases from east to west, with significant scarcity in the Marmara Region, particularly in Thrace. Similarly, in southeastern Anatolia, especially south of the southeastern Taurus Mountains, there is a noticeable reduction in meadow-pasture resources. Türkiye's relatively limited meadow areas, as shown in Figure 2, are observed as a belt along the north-facing slopes of the mountains in the Eastern Black Sea region, scattered in the north of Erzurum, and widely present in Ardahan on

the Georgian border. These areas are also known for their prevalence in cattle farming.

Following the enactment of the Pasture Law in Türkiye in 1998, within the 25-year period up to 2023, fieldwork has been completed for 90% (13,171,518 ha.) of the existing 14,616,687 ha. of meadow-pasture areas. Significant restriction work has been carried out on 87.5% of the current meadow-pasture areas, while 61.4% of these areas have been subjected to allocation. However, there are no definitive data on meadow-pasture resources in Türkiye. As of 2024, meadow-pasture identification studies are ongoing, and values are continually being updated. Therefore, it is expected that Türkiye's 14.6 million hectares of meadow-pasture resources will be updated in the future.

Looking at the trends in the studies over the selected years, as seen in Table 1, quite a variable development can be observed. For example, from 2000 to 2020, the meadow-pasture areas identified increased from 386,597 ha. to 1,248,841 ha. However, the process has followed a fluctuating development, with only 306,028 ha. of meadow-pasture area identified in 2010. Restriction studies, except 2020, generally fluctuated within a certain range and remained around 280 thousand hectares, with a remarkable increase to 889,572 hectares only in 2020. Allocation areas have remained much more limited than in other categories. Often remaining below 100,000 ha, allocation areas reached their highest value of 797,495 ha. in 2020 (Table 1). The main factors affecting this include security issues leading to the closure of some pastures and the resting of some pastures during management activities.

Figure 2

Geographical Distribution of Meadows-Pastures in Türkiye



Table 1

Determination, Limitation, and Appropriation Quantities of Meadows-Pastures in Türkiye by Year (ha.)

Years	Determination	Limitation	Appropriation
2000	386.597	284.860	38.020
2005	690.026	244.673	85.417
2010	306.028	299.716	574.898
2015	414.637	288.368	64.280
2020	1.248.841	889.572	797.495
2023 Total	13.171.518	12.793.113	8.984.257

Source: Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Pasture, Forage Crops, and Livestock, 2024

Based on 2023 data from the Pasture Information System (MERBİS), the geographical distribution of meadow-pasture areas indicates that the Eastern Anatolia Region has 5.7 million ha. as determined, 5.6 million ha. as limited, and 3.3 million ha. as appropriated areas (Figure 3). The Eastern Anatolia Region, one of the most problematic regions in Türkiye, is also considered the country's livestock centre due to its topography and floristic characteristics. The meadow-pasture resources support this economic activity. The Central Anatolia Region follows this region, with a total of 4.2 million ha. of determined meadow-pasture areas. In this region, the limited area is 4.1 million ha., and the appropriated area is 3.6 million ha. (Figure 3). These two geographical regions together account for a significant portion (75.8%) of Türkiye's total meadow-pasture areas, or approximately 10 million ha. The Black Sea Region ranks third, with 1.1 million ha. determined, 1 million ha. limited, and 530.069 ha. appropriated areas. Among the geographical regions, the Black Sea Region has the largest discrepancy between identified and allocated meadow-pasture areas. Following the leading region, the Southeastern

Anatolia Region has 741.351 hectares determined, 735.032 hectares limited, and 643.450 hectares appropriated. The other three coastal regions, particularly the Marmara Region, have very low proportions of meadow-pasture resources (Figure 3). As of 2023, the appropriation ratios of determined meadow-pasture areas by region are as follows: 87.6% in the Marmara Region, 86.8% in the Southeastern Anatolia Region, 85% in the Central Anatolia Region, 64% in the Mediterranean Region, 64% in the Aegean Region, 57.3% in the Eastern Anatolia Region, and 47.2% in the Black Sea Region. The low appropriation ratio of meadow-pasture areas in the Eastern Anatolia Region is particularly due to the closure of some pastures for security reasons. In contrast, in the Marmara Region, where meadow-pasture resources are quite limited, a significant portion of the study area has been opened to livestock activities.

When examining meadow-pasture resources at the provincial level, data from past General Agricultural Censuses indicate that provinces in the inner regions (such as Erzurum, Van, Ankara, Kayseri, Konya, Kars) stand out. As a general trend, meadow areas in the provinces of the western regions are beginning to occupy smaller areas (Figure 4). Although meadow-pasture areas appear to have diminished from 1991 to 2022, the key point to emphasise is that this perception is largely due to the lack of reliability in historical meadow-pasture data.

Finally, the map prepared based on the 2023 data in Figure 4 uses current and reliable data obtained from the Meadow-Pasture Information System (MERBİS). According to these findings, meadow-pasture areas in the inner provinces cover a broader area at the provincial scale. Meadow-pasture areas, extending in a band-like manner from the provinces of the Eastern Anatolia Region, are beginning to thin out in the

Figure 3

Determination, Limitation, and Appropriation Values of Meadow-Pastures in Geographical Regions

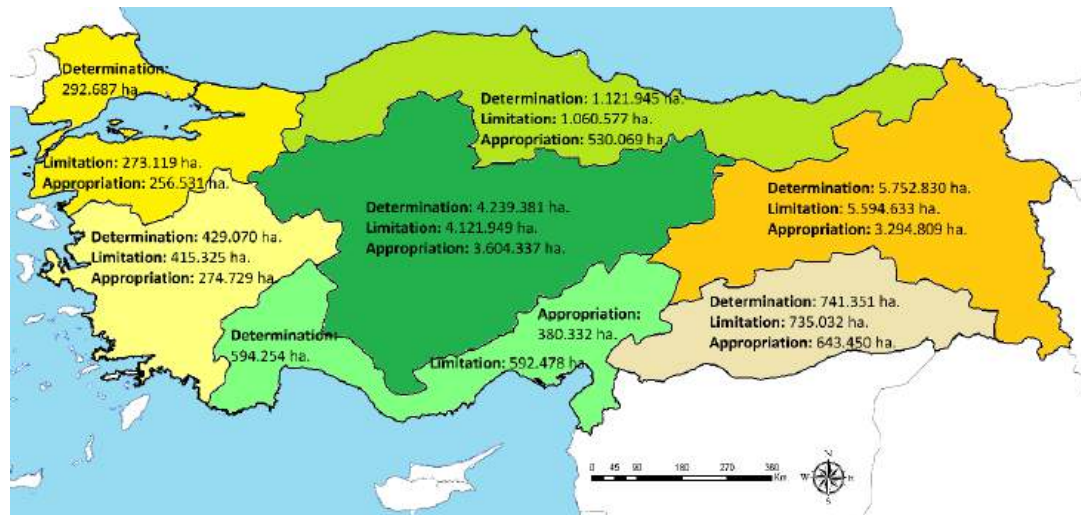
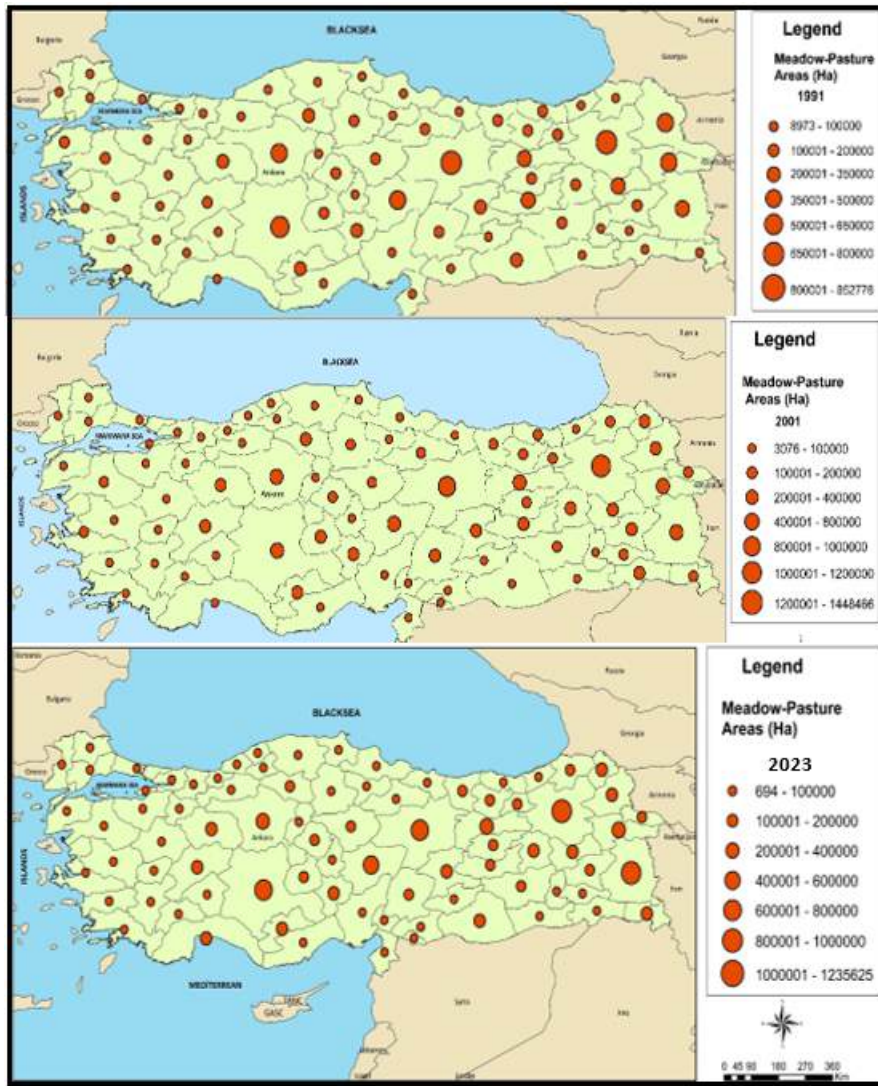


Figure 4

Distribution of Meadows-Pastures by Province in Türkiye for the Years



Aegean and Marmara regions. Notably, the weakness in Trakya is striking. When examining the determination, limitation, and appropriation amounts and proportional values of leading provinces in Türkiye, only Antalya from the coastal provinces is among the top 15 provinces, ranking 15th (Table 2). Van, the province with the highest meadow-pasture resources, has determined 1.2 million hectares of meadow-pasture, with almost all of it appropriated, making up 76.4% of the total agricultural land (Table 2). However, the appropriation rates show that only 44.2% of the existing meadow-pastures are used for livestock. Erzurum, ranks second, with over 1 million hectares of meadow-pasture resources, with these areas making up 71.5% of the total agricultural land. Unlike Van, approximately 80% of the meadow-pastures in Erzurum are in use. The third-ranked province is Konya, which has the largest meadow-pasture resources in the Central Anatolia Region. A significant portion of Konya's identified 845.580 hectares has been restricted, and meadow-pastures constitute only 30% of

the province's vast agricultural land (Table 2). Among other notable provinces, Sivas is one. Almost all the meadow-pasture areas in the province (96.2%) were allocated for livestock use. A similar situation applies to Şanlıurfa, Ankara, and Muş. A notable aspect of Ankara is that it has the smallest proportion of meadow-pastures among the top 15 provinces in terms of total agricultural land. The low allocation rate in Hakkari is due to the closure of many pastures for security reasons. In Kars, where livestock is a significant activity, the both limited meadow-pasture rate is very low, and the appropriated areas are very limited. This increases livestock pressure on used meadows and pastures.

Improvement and Management of Meadows and Pasture in Türkiye

In Türkiye, the first and most significant development in the improvement and management of meadows and pastures was the establishment of the "Meadow-Pasture and

Table 2*The Top 15 Provinces in Türkiye with the Largest Meadow and Pasture Area as of 2023*

Cities	Determination	Limitation	Rate of Limitation of Total Agricultural Land (%)	Appropriation	Rate of Appropriation within the Total Meadow and Pasture Areas (%)
Van	1.248.970	1.235.625	76.4	552.290	44.2
Erzurum	1.072.172	1.036.393	71.5	855.692	79.8
Konya	845.580	816.559	30.2	680.351	80.4
Sivas	830.362	800.214	50.5	799.336	96.2
Kayseri	638.791	620.319	50.7	559.916	87.6
Ağrı	537.422	530.747	60.7	333.261	62.0
Erzincan	435.064	435.075	75.3	218.797	50.3
Ankara	424.713	407.916	26.0	407.876	96.0
Kars	417.936	341.784	59.3	198.711	47.5
Şanlıurfa	335.242	342.237	23.3	335.242	100.0
Muş	334.928	350.868	53.8	320.797	95.8
Malatya	303.294	279.422	50.8	195.225	64.3
Eskişehir	292.088	287.231	34.5	191.009	65.4
Hakkâri	254.498	254.331	37.0	2.623	1.0
Antalya	235.861	237.460	42.2	72.710	30.8

Source: Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Pasture, Forage Crops, and Livestock, 2024

Animal Husbandry Research Institute” under the Ministry of Agriculture in 1952, and shortly thereafter, the “Meadow-Pasture, Forage Plants, and Feeding Research Institute” was established on May 29, 1959 (Anonymous, 1982: 1). This marked a significant step in both the conservation and utilisation of these natural resources, as well as in achieving integrated development with animal husbandry. The next major development was the establishment of the “Meadow Commission” under the leadership of a Deputy Governor under Law No. 4342 on Meadows.

When considering meadows and pastures in Türkiye, the most important topics include DLA (Determination – Limitation – Appropriation) and meadow improvement and management. Meadow improvement is defined as “the facilities and arrangements established on meadows to increase their productivity and quality, and to ensure that grazing animals benefit more and more easily from the produced forage.” Thus, the primary aim of improvement is to increase the density of plants with high forage value and to promote the spread of species that are preferred, nutritious, and easy to digest for animals. Selecting suitable species for geographic conditions and ensuring sustainable pasture management is crucial. In addition to high-nutrition cereal and legume forage plants, preventing the suppression of native flora is also important for the continuity of the ecosystem. This will make meadows useful both economically and ecologically for both domestic and wild animals.

In meadow management or administration, the capacity of the meadow and the rule/programs on how the meadows are used are established. Based on geographic conditions, the “Provincial Meadow Commissions” declare each year which types of animals will graze, and when and where they will graze, in light of vegetation elements and climatic conditions in a given area. This prevents excessive and untimely grazing of meadows. In Türkiye, the grazing season is roughly defined as between April and October (Table 3). However, depending on geographical conditions, different periods can be set within the same province. For example, in the southern part of Diyarbakır, the grazing season is from March 15 to September 15, whereas in the northern districts, it begins with a delay of about two weeks and ends on September 15 as well (Table 3). The same situation applies to Bolu, Hakkâri, Iğdır, and Adana. The altitude and distance of the meadows from the villages also affected the schedule. For instance, in the Bozkır district of Konya, the start date for grazing is May17 for areas with an altitude of 1200 metres or higher, and the end date is October 20 for areas below 1200 metres and October 5 for areas at 1200 meters or higher. However, it would be incorrect to consider only natural conditions when determining the grazing season. The number of animals to be grazed and their characteristics (whether they are culture or native breeds) are also considered. Additionally, grazing dates may vary each year depending on factors such as spring and autumn grazing, rotational grazing, and proximity to settlements.

Table 3*Grazing Season in Different Locations in Türkiye (2021–2024)*

Location	Season	Location	Season
Diyarbakır (Merkez, Çınar, Bismil, Ergani, Çermik, Eğil, Kocaköy, Silvan)	15 March–15 September	Kırklareli	20 April–20 October
Diyarbakır (Kulp, Lice, Dicle, Hazro, Çüngüş, Hani)	1 April–15 September	Niğde (Çamardı, Çiftlik, Ulukışla)	1 May–15 October
Mersin	1 April–15 October	Isparta	1 May–15 October
Bolu (Göynük, Mudurnu, Seben)	1 April–15 October	Bayburt	1 May–15 November
Bolu (Diğer ilçeler)	15 April–15 October	Burdur (Tefenni)	1 May–20 October
Iğdır (Merkez, Aralık, Karakoyunlu)	1 April–1 October	Hakkâri (Şemdinli, Çukurca, Derecik)	25 April–15 November
Iğdır (Tuzluca)	15 April–15 October	Hakkâri (Merkez, Yüksekova)	5 May–30 October
Erzincan	10 April–31 October	Van	15 May–15 October
Edirne	15 April–1 November	Adana (Aladağ, Feke, Saimbeyli, Tufanbeyli, Pozantı)	1 May–15 October
Kayseri	15 April–30 September	Gümüşhane	15 May–31 October
Niğde (Merkez, Altunhisar, Bor)	15 April–15 October	Giresun	20 May–10 October
Çanakkale	15 April–15 November		

In the management of pastures, determining the carrying capacity of the land and understanding its geographical conditions, including flora characteristics, are crucial. This is particularly important because industrial cattle farming, which has a significant impact on global climate change, must be addressed when considering pastoral farming on pasture. It is noteworthy that animals that graze freely on pastures typically do not experience vitamin and mineral deficiencies (Gökkuş, 2014: 151). At this stage, “Determination – Limitation – Appropriation” constitutes three basic steps. Initially, areas designated for permanent use as pastures must be determined and registered under the “Public Common Goods Registry” as “Pasture Special Registry” in accordance with relevant regulations. In evolving socioeconomic conditions, decisions regarding the reclassification of pastureland should be made by a team consisting of the Governor, Municipality, Village Head and, the Elderly Council. During the limitation phase, the pastures are delineated and divided into parcels for sustainable pasture management. The parceling process is essentially a form of allowing pastures to open. In this way, instead of allowing an entire pasture area to be exhausted in a single season, the area is opened for grazing in sections, and the ecosystem’s health is maintained in the rested parcels. In the appropriation phase, the areas designated for grazing, the time of year, and the capacity to meet the needs of a particular herd are considered. The land is then allocated to the village, neighbourhood, or municipal legal entity. In addition, pastures may be rented for improvement. Indeed, in Türkiye, a significant area of 4.645.374 hectares was leased for this purpose from 2002 to 2023 (Pasture and Forage Crops Department, 2024).

After identifying pasture and meadow areas and making them available for use according to certain principles, the improvement and management of existing pastures and meadows becomes the most pressing issue. This is because pastures in Türkiye are very weak and are greatly degraded. At this stage, it is essential to first understand the vegetation well, address flora elements that are suitable for geographical conditions, and support livestock activities. Under the “Pasture Law” No. 4342 in Türkiye, pastures are classified into various quality grades based on the types of vegetation (decreasing, increasing, invasive, etc.). However, at classification based solely on species (weak, medium, good, very good) is often insufficient, as some researchers have mentioned. It would be more appropriate to determine quality by considering the species density. Given that nearly ¾ of the country’s pastures require improvement and management, monitoring changes in vegetation structures and managing the process with up-to-date strategies (İspirli et al., 2016: 15).

In Türkiye, a mid-latitude country with predominantly continental conditions, pastures in the interior regions have been significantly worn out because of heavy grazing over the years. Therefore, drought-resistant, nutrient-rich cereal and legume forage plants should be widely used for pasture improvement. While doing so, a plant pattern suitable for geographical conditions and regional ecology must be established. Generally, rising temperatures lead to the dominance of perennial legumes in pastures; in semi-arid conditions, the plant pattern includes perennial cereals and legumes, as well as annual plants. In arid conditions, annual species and shrubby formations become dominant (Tahtacıoğlu, 2008: 76). At this point, measures should also be

taken to improve pasture to address global climate change and extreme weather events.

Under Türkiye's geographical conditions and sustainable pasture management, plants suitable for selection include high meadow grass (*Agropyron elongatum*), which is highly drought-resistant and moderately tolerant to salinity; pasture button (*Potaryum sanguisorba*), known for its drought resistance and disease resistance; meadow fescue (*Festuca pratensis*), which is also highly drought-resistant; bermudagrass (*Cynodon dactylon*), noted for its excellent drought resistance; smooth brome (*Bromus inermis*), which can withstand both drought and cold; and bird's foot trefoil (*Lotus corniculatus*), ideal for saline and arid soils. In dry and semi-dry climates, a balanced mix of cereals, legumes, shrubs, and certain tree species can be used for pasture improvement. In particular, drought-resistant shrubs are valuable as they provide feed during dry seasons. Examples of such shrubs and erosion-controlling plants include *Acacia ligulata*, *Acacia salicina*, *Atriplex halimus*, *Atriplex nummularia*, *Coronilla minima*, and *Bassia* (*Kochia*) *prostrata*. In addition, species such as kermes (Holly) oak (*Quercus coccifera*), sage-leaved cistus (*Cistus salviifolius*), and hairy cistus (*Cistus creticus*) are valuable woody pasture formations. Some shrubs, although not highly preferred by animals, can still be used in areas with degraded plant compositions and erosion-prone Mediterranean climates. For example, the spiny broom (*Calicotome villosa*), which is thorny but helps with erosion control and provides an alternative feed source in dry conditions, can be beneficial. On the other hand, invasive shrubs such as common juniper (*Juniperus communis*), prickly juniper (*Juniperus oxycedrus*), dyer's sumac (*Cotinus coggygria*), rhododendron, and daphne (*Daphne pontica* L.) should be removed from pastures because they generally offer no feed value and, some can be toxic.

In addition to the recommended improvement plants, some species need to be removed from pastures. As previously mentioned, the number of climax plants in Türkiye's pasture lands is decreasing, and the proportion of desired species in the plant composition is decreasing. This results in the dominance of thorny and toxic species, which can prevent animals from grazing properly and may even lead to animal death. Examples of species that should be removed or controlled in pastures include spurge (*Euphorbia*), poison hemlock (*Conium maculatum*), water hemlock (*Cicuta virosa*), deadly nightshade (*Atropa belladonna*), astragalus (*Astragalus*), redroot pigweed (*Amaranthus retroflexus*), St. John's wort (*Hypericum perforatum*), and mullein (*Verbascum*). Toxic species must be eliminated from pastures to ensure the safety of ruminants. Some species, although potentially

harmful to animals at certain growth stages, are still used in pasture improvement. For instance, sorghum (*Sorghum*) can contain hydrocyanic acid during its early growth phase (up to 50 cm in height), which may lead to poisoning or even death in grazing animals. Although they are good nutritional sources, certain species can be harmful due to their thorns. For example, Christ's thorn (*Paliurus spina-christi*) appears to be a valuable food source due to its high nutritional value, but it can damage the udders of small livestock due to its thorns and complicate pasture improvement due to its invasive nature. Therefore, careful selection of species is crucial for improving pasture quality. In areas that are either rested or previously used as fields and are now being considered or pastured, there can be significant increases in invasive species populations. Plants like marsh horsetail (*Equisetum palustre*), nodding thistle (*Carduus nutans*), lesser knotweed (*Veronica gentianoides*), and male ferns (*Dryopteris filix-mas*) can become problematic in ecosystems, despite their low nutritional value. Weed control in pastures is a critical issue for organic farming and animal health. The use of herbicides to control weeds can lead to undesirable results in the ecosystem. It is also important to note that pastures should not be managed solely for livestock purposes. These areas are also valuable for beekeeping and should be managed with a holistic approach that considers both the selection of plants (including nectar plants) and the impact of herbicides on bees. This approach will ensure sustainable livestock and poultry management.

It has previously been noted that selecting species for sustainable pasture improvement solely based on animal feed concerns is a flawed approach. One crucial aspect to consider in species selection is erosion, which is one of Türkiye's significant challenges. It is essential to include species that contribute to erosion control and to pay close attention to invasive characteristics. For Turkish conditions, particularly dry and semi-arid conditions, species such as buffalo grass (*Buchloe dactyloides*) and smooth brome (*Bromus inermis*) are recommended because of their ability to prevent erosion and their high nutritional value. These species exhibit rapid growth, regenerate easily, protect the soil effectively against wind erosion, and contribute organic matter to it. In humid areas, plants like white clover (*Trifolium repens*), timothy (*Phleum pratense*), and reed canary grass (*Phalaris arundinacea*) can cover the soil within 1-2 years when planted with alfalfa, making them suitable for erosion control. In arid and high-altitude areas, crested wheatgrass (*Agropyron cristatum*), which is ideal for pasture establishment, also positively impacts erosion control in the harsh winter conditions of Eastern Anatolia. At this point, it is

crucial for shepherds to promote and introduce species that offer both erosion control and animal feeding. Additionally, it is important to include nectar plants favoured by bees in the pasture composition. Species from the mint family (*Lamiaceae*), such as thyme (*Thymus*) and borage (*Borago officinalis*), are examples of nectar-rich plants that can benefit both the ecosystem and apiculture.

When it comes to improving and managing pastures and meadows, plant-based interventions are often the first consideration; however, certain physical facilities are also essential for animal welfare and sustainability. These include scratching posts, shelters, troughs, feeders, salt licks, protective areas, and resting spots for shepherds. Creating optimal conditions for shepherds is particularly important, given the increasing and chronic issues in livestock management, and these facilities are crucial for the sector.

In Türkiye, the improvement and management of pastures and meadows have seen significant progress, particularly since the 1990s. Although successful efforts have been made in this area, they have not been sufficient. The implementation of Law No. 4342, known as the “Pasture Law”, and related regulations that came into effect in 1998 accelerated the improvement of these areas, and the practice of leasing pastures for improvement purposes has been a significant step. In 2023, a total of 451.684 hectares of pastureland across 37 provinces were leased for seasonal improvement, and over the last five years, the leased area amounted to 1.728.700 hectares (Ministry of Agriculture and Forestry, 2024). Between 1998 and 2023, 2.958 pasture improvement and management projects were implemented. These projects involved improvement and management activities on 2.201.297 hectares of pastureland, which constitutes 15% of the existing pasture and meadow areas. Under the United Nations Convention to Combat Desertification (UNCCD) “Land Degradation Neutrality (LDN)” targets, restoration efforts have been carried out on 585.000 hectares of land, with a goal of achieving 750.000 hectares of pasture improvement by 2030 (Anonymous, 2016: 19). As of 2021, the targeted area represents 5.1% of the existing pasture and meadow area in Türkiye.

Between 2000 and 2023, Türkiye conducted 2.958 pasture and meadow improvement projects across 2.201.297 hectares, which accounted for 15.1% of the country’s total pasture and meadow area (Table 4). Analysing the distribution of these projects by region, the Eastern Anatolia Region, which ranks first in terms of pasture and livestock activities, has 632 projects conducted between 2002 and 2023, covering 915.095 hectares (Table 4). The Central Anatolia Region ranks second with 471 projects covering 486.448 ha. In the Black Sea Region, which features the largest pasture and meadow area among

coastal regions, 592 projects were carried out over 363.348 hectares. These three regions together account for 80.2% of the total area that has been improved through these projects. In the Aegean Region, which has a total of 429.070 hectares of pasture and meadow, only 55.037 hectares have undergone improvement. In summary, improvement efforts are concentrated in areas where pastures and meadows are most heavily used, most degraded, and where the potential for livestock farming is highest.

Table 4

Distribution of Pasture Improvement and Management Projects by Region in Türkiye (2000 – 2023)

Regions	Number of Projects	Project Area (ha.)	Share in Türkiye (%)
The Eastern Anatolia Region	632	915.095	41.6
Central Anatolia Region	471	486.448	22.1
The Black Sea Region	592	363.348	16.5
Mediterranean Region	350	172.301	7.8
The Southeastern Anatolia Region	259	129.448	5.9
Marmara Region	381	79.618	3.6
Aegean Region	273	55.037	2.5
TOTAL	2.958	2.201.297	15.1
Total Meadow-Pasture Area in Türkiye	-	14.616.687	100.0

Source: Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Pasture, Forage Crops, and Livestock, 2024

The positive outcomes of these reclamation efforts have been observed. Significant improvements in dry forage yields were observed due to pasture and meadow reclamation. For example, between 2003 and 2009, 73 pasture reclamation and management projects conducted in collaboration with the Çukurova Agricultural Research Institute and Çukurova University Faculty of Agriculture resulted in dry forage yield ranging from 35 kg to 260 kg per decare before the projects, which increased to values between 90 and 1.500 kg per decare after the projects (Çınar et al., 2009: 580). In 2010, the “Golden Flag” incentive was introduced to raise awareness and highlight successful pasture and meadow reclamation projects across Türkiye. Meadows with exemplary and successful reclamation projects were awarded the “Golden Flag” award. Successful pasture and meadow reclamation projects in Samsun (Bafra/Emenli), Erzurum (Narman/Şekerli), İstanbul (Silivri/Fenerköy), Ordu (Mesudiye/Bayırköy), Niğde (Merkez/Aşlama), Edirne (Merkez/Demirhanlı), Tekirdağ (Süleymanpaşa/Kaşıkçı), Isparta (Yalvaç/Kumdanlı), Hatay (Kırıkhan/Kodallı), and Malatya (Akçadağ/Karacadağ) received the “Golden Flag”

award. According to discussions with agricultural engineers about the productivity of the awarded meadows in Samsun, Hatay, Tekirdağ, and Edirne, it was noted that the forage yield exceeded by 2-3 times.

Problems with Pastures and Meadows in Türkiye

When listing issues related to pastures and meadows in Türkiye, overgrazing and the resulting floristic impoverishment are at the top. This situation leads to severe problems such as erosion, resulting in dramatic damage and even collapse of the pasture-meadow ecosystem. Moreover, considering that Anatolia has been one of the oldest settlement areas throughout our civilisation history, it can be said that the natural resources of pastures and meadows have been more extensively degraded compared to many parts of the world due to thousands of years of pastoral activities. Despite covering a significant portion of Türkiye's land area (18.6%), approximately 87.6% of the pastures and meadows are in poor condition. In addition, approximately 64% of our pasture areas experience various levels of erosion (Anonymous, 2016: 19). This negative situation is particularly pronounced in our interior regions. Studies from the 1970s showed that 70% of the pastures in these interior regions had deteriorated significantly, and the beneficial forage plants had decreased by 80% to 90% (Anonymous, 1977: 16). This has further intensified the already severe erosion in these areas.

Some problems related to pasture and meadow resources in Türkiye have become chronic, while others have emerged, particularly in recent years. These include:

- Grazing out of time without considering geographical conditions,
- Overgrazing
- Conventional farming practices
- Changes in plant patterns
- Non-purposeful use (such as mining, land development)

The main problem with Türkiye's pastures and meadows in Türkiye is untimely and excessive grazing. Grazing occurring outside the schedule determined by geographical conditions has led to the dominance of unwanted plant species in pastures. Early grazing, particularly when plants are at their weakest, poses the greatest threat to pasture and meadow areas. Along with untimely grazing, excessive grazing is also prevalent in Türkiye, leading to the near or complete disappearance of high-quality forage plants that support livestock. Unfortunately, there are significant mismatches between the flora of pastures and meadows and the breeds

and numbers of livestock in Türkiye. The prevalence of high-performance cultured breeds has increased the pressure on pastures and meadows. Current pastures and meadows do not meet the needs of these cultured breeds. Therefore, it is essential to conduct meadow improvements in parallel with livestock breed improvements. In addressing this issue, pastures should be managed with different animal species, i.e. in a mixed grazing system. For instance, sheep prefer broad-leaved, short, and mostly leguminous forage plants, whereas cattle consume tall, cereal-type forage plants.

Another practice that disrupts plant composition is conventional agricultural activities. Between 1960 and 1980, the use of chemical fertilisers, herbicides, and insecticides led to the loss of many plant species and disruption of the floristic composition in pasture areas (Okuyucu and Okuyucu, 2009: 549). This situation also poses a serious problem for organic livestock farming.

In recent years, one of the most frequently discussed issues regarding pastures registered as public common property has been the change in their purpose of use. In essence, the "Pasture Law" protects our pastures to prevent inappropriate use. However, in certain cases (such as mining, urban development, allocation to industrial zones, or conversion to arable farming), the designated purposes can be altered, thereby removing the status of pastures. Mining is one of the primary inappropriate uses that impact pastures. Mining is not an economic activity that can be carried out based on personal preferences but has to be conducted where the resource is located. As a result, if mineral resources are found near a forest area or other natural resources (such as lakes or rivers), their use often leads to serious public debate worldwide. Mining activities have also significantly affected pastures. Although mining activities on pastures designated for public use are subject to permits, the status of these areas is often changed to facilitate mining operations. According to relevant regulations, if mining is required on a pasture, an application must first be submitted to the General Directorate of Mining and Petroleum Affairs. Following this, a report is prepared through an examination by the Ministry of Agriculture and Forestry and the provincial directorate and, then sent to the Ministry along with the governor's approval. At this stage, monitoring the duration of mining activities and post-mining conditions is crucial. Certain mining sectors, especially gold mining, can cause serious environmental damage, even with the slightest negligence. Even if mining activities cease, livestock farming in the affected area may become impossible. Therefore, performing a "Pasture Rehabilitation Project" with the relevant mining company and

ensuring its implementation in accordance with the relevant geographic conditions is of utmost importance.

In recent years, there has been an increase in the practice of changing the designation of pasture lands for mining activities in Türkiye. Examples of locations where this has occurred include Kastamonu (Hanönü: 65 ha), Aydın (Ömerler: 120 ha), Tokat (Reşadiye-Kuyucak: 28.3 ha), Balıkesir (Karaayıt-Bulutçeşme: 10 ha), Afyonkarahisar (Sinanpaşa: 2 ha), and Ordu (Kargan-Aybastı: 0.5 ha). However, it is worth noting that in some of these locations, successful "Pasture Rehabilitation Projects" have been conducted. For instance, in the Hanönü district of Kastamonu, there is a total of 97 ha of pasture, and the neighbourhoods of Merkez (16.7 ha) and Vakıfgeymene (8.6 ha), as well as the villages of Bağdere (18.5 ha), Küreçayı (21.6 ha), and Gökçe ağaç, have been directly impacted by mining activities (Anonymous, 2017: 48). In response, a 5.3-hectare pasture rehabilitation project has been planned for the Karayaprak area, in collaboration with an operating mining company and the Provincial Directorate of Agriculture and Forestry. However, it is not always possible to mention such rehabilitation efforts in all areas where the designation has been changed.

One of the most common activities that leads to changes in the allocation of pasture lands after mining activities is their conversion into Organised Industrial Zone (OSB in Turkish) areas. Because these facilities are generally established outside urban areas, pasture lands are often preferred for this purpose. However, this practice frequently encounters resistance in Türkiye, especially in rural communities, and the issue is often brought to legal proceedings. In Türkiye, serious disputes have occurred regarding the allocation of certain pasture areas for OSBs in districts such as Meram and Çumra in Konya, Bergama in İzmir, Taşova in Amasya, Eski in Aksaray, Terme in Samsun, and Merkez in Niğde. In some of these areas, Organised Industrial Zones have been established, while in others, the legal process is ongoing.

A controversial issue regarding the use of pastures for different purposes is their conversion to crop farming. Although it might seem like it serves an agricultural purpose, this is an undesirable situation. Pastures are natural resources, whereas agricultural fields are areas where various farming activities are carried out and are exposed to human impact. Moreover, the recycling of pastures converted to farmland is often not very effective. The natural regeneration of pasture features in areas transformed into farmland, especially in arid regions, is a very lengthy process. For example, in Erzurum, it has been noted that it takes at least 35 years for the plant cover and soil of a lightly sloped, abandoned pasture to regain its natural pasture

characteristics (Gökkuş, 2014: 152). Such areas can only be restored through the establishment of artificial pastures, which involve significant costs and a complex management process.

Conclusion

Meadows and pastures, which cover a vast area globally and in our country and serve many functions, can be considered strategic natural resources. The value of these areas in the ecosystem and the lack of alternatives for sustaining livestock activities are the most important factors affecting their preservation and use. On the other hand, both globally and in Türkiye, these areas are among the natural resources that are experiencing the fastest changes in their characteristics and a trend towards decline.

As Türkiye celebrates its 100th anniversary, meadows and pastures, which have long been among the most neglected spatial units, have been greatly overlooked when examined through the lens of Agricultural Geography. The lack of reliable statistical data and the fragmented collection of such data have emerged as the biggest barriers to accurately interpreting the chronology of meadows and pastures. Researchers consider the early years of the Republic and the period after 1998 as the most reliable periods for Türkiye's meadows and pastures. Field observations at various locations, discussions with technical teams, and limited literature have been used to address the issues as a whole. According to this, Türkiye's meadows and pastures are largely degraded, with a significant portion on the brink of being lost, and have suffered from long-standing improper grazing methods that have disrupted plant composition. They have also been excessively used for non-intended purposes. Indeed, existing meadows and pastures are far from meeting even half of Türkiye's 55 million tons of roughage. This situation has caused serious problems both economically and ecologically. Ecologically, issues include erosion, loss of genetic resources, decrease in bee populations, increase in soil temperature, and loss of water resources. Economically, problems such as decreased animal welfare, which affects meat and milk production, and inability to meet the needs of breed-specific requirements, pose challenges for producers and, consequently, the national economy. In this regard, Determination–Limitation–Appropriation are crucial steps for our pastures, followed by focusing on management efforts, which are of vital importance.

In terms of Türkiye's meadow and pasture resources, significant improvements have been made through successful restoration and management projects, the implementation of pasture fallows, the establishment of grazing schedules at

the provincial level, and the leasing system. Additionally, the practice of “Golden Flag” has encouraged pasture restoration, and the establishment of artificial pastures, albeit limited, represents hopeful developments. However, it should be noted that these successes have occurred only in a very small fraction of our existing meadow and pasture areas.

The issues that need to be urgently addressed, as identified by us, are as follows:

- When selecting high-yielding livestock breeds, existing meadow and pasture resources must also be considered. High-yielding breeds cannot achieve the expected performance in weak or insufficient meadows and pastures.
- If organic farming is to be practised, especially in meadows and pastures where restoration work has been carried out or in areas being converted from cropland back to meadows, the use of chemical fertilisers, herbicides, and pesticides must be considered. Otherwise, it would not be possible to claim that organic farming and animal products are being produced.
- A broad-based committee should determine the process of changing the use and designation of meadows and pastures, rather than a legal advisory board. Furthermore, the “Pasture Rehabilitation Project” should also be the result of a broad-based and multidisciplinary effort.
- When assessing meadows and pastures for livestock activities, animal welfare must be prioritised, and management plans should be developed accordingly. There are significant inadequacies in this regard in Türkiye’s meadows and pastures.
- The populations of invasive and toxic species in our meadows and pastures should be monitored and reported by both technical teams and shepherds. In particular, there are significant problems with regard to the meadows and pastures of Türkiye’s inland regions.



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Urban Heat Islands in Bulgaria during the Heatwave of July 2024



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Abstract

This research paper investigates the Urban Heat Island (UHI) phenomenon in Bulgaria during the extreme heatwave event in July 2024, using high-resolution ECOSTRESS satellite data from the International Space Station. The analysis focuses on mapping and visualising temperature variations across major urban centres in the country. The data cover 26 of 27 capitals of regions, highlighting the pronounced UHI effect in densely populated and industrial areas. The findings reveal that urban regions consistently exhibit higher surface temperatures, particularly during nighttime, compared to surrounding rural and mountainous areas, which benefit from natural cooling effects. Cities like Sofia, Plovdiv, and Stara Zagora show substantial heat retention, whereas cooler profiles are observed in areas like Smolyan, due to higher altitudes and forest cover. The study also relates these results to demographic data from the latest population census. It identifies a concerning trend of population decline in rural regions, while urban areas face environmental stresses from heat accumulation. Recommendations include enhancing green infrastructure, promoting sustainable urban development, and focusing on rural revitalisation to mitigate the dual challenges of population loss and heat-related environmental risks. These insights are critical for improving resilience to future heatwaves in Bulgaria.

Keywords

Urban Heat Island • heatwave • mapping



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Introduction

Climate change is one of the most discussed topics in society, e.g., in recent decades, the climate of the planet has significantly changed. According to research conducted by the Joint Research Centre of the European Commission (JRC), heat waves in Europe are expected to be more frequent and intense (Feyen *et al.*, 2020). If no action is taken, by the end of the XXI century, the number of deaths in Europe caused by heat waves is expected to increase 30 times. In a scenario with a temperature increase of 3° C by 2100, this would lead to 90 000 deaths per year. As the average temperature increases by 1.5° C, the data shows that there will be 30 000 deaths per year. To a greater extent, people living in the southern part of the continent are most in danger. According to the JRC report, there are two additional factors –the health status and age of people and whether they are living in cities experiencing the urban heat island effect. Bulgaria is particularly vulnerable to the effects of climate change, as air temperature rises and intense rainfall occur more often in the region. The interconnected nature of the climate system suggests that the observed increase in average temperature will lead to changes in various meteorological factors, including precipitation patterns, wind dynamics, and atmospheric pressure. These changes are poised to have far-reaching implications for several sectors, such as the economy, water resources, biodiversity, infrastructure, and public health.

Heatwaves and their impacts on the population have been studied for just several decades. Currently, there are many studies on this topic, because of new data sources that became available for free use in recent years, such as Landsat, Sentinel-3, and EOSTRESS. In the last 5 years, such analysis has been performed for different parts of the world (Fernandes, Ferreira, Nascimento, Freitas & Ometto, 2024), (Raufu, 2024), (Garcia, 2022), (Nasir, Ul, Rashid, Coluzzi & Lanfredi, 2022), and in the region (Cetin *et al.*, 2024) (Nojarov & Nikolova, 2022), showing the significant effect of heat on urban areas.

Heat waves and their effects on the health of Bulgaria's population have not yet been sufficiently studied. A study performed 10 years ago (Ivanov & Evtimov, 2014) assesses heat stress in the country for the period 2003–2012. After that, (Dimitrov & Spasova, 2020) considered the heat waves in Sofia and their impact on heart attack and stroke cases in the summer, establishing that for the warm half-year between 2007 and 2011, 24 heat waves were registered in Sofia city, which in total made 148 days or 19.3% of all time during the warm half-year. In the same year, (Dimitrov, Popov, & Iliev 2020) use an Unmanned Aerial Vehicle, equipped with a

thermal camera, which clearly demonstrated the differences in surface temperature in the urban area of the capital city. On the other hand, more studies dedicated to population structure, urban ecology, and extreme events in Bulgaria have been published in the last 5 years, and some of them relate to the problems of climate change in urban areas (Stoycheva & Geneletti, 2023), (Nojarov, Vlaskov & Vatova 2023), (Todorov & Kirilov, 2022), (Sarafova, 2021), (Sarafova, 2021), (Burdarov & Petrova-Hristova, 2020), (Atanasova & Naydenov, 2020).

According to the National Statistical Institute, Bulgaria's demographic trends indicate a relatively high average age, with the elderly population being especially vulnerable to extreme temperatures. The life expectancy data for the 2021-2023 period across Bulgarian regions show significant regional and gender disparities. On average, women have a higher life expectancy than men, with most regions showing a gap of about 4 to 6 years. For instance, in Sofia (the capital), the average life expectancy is 75.4 years, with men at 71.9 years and women at 78.9 years. The regions with the lowest life expectancy are Vidin and Vratsa, where life expectancy is notably lower for both men and women, with Vidin's male life expectancy at just 66.5 years. These trends highlight the continued health and social inequalities between regions and genders. All these factors present significant challenges, particularly in light of substantial regional disparities that, when combined with an ageing demographic, threaten to impact the economy through labour shortages, as well as strain social and healthcare systems. Therefore, investigating the health impacts of heatwaves on this demographic is critical for developing effective public health strategies and climate adaptation measures.

Data from the Barcelona Institute for Global Health and a recent publication (Gallo *et al.*, 2024) show that urban heat islands (UHI) are responsible for over 4% of deaths in European cities during the summer of 2023. The Global Health Institute report indicates that over the past year, countries in Southern Europe, such as Greece, with 393 deaths per million people, and Bulgaria, with 229 deaths per million people, have experienced the highest mortality rates. The report also highlights that women and the elderly are particularly vulnerable to heat-related deaths, with individuals aged 80 and over facing up to 78% higher risk compared to those aged 65-79. Given the concerning data on mortality due to heat waves and climate change, especially in Bulgaria, which has one of the highest mortality rates in Europe and an ageing population, it raises crucial questions about the impact of climate change on the health of the population in the coming years.



The impact of climate change on human health in Bulgaria has not yet been sufficiently studied. It is expected that extreme weather events will affect large cities where the population is concentrated due to increased vulnerability. The combination of densely populated urban centres, heavy traffic, limited green space, and numerous sealed areas make these areas particularly susceptible to severe climate impacts. The phenomenon of urban heat islands is receiving increasing scientific attention in Bulgaria, with a focus on understanding their harmful effects on public health and well-being.

ECOSTRESS (Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station) is a valuable tool for measuring land surface temperature (LST) via high-resolution thermal infrared observations. The instrument operates at a spatial resolution of 70 metres, which allows for detailed assessments of temperature variations across urban and natural landscapes. ECOSTRESS is mounted on the International Space Station (ISS) and gathers data globally within latitudes of 52° N to 52° S. ECOSTRESS data has been widely used in urban studies to assess land surface temperature (LST) and urban heat island (UHI) effects. For instance, Hu *et al.* (2022) evaluated ECOSTRESS LST products and validated their use in urban environments. Similarly, Chang *et al.* (2022) leveraged ECOSTRESS LST data alongside The Geostationary Operational Environmental Satellite (GOES) – R Series to investigate the diurnal variation of surface urban heat islands, while Zhang *et al.* (2022) combined ECOSTRESS LST with machine learning techniques to study the urban heat exposure dynamics in the city of Xi'an.

According to the National Institute of Meteorology and Hydrology of Bulgaria (NIMH)'s monthly bulletin and its section "Particularly dangerous phenomena", during the period 06 – 24.07. 2024. Bulgaria is experiencing an intense heatwave. The number of consecutive days with a maximum air temperature above 40 °C in the town of Sandanski (Blagoevgrad region) was 9 (10–18.07.2024), and in both the village of Parvomay and the municipality of Petrich – 6 (13.07. – 18.07.2024). The average monthly temperatures deviated from the monthly norm between +1.4 °C (Gabrovo) and +3.9 °C (Ruse). According to the NIMH, July 2024 was almost as warm as July 2012—the warmest July since 1930 in the country. The monthly maximum temperature was measured in Ruse on 17.07.2024, with an average daily temperature of 33.3°C. The highest maximum temperatures in urban areas were between 32°C and 42 °C and were measured from 14 to 18.07.2024.

According to the report, as a result of the high temperatures and lack of precipitation, as well as human negligence, from 12.07.2024 to at the end of the month dozens of fires raged in the country. Strong wind gusts contributed to the growth

of fire fronts and made extinguishing difficult. In some municipalities, a partial state of emergency was declared, and residents of several villages were evacuated. On July 16, 2024, a large fire in Sakar Mountain consumed over 100,000 hectares, including 24,000 hectares of forest, resulting in the injury of a 19-year-old volunteer. These fires not only caused significant ecological damage but also forced the evacuation of multiple villages. The intense heatwave and the ensuing fires highlight the growing risk of extreme weather events in Bulgaria, particularly under the influence of climate change.

The aim of this study was to map and analyse urban heat islands in the capitals of the Bulgarian regions during the July 2024 heatwave using the ISS instrument ECOSTRESS. By analysing and visualising the thermal data for these urban areas, this study seeks to provide insights into the occurrence and spatial distribution of UHIs, with a focus on understanding their intensity, to help the process of urban planning and disaster risk reduction in the context of extreme heat events. The findings contribute to the development of effective mitigation strategies for managing heat-related risks in Bulgarian regions and municipalities.

Data and Methods

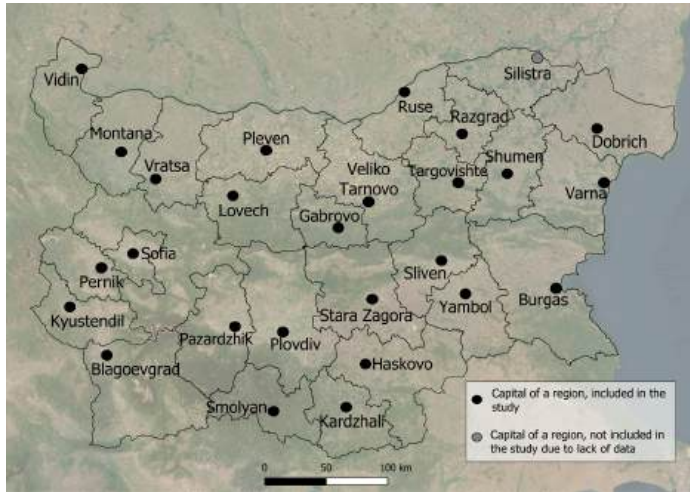
Remote Sensing Data

The research methodology involved a systematic approach to analysing and mapping urban heat islands in Bulgaria using ECOSTRESS Land Surface Temperature (LST) data. First, LST data were sourced from the ECOSTRESS product available on the LP DAAC (Land Processes Distributed Active Archive Centre) website, focusing on the relevant datasets for the July 2024 heatwave. The start and end dates for the search were selected from the information for the heatwave of NIMH's report, i.e. from 06 to 24.07.2024. The acquired LST data underwent a projection change to ensure compatibility with the study area, and temperature values were recalculated from Kelvin to Celsius using the Raster Calculator in QGIS, allowing for more interpretable results. A preliminary data quality check was conducted to identify and reject any rasters that could be unreliable due to issues such as cloud cover and minimal coverage within the country, ensuring that only high-quality data were retained for further analysis. Finally, the cleaned and processed LST data, together with cloud mask layers for each specific date selected was analysed to identify and map urban heat islands across the capitals of the Bulgarian regions. This involved employing spatial analysis techniques in QGIS to visualise temperature variations and assess the intensity and distribution of urban heat islands. Through this comprehensive methodology, the research aimed to enhance understanding of urban heat islands in

the context of the extreme heat conditions experienced in July 2024, ultimately contributing valuable insights for urban planning and disaster risk management.

Figure 1

Capital of the regions (NUTS 3) in Bulgaria



The results were datasets covering 26 of 27 capitals of the regions in Bulgaria (the regions are 28 in total, but Sofia is the capital of two of them, Figure 1).

Population data

The data from the National Statistical Institute (NSI) of Bulgaria reveal a general trend of population decline across most regions in the country. This trend is consistent with broader demographic patterns observed in Eastern European countries, where factors such as ageing populations, declining birth rates, and emigration contribute to shrinking populations. For instance, the total population of Bulgaria has decreased steadily from approximately 7.85 million in 2002 to approximately 6.45 million by 2022.

From a regional perspective, there is considerable variation in population changes across administrative levels. Larger urban areas, particularly municipalities and cities like Sofia, Plovdiv, and Varna, may have experienced slower rates of population decline compared to rural municipalities and smaller towns, which tend to show sharper decreases. For example, regions such as Vidin show significant declines, with populations halving over the studied period, highlighting the impact of rural depopulation and migration to urban centres or abroad.

Table 1 presents the future population scenario data developed by the NSI. The most likely scenario indicates a significant and steady population decline across all regions. For instance, in the Blagoevgrad region, the total population is expected to decrease from 306 370 in 2020 to 184 242 by 2070, representing a 39.9% decrease. Similar trends are observed in other regions, such as Burgas, where the population is

projected to shrink by approximately 23.7% over the same period.

Table 1

Population statistics for the regions in Bulgaria. The percentage change in the total population in Bulgaria from 2020 to 2070, according to the National Statistical Institute data, is the most likely scenario.

Region	Total Population (2023)	Population < 19 y (2023)	Population > 65 years of age (2023)	% Change from 2020 to 2070
Blagoevgrad	287077	55843	63609	-39.9
Burgas	384446	78099	86611	-23.7
Varna	434191	86027	56458	-20.5
Veliko Tarnovo	202232	34555	55467	-40.4
Vidin	71773	11556	22431	-60.0
Vratsa	147619	28034	36890	-45.9
Gabrovo	94862	15311	28716	-56.7
Dobrich	146635	25924	39233	-41.3
Kardzhali	146562	24517	38715	-41.9
Kyustendil	107673	17891	30649	-50.6
Lovetch	112225	20710	31347	-45.5
Montana	114526	14724	32269	-38.5
Pazardzhik	225261	43161	54652	-37.6
Pernik	111032	19264	29026	-46.5
Pleven	217881	39183	61512	-38.2
Plovdiv	633586	93774	142393	-16.2
Razgrad	100696	17848	25203	-40.1
Ruse	187830	23253	50574	-35.1
Silistra*	94739	16564	26263	-43.6
Sliven	170051	42903	38019	-11.3
Smolyan	92107	13548	26616	-65.0
Sofia	226420	32320	54413	-37.0
Sofia (capital)	1286965	250866	247474	6.5
Stara Zagora	290350	57379	71343	-29.9
Targovishte	95609	17601	24324	-33.8
Haskovo	207114	39459	53381	-36.0
Shumen	149699	27018	37766	-42.9
Yambol	106320	16134	28483	-32.2

* Silistra was not included in this research because of a lack of sensor data.

There are no specific data regarding future age structure within these scenarios, although it is evident that if the current birth rate remains the same, the population will become significantly older. This trend poses substantial challenges in addressing urban heat island (UHI) effects, as an ageing population may be more vulnerable to extreme heat

events and less able to adapt to increasing temperatures in urban environments. The combination of an older, shrinking population and the intensifying UHI effect could further strain public health resources and urban planning efforts, making it imperative to consider age dynamics in future climate adaptation strategies.

The expected depopulation implies a continued ageing of the population, with models showing that fewer and fewer young people will remain in Bulgaria due to factors such as low birth rates, emigration, and lower birth rates. The long-term implications indicate the likelihood of major challenges in sustaining economic growth, maintaining workforce, and addressing regional imbalances, particularly in rural areas. These trends are consistent with current demographic trajectories and highlight the need for policy interventions to mitigate the social and economic impacts of such significant population losses.

Geographical perspectives and predispositions

The diverse physical geography of Bulgaria predetermines the appearance of the UHI. Altitude, topography, land cover, and atmospheric circulation are natural predispositions of landscapes that affect the appearance of the UHI phenomenon in urban areas. The size of an urban area, the density of buildings, and the city's morphology are additional society-determined factors determining spatial diversity.

The altitude of the examined cities in Bulgaria varies between 0 and 30 m (Burgas) and 1002 m (Smolyan). Several cities are located in lowlands near 100 m of altitude or even below: Burgas (0-120), Vidin (34-45m), Ruse (22-150 m), and Varna (0-150 m). Most of the examined cities were located between 100 and 500 m altitudes: Plovdiv, Pazardzhik, Pleven, Stara Zagora, etc. They all display intense features of urban heat islands like the outlined shape of downtown, industrial zones, extensive roads, and other manmade facilities.

There are only three examined cities above 500-m altitude. The capital city Sofia (550-700 m), the largest in the country, Kyustendil (530-600 m), and Smolyan (900-1002 m), one of the smallest examined cities. The altitude has a cooling effect in all three cases based on the vertical temperature gradient. The cooling effect is visible in Sofia, even the most prominent city with the most significant heat island. The heat island is observed, but the temperature values are lower than those in lower cities like Plovdiv, Ruse, and Stara Zagora.

In terms of topography, most of the examined cities are located in plains and lowlands. Most of the land in these areas is arable and is actively used for agriculture. These areas have no abundance of natural vegetation, and the black soil types dominate (Vertisols in the Upper Thracian Plain,

South Bulgaria, and Chernozems in the Danubian Plain, North Bulgaria). Dark soil albedo causes heating of the surface, and in periods after harvest, it may stimulate a vaster heating screen on the surface of agricultural lands.

Few cities (Smolyan, Kardzhali, Gabrovo, Veliko Tarnovo, and Lovech) are not placed in such landforms as plains or landforms. They are located in river valleys formed by mountainous topography. The limited space for building in valleys determines the extreme density of concrete infrastructures and asphalt roads. In the case of heat waves, these territories explicitly heat up among the hilly surroundings, which are pretty visible phenomena in the thermal maps described in the next section.

Several Bulgarian cities are located in transitional zones between mountains and lowlands (plains): Stara Zagora, Sliven, Kyustendil, and Haskovo. These cities experience the phenomenon of urban heat islands even more distinctively because the forested hilly landscapes are cooled in contrast to warmed urban infrastructure.

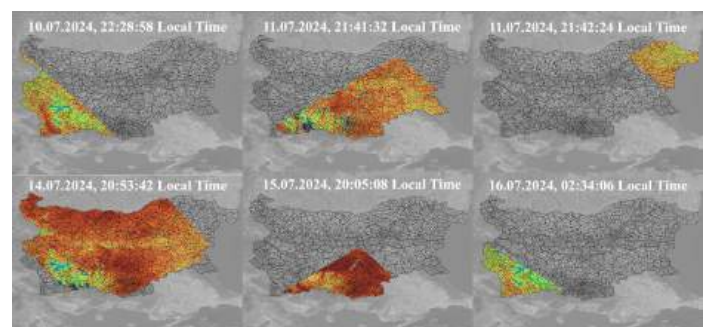
Diurnal sea breezes are another natural predisposition that partially affects the appearance of the urban heat island in the cities of Varna and Burgas. The local winds across the rivers exert a similar cooling effect. The riverbank areas of Vidin and Ruse demonstrate atmospheric influence. Most of these areas are well-forested and are part of riverside gardens and parks. As a result, they appear as a narrow strip next to an urban heat island.

Results

After the first round of data availability analysis and quality control procedures, the data mapped on Figure 2 was selected for further analysis. The largest area coverage was captured on 14.07.2024, the date on which most of the Bulgarian regional capitals were covered. The city of Silistra, located in the northeastern part of the country, is not covered during the heatwave.

Figure 2

Data availability from ECOSTRESS during July 2024 heatwave in Bulgaria



The minimum temperatures recorded in the raster layers varied widely, with some instances reporting negative values, likely due to cloud cover or sensor anomalies. For example, on July 11, 2024, the minimum recorded temperature was -41.39°C , indicating potential interference from clouds, which can obstruct accurate readings (Table 2). The maximum temperatures reached high levels, especially on July 14 and 15, when values approached or exceeded 42°C . The extreme temperature of 47.89°C was identified near a fire spot near the city of Stara Zagora on July 14, highlighting the influence of local events on the temperature readings. In these two raster layers, there were also pixels with much higher values, due to fires. They were excluded from the analysis of this research as they are not related to UHI.

Table 2
Raster statistics for the examined dates

Raster	Min Value $^{\circ}\text{C}$	Max Value $^{\circ}\text{C}$	Mean Value $^{\circ}\text{C}$	Std Dev $^{\circ}\text{C}$
10.07.2024, 22:28:58 local time	3.39	30.09	19.26	3.52
11.07.2024, 21:41:32 local time	-41.39 (clouds)	32.95	21.06	5.90
11.07.2024, 21:42:24 local time	12.95	28.09	20.5	1.99
14.07.2024, 20:53:42 local time	-76.81 (clouds)	47.89 (near fire spot)	23.91	4.74
15.07.2024, 20:05:08 local time	-7.61	42.05 (near fire spot)	27.10	3.70
15.07.2024, 02:34:06, and 16.07.2024 local time	3.13	26.05	17.16	3.54

The mean temperature across the recorded dates showed a consistent upward trend, with an average of around 19.26°C on July 10 and escalating to 27.10°C by July 15. This increase indicates significant heat accumulation likely influenced by urbanisation and the ongoing heatwave. The standard deviation values (ranging from 1.99°C to 5.90°C) show varying degrees of temperature consistency. A higher standard deviation indicates greater variability in temperature, particularly on July 11, when conditions likely fluctuated significantly due to environmental factors, such as cloud cover and urban heat effects. The temperatures recorded late in the evening (around 21:41) still reflect high values, underscoring the persistent heat characteristics of urban heat islands.

The data captured on July 10, 2024, at 22:28 local time (Figure 3), illustrates the distribution of surface temperatures within the urban and surrounding areas of Sofia, Blagoevgrad, Pernik, and Kyustendil. In all the maps, the central urban regions exhibit significantly higher temperatures, indicated by red and orange hues, than the cooler peripheral and green zones, such as the mountains and less densely populated areas. Sofia Airport can be seen from the eastern part of the capital. This region is a place in the country where records are being recorded during the summer heatwaves. As seen on the maps, this area experiences a combination of climatic and geographical factors that contribute to elevated temperatures, especially in lowland and valley areas where heat accumulation is more pronounced.

The data captured on 11 July 2024, at 21:41 highlights the urban heat island (UHI) effect across several cities, as mapped in

Figure 3
UHI mapping in Sofia, Blagoevgrad, Pernik, and Kyustendil on 10.07.2024

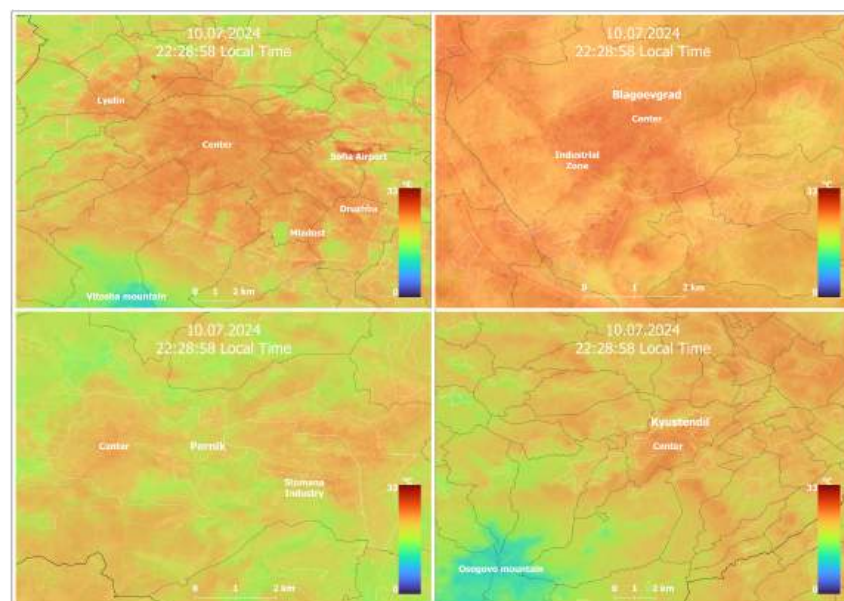


Figure 4 - Plovdiv, Stara Zagora, Sliven, Yambol, Burgas, Varna, and Dobrich. As with the previous data, urban centres and industrial zones appear in red and orange, indicating elevated surface temperatures near 33°C, while surrounding rural and natural areas are cooler, which are depicted in green and blue. Plovdiv, for example, shows significant heat accumulation in the city centre and industrial zones, with cooler areas around the Maritsa River and regions to the west, potentially due to cloud cover or water bodies helping to moderate temperatures. Stara Zagora and Sliven also exhibit high-temperature zones, particularly in industrial regions, while

areas of cloud cover may affect the temperature readings in some parts of the cities.

In coastal regions like Burgas and Varna, the UHI effect is more pronounced around the urban centres and airports, whereas the proximity to bodies of water like Lake Burgas and Lake Varna introduces localised cooling effects. The presence of water bodies contributes to temperature moderation, as reflected in the cooler patches surrounding these lakes. Dobrich, in contrast, shows more green and blue tones, indicating cooler surface temperatures compared to the other cities in this set, which leads to lower urbanisation or the presence of more vegetation.

Figure 4

UHI mapping in Plovdiv, Stara Zagora, Sliven, Yambol, Burgas, Varna, and Dobrich on 11.07.2024

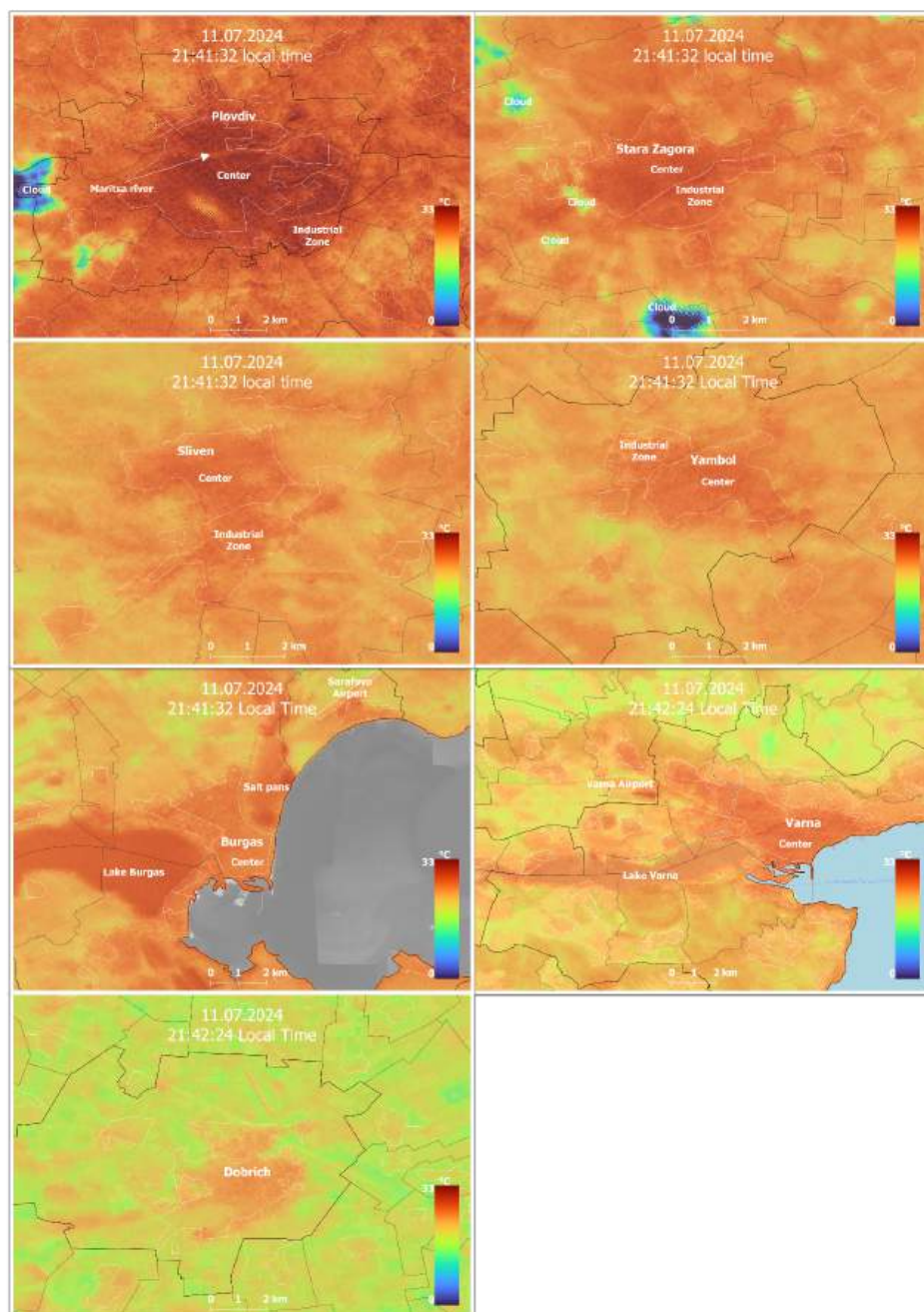


Figure 5 recorded data on 14 July 2024. The urban centres in cities such as Vidin, Montana, Pleven, Veliko Tarnovo, and many others are shown in bright red and orange tones, indicating high surface temperatures of up to 33°C. The distinct colour gradient emphasises the significant temperature differences between urban and rural areas, with the surrounding green and blue regions remaining cooler, likely due to vegetation, open land, or water bodies.

The data that was analysed for 14.07.2024 covered many regional capitals in the country (Figure 5). Particularly noticeable is the recurring UHI effect in cities like Sofia, Burgas, and Ruse. Sofia has significant heat retention, especially around its industrial and densely populated areas, with slightly cooler regions around Vitosha mountain. Burgas, a coastal city, benefits from some cooling near the water and additional heating as it is located near the salt pans, yet its urban and industrial zones remain highly affected by heat buildup. Ruse's proximity to the Danube River also moderates temperatures slightly in certain areas, but still the UHI effect is significant.

Several smaller cities, including Shumen, Yambol, and Kardzhali, also exhibit distinct UHI patterns, with heat concentrated on their centres and industrial areas. The city of Smolyan appears to be one of the coolest cities in the world, with its predominantly green tones indicating much lower temperatures due to its mountainous terrain in Rhodope mountains, and lesser urbanisation.

The results for the surface temperature of the Burgas Lakes are quite interesting. The surface of this shallow water basin was warmer than the surrounding waters during the observed heat wave. The neighbouring territories were cooler, which could be explained by the predominant hydrophilic vegetation. Similar but not outlined thermal contrast was observed in Varna Lake. The outcome of this observation is that these shallow seaside lakes do not provide an external cooling effect on the neighbouring urban areas.

The data taken on July 15, 2024 (Figure 6), captures the urban heat island (UHI) effect in the cities of Plovdiv, Stara Zagora, Haskovo, Kardzhali, and Smolyan. As in the previous maps, urban areas are shown in deep red and orange, indicating high temperatures, while cooler surrounding regions are shown in

Figure 5
UHI mapping in many regional capitals on 14.07.2024

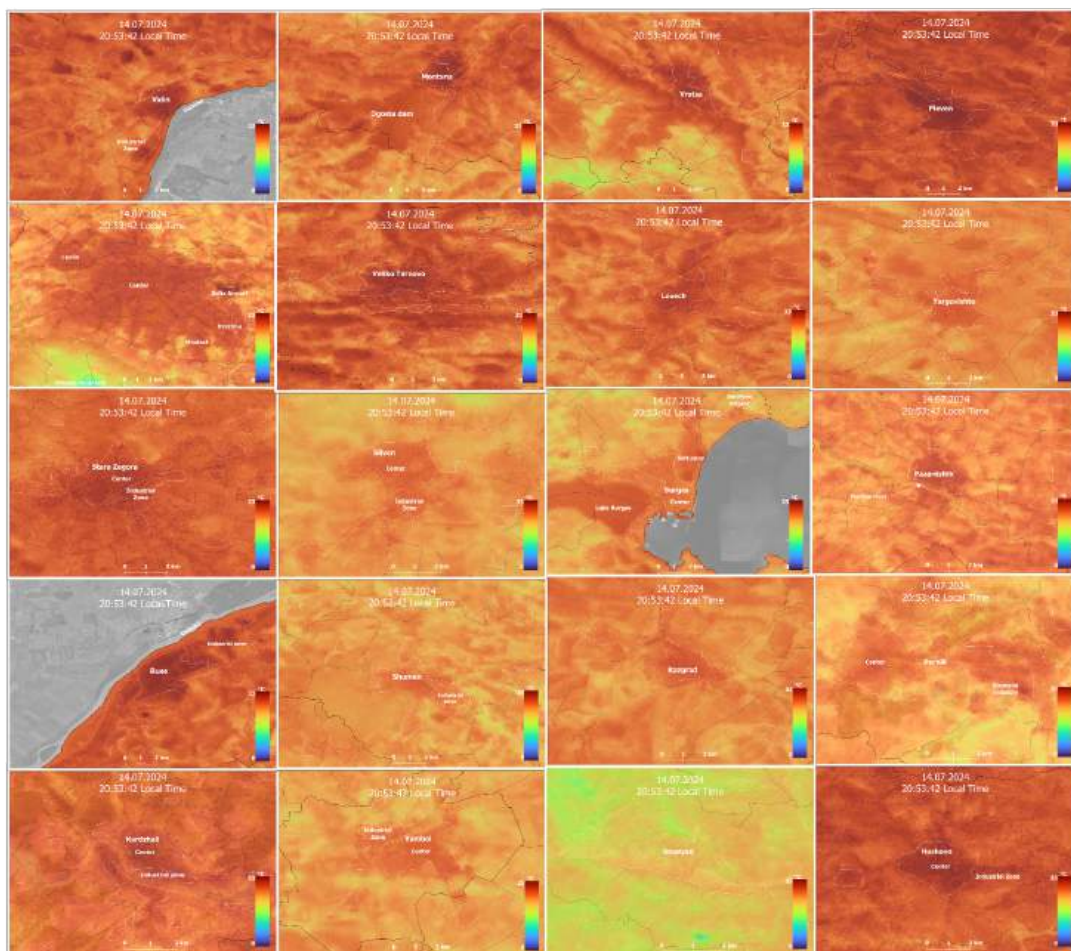
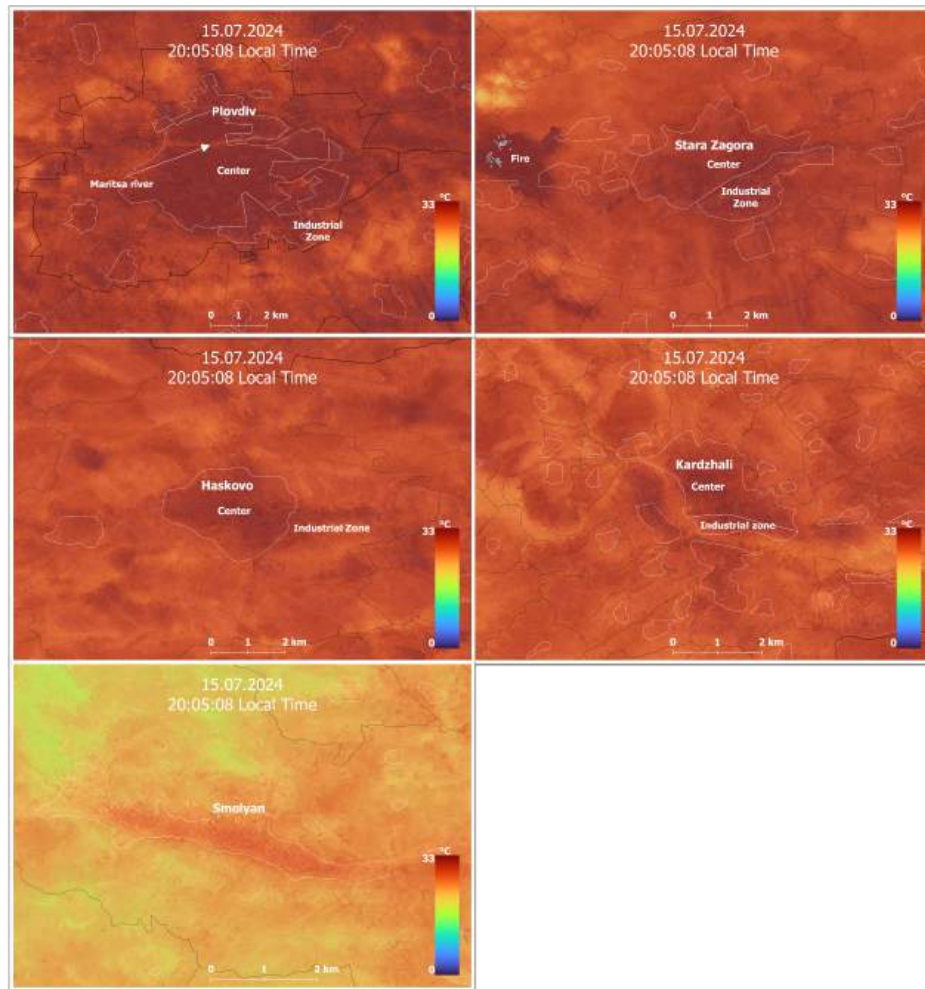


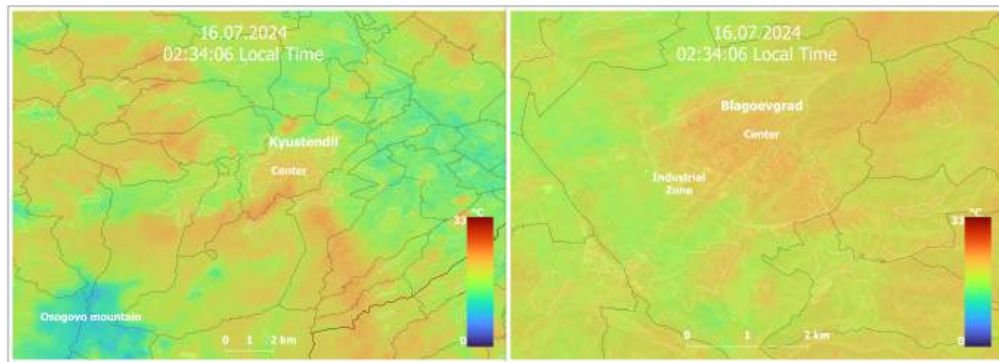
Figure 6*UHI mapping in Plovdiv, Stara Zagora, Haskovo, Kardzhali, and Smolyan on 15.07.2024*

green or yellow. Plovdiv stands out for its well-defined heat concentration in its centre and industrial zones, particularly around the Maritsa River. Stara Zagora similarly exhibits elevated temperatures, but what is especially notable in this map is the marking of a fire hotspot, indicating an active or recent fire event (bTV Media Group, 2024) contributing to localised extreme heat. The industrial zones in both cities are significant sources of heat, worsening the UHI effect.

Haskovo and Kardzhali, much like the other cities, show the hottest areas concentrated around their urban centres and industrial zones, demonstrating the typical pattern of higher surface temperatures in developed areas due to the accumulation of heat in buildings, roads, and other infrastructure. Smolyan, by contrast, remains cooler, with more green areas indicative of lower temperatures. As mentioned above, the cooler tones align with Smolyan's location in a more mountainous and vegetated region, suggesting that natural features like forests and terrain continue to mitigate heat buildup, resulting in much lower surface temperatures compared to more urbanised cities.

The visualisation of the heat wave in the urban areas displays the effect of altitude. The best example is the City of Smolyan, where a heat island appears but is not considered a health risk. An additional factor in the mitigation of the heat island effect in Smolyan is the forested land cover that dominates the West Rhodopes Mountain region. The vast coniferous woodlands are a local climate factor. Moreover, the city is located in a narrow downward (diurnal) and upward valley, where local winds prevail and cool down the city's surface.

The final data captured on July 16, 2024 (Figure 7) shows the surface temperature distribution in the Kyustendil and Blagoevgrad regions. It indicates lower overall surface temperatures compared to previous images, as suggested by the predominant green and yellow tones, likely due to the earlier time in the morning when the data was collected (02:34 local time). The cooling effect of the night can be clearly seen. In Kyustendil, the UHI effect is still present but more subtle, with the urban centre showing slightly warmer areas in orange hues, while the surrounding natural landscape, including the Osogovo mountain, remains much cooler. The lower

Figure 7*UHI mapping in Kustendil and Blagoevgrad on 16.07.2024*

temperatures in the green and blue areas are showing the the mitigation of the influence of natural features such as forests and higher elevations. Blagoevgrad exhibits a similar pattern, where the industrial zone and urban centre are warmer than the surrounding rural areas. However, the overall temperature was lower than that of daytime UHI recordings, emphasizing the nighttime cooling effect. This image provides a clear contrast between urban and natural environments, with cities retaining heat from the day, even at cooler nighttime hours, and rural areas cooling more rapidly.

This comparison highlights the temporal dynamics of the UHI effect, demonstrating that while urban areas continue to emit heat into the night, natural areas, particularly mountainous regions, cool down significantly faster, reducing their thermal footprint during non-peak hours. This observation reinforces the role of natural landscapes in moderating extreme temperatures, particularly during night-time.

The UHI phenomenon reinforces how urban development significantly impacts localised microclimates by retaining heat, particularly in industrial and densely populated areas. The temperature differentials between urban centres and surrounding rural or natural areas highlight the need for urban planning strategies that could mitigate the negative impacts of heat retention, such as increasing green spaces and improving building designs to reduce heat absorption.

There are several places that could be further analysed and require additional data. For example, the Sofia International Airport has an entirely outlined spatial appearance on thermal maps. Asphalt and concrete infrastructures (airstrips, buildings, roads) generate enormous heat accumulators during the day. The lack of trees and the low-mowed grass are a result of the safety standards of the airport complex. This poor green infrastructure determines extreme heating patterns, which result in the heated pole of Bulgaria's capital city. Similar spatial patterns of the heated surfaces were also observed at the international airports in Varna and Burgas.

Discussion

The analysis of population dynamics and surface temperature patterns across Bulgaria provides a comprehensive understanding of demographic trends and the urban heat island (UHI) effect. The population data demonstrate a marked decline in population across most regions, particularly in rural areas, consistent with ongoing trends of urban migration, low birth rates, and emigration. This depopulation intensifies regional disparities as rural municipalities continue to lose residents, while urban centres face challenges of over-concentration. Simultaneously, the ECOSTRESS sensor imagery from the International Space Station highlights the pronounced UHI effect in Bulgarian cities, capitals of regions, with significant heat retention in urban and industrial zones, particularly during nighttime hours. Cities like Sofia, Plovdiv, and Stara Zagora consistently display elevated surface temperatures, whereas mountainous and rural regions, such as Smolyan, exhibit much cooler thermal profiles. These patterns underscore the dual pressures of urbanisation: declining rural populations in many areas on one side and the environmental consequences of heat accumulation in urban centres, on the other.

The examination of Urban Heat Islands (UHI) and their impact on health in this study aligns with prior research that highlighted increased temperatures in urban settings during heatwaves (Fernandes et al., 2024; Garcia, 2022; Nasir et al., 2022). Our analysis adds to this body of knowledge by detailing nighttime heat retention in Bulgarian urban centres, revealing significantly higher temperatures compared to rural and mountainous areas that experience natural cooling. This observation is consistent with earlier findings, such as those by Dimitrov and Spasova (2020), who noted an increase in health incidents like heart attacks and strokes, on hotter days in Sofia. By extending these observations across a broader geographical area and integrating demographic data, the study maps heat distribution and identifies

urban populations—especially the elderly—as particularly vulnerable to heat-related health risks. The use of high-resolution ECOSTRESS satellite data has been instrumental in pinpointing critical areas for urban planning and public health initiatives, as well as in developing new ways to enhance heatwave resilience. Thus, this research supports and expands on existing understandings of how UHI effects can influence public health in urban environments. In the other,

The analysis of ECOSTRESS data for the summer heatwave of 2024 addresses a critical gap in surface temperature observations, facilitating a more comprehensive and accurate analysis of urban heat island (UHI) dynamics. The data availability and mapping applications are essential for the continuous monitoring of UHIs, which are known to pose significant health risks, particularly to vulnerable population groups. Considering Bulgaria's ageing demographic profile, the need for systematic, high-resolution monitoring has become increasingly imperative to inform public health strategies and urban adaptation measures.

Conclusion

Bulgaria's diverse geography, including altitude, topography, and land cover, significantly shapes the intensity and distribution of these heat islands in urban areas. Cities at higher altitudes, like Sofia and Smolyan, experience a cooling effect due to the vertical temperature gradient and forested surroundings, whereas lower-altitude cities, such as Plovdiv and Burgas, experience more intense heat islands. Urban infrastructure, including dense buildings, roads, and industrial zones, further amplifies heat retention, particularly in cities located in plains and valleys. Additionally, natural elements such as sea breezes and river winds offer localised cooling effects, although their scope is limited. These findings highlight the complex interaction between geography and urban development in determining heat dynamics in Bulgarian cities.

In terms of health effects on the population, currently available data indicate a clear link between age and susceptibility to heat waves. The regions with the highest percentage of residents over 65 years old coincide with areas experiencing higher temperatures, as determined by satellite imagery. These regions also exhibit higher mortality rates. This supports the theory that older people are at risk of extreme heat events. When considering regional disparities, noticeable variations exist in the distribution of elderly populations and high temperatures. This leads to the fact that adaptation strategies for climate change must be tailored to the specific characteristics of each region.

Endnotes

The combination of demographic and thermal data underscores the need for integrated urban planning and disaster risk preparedness strategies in Bulgaria. As rural depopulation continues, urban centres are likely to face increasing environmental stresses due to the UHI effect, potentially threatening public health and leading potentially to energy consumption issues. To mitigate these challenges, policy interventions should focus on enhancing green infrastructure, promoting sustainable urban expansion, and incentivizing population retention in rural areas. The cooling effects observed in natural landscapes highlight the importance of preserving green spaces and incorporating nature-based solutions to reduce urban heat stress. Addressing both demographic and environmental concerns is crucial for fostering long-term regional sustainability in Bulgaria.



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Peer Review		Externally peer-reviewed.
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Path Dependence of Space Production in Turkey: The Hegemonic Construction of Neoliberalism in Eskişehir and Konya



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Abstract

Neoliberalism, which emerged as a global discourse and was shaped by the foundations of the capitalist economy, has turned space into a political tool at the local scale by developing capital-friendly strategies. This ideology prevailing in Turkey's urbanisation since 1980 has significantly shaped its specific geographies in the last 20 years. Based on the path dependence theory in the urbanisation of neoliberalism, this study analyzes neoliberal practices and hegemonic construction in two cities, one with conservative liberal and the other with social democratic administration practices. The data was gathered from the city actors in Eskişehir and Konya through in-depth interviews. Our findings indicate that while the urbanisation process in Konya progresses in a path-dependent manner and localities pave the way for new trajectories, this process in Eskişehir progresses in different trajectories, although it is path-dependent and creates its own unique process by drifting away from universal neoliberalism.

Keywords

Neoliberalism • actually existing neoliberalism • path dependence • hegemonic construction



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INTRODUCTION

As the Keynesian economy has entered a crisis since the 1970s, deliberalization and market-friendly policies have started to dominate the development of cities (Taşan-Kok, 2011). In this period, all neoliberal interventions were seen as a “strategic response to the crisis” (Theodore, Peck and Brenner, 2012), and it was thought that the market could only be stimulated through various regulations. With such regulations as the differentiation of the understanding of the social state in public services, privatisations, and free-market formation, “what started as a utopian intellectual movement has been aggressively politicised” (Peck and Tickell, 2002).

The uncertain economic environment, especially in underdeveloped and developing countries, has been taken under control by capitalist countries, and the uncertainty of the market has been kept under control with the interventions of international organisations (Ritzer, 2011; Savaşkan, 2013). In the deliberalization process, the best area of investment to which accumulations can be directed has placed the cities at the forefront and “the city has been used as a tool in the creation of a new social structure and consolidation of capital power” (Eraydın, 2013). The majority of the critical studies on the urbanisation of neoliberalism agree that this phenomenon produces similar results in the urban space (Aksoy, 2014; Beck, 2020; Geniş, 2005; Harvey, 2015; Kurtuluş, 2005; Kurtuluş, 2005a; Macleod, 2002; Öktem, 2005; Peck and Theodore, 2007; Penpecioglu, 2016; Smith, 1996; Smith, 2002; Swyngedouw, 1997; Şen, 2005). In fact, neoliberalism has imprisoned the urban space in an “incubator” (Smith, 2002) that “serves political and ideological strategies” (Brenner and Theodore, 2002) by making it a part of the rapidly producing-consuming-reproducing cycle.

The fact that the space can be organised by different social actors has given the city an increasingly passive character (Harvey, 2012). With the “inevitable” pressure of globalisation, the role the city has assumed in the national and international arena and the role of the actors governing it have brought the city together with the capital (Türkün and Kurtuluş, 2005). In the process initiated by these events, the urban space transformed in line with the necessities of the neoliberal prescription, and a trajectory has now occurred. Thus, urbanisation has become a “spatially based social practice” (Harvey, 2012).

In this study, to enrich the analytical framework concerning the reproduction of urban space, we will integrate the concept of “path dependence” inspired by Brenner and Theodore’s model of *actually existing neoliberalism* and the concept of “hegemonic discourse” inspired by Gramsci’s hegemony to

the political economy dimension of urbanisation. Neoliberal discourses are substantially produced at the national level and dictate “indispensability” as an obligation for the implementation of the development prescriptions of the right policy (Bora, 2017). However, the political left is also of the opinion that global changes do not offer an alternative to urban administrations other than neoliberalism, and this discourse of inevitability harms the creation of all kinds of developmental alternative policies (Broomhill, 2001).

While most studies on neoliberal urbanisation discuss the process through structural dynamics, how and by whom these policies are constructed at the local level, and especially how they are implemented by municipalities with different ideological positions, are relatively less examined area in the literature. Neoliberal urbanisation in Turkey has become evident with the integration of urban space into capital accumulation processes through urban transformation projects, gentrification projects and mega infrastructure investments that have gained momentum since the 2000s (Öktem, 2005; Aksoy, 2014; Penpecioglu, 2016). Transformation projects carried out in the Sulukule, Tarlabası and Ayazma neighbourhoods of Istanbul have resulted in the displacement of low-income groups and the deepening of spatial injustices (Kuyucu and Ünsal, 2010). In this process, housing policies and mega projects led by TOKİ have transformed housing from a right to shelter into an investment tool (Bartu Candan and Kolluoğlu, 2008).

However, this structural transformation is also shaped by the political positions of local governments. For example, the New City Centre project in Izmir was carried out by a social democratic municipality (Tutar and Bal, 2019). Similarly, the luxury housing project in the Beysukent district of Ankara shows that neoliberal urbanisation encourages elite consumption patterns and spatial segregation (Güzey, 2014). These examples reveal that municipalities with different political ideologies adopt and implement neoliberal urbanisation practices. This shows that neoliberal urbanisation is a process that is constructed politically not only at the central but also at the local level. Therefore, neoliberal urbanisation emerges as a flexible regime where different political positions can meet around the norms of market urbanisation, not a single ideological orientation (Brenner and Theodore, 2002; Tansel, 2018).

The fact that this study addresses both theory and practice based on two different political ideologies gives originality to the study. In this context, the aim of the study is to discuss the use of discourses produced by neoliberal policies as a complementary tool through the “spatialization of politics” (Işık, 1999). The research questions developed within

this scope are as follows; What alternatives has the political discourse of space production created? Can the reproduction of urban space under neoliberal pressure reveal its original context? Can social democracy resist the inertia of path dependence? While the selected cases seek partial answers to these questions, it will be discussed whether the rules of the game are rewritten.

In parallel to previous studies, this paper offers a critical perspective on the transformation created in space by neoliberal urbanisation processes and criticises the social democratic governments' integration of neoliberalism into urban space with a softer language, unlike the hard practices of conservative liberal governments. In the next section of the study, the path-dependent character of neoliberal urbanisation constitutes the theoretical framework. The third section covers the research process that deals with data collection and analysis. In the fourth section, the construction of neoliberal hegemony is presented in the case of Eskişehir and Konya, considering the findings. In the discussion and conclusion section, the political construction of space production is discussed through originality.

STABLISHING THE GROUND: THE PATH-DEPENDENT CHARACTER OF NEOLIBERAL URBANISATION

Neoliberalism is not a simple state or economic relationship model (Brenner and Theodore, 2002). The notion of "actually existing neoliberalism" is not simply a program based on social, political and economic relations, but a tool with a "destructive" effect that enables transformation across the global economic and political sphere (Brenner and Theodore, 2002). Jessop's argument is similar to this argument. Referring to the "actually existing neoliberalism" concept of Brenner and Theodore, Jessop discusses liberalism, neoliberalism, and urban governance from a state-theory perspective considering liberalisation that supports free competition, deregulation that reduces the role of law and the state, privatisation that stipulates the sale of the public sector, transnationalization that allows free movement, and low wage taxes that increase consumption (Jessop, 2002).

Neoliberalism, the pure economic doctrine of the 1970s, evolved into a process in which regulating reforms were implemented with the abolishment of the Fordist-Keynesian economy in the 1980s and with the implementation of tougher political decisions in the 1990s (Peck and Tickell, 2002). This political-ideological shift occurred along a highly path-dependent evolutionary trajectory. The radical anti-state neoliberalism of Reagan and Thatcher in the 1980s to the

socially more moderate neoliberalism of Blair, Clinton, and Schröder, which prevailed in the 1990s, can be understood as an adaptation to path dependence and neoliberal reorganisation strategies in response to their own destructive and dysfunctional socio-political influence (Brenner and Theodore, 2002).

The concept of path dependence emerged with the idea that a small beginning or small random shocks along the path can change the course that started in the past (David, 1985; Page, 2006). Path dependence means that the current and the future situation, actions, and decisions depend on the path of past situations, actions, and decisions (Page, 2006). The process of adaptation to the path above-mentioned dependence occurs on the axis of various events and trajectories (Taşan-Kok, 2015).¹ When path-creating processes occur, the creative and destructive dynamics that generate moments differ from place to place (Taşan-Kok, 2015).

The dynamic of creative destruction is not represented by an order in which the old is destroyed and the new is built in its place. Rather, it creates a complex and conflicting order in which the new contradicts the old (Peck, Theodore and Brenner, 2013). The destruction of market-oriented reform initiatives and the institutional regulations and political consensus correspond to the destructive moment. The creation of a new institutional infrastructure for market-oriented economic growth, commodification and capital superiority represents the creative moment (Brenner and Theodore, 2002). In this way, new interventions regarding the accumulation of capital and escape from the crisis are merged with some inherited path-dependent institutional arrangements and are articulated in the neoliberal prescription (Lipietz, 1992). New political areas and interests are redefined in order to reorganise the capital accumulation and overcome the obstacles related to it so that the confusion that occurs in the meantime is cleared (Peck, Theodore and Brenner, 2009).

According to Vincensini (2001), although these arrangements made at the institutional and organisational level, also known as "path shaping", are sometimes restricted by the context-dependent on the path, there are a number of possibilities that can pave the way. Here, actors can step in and play the game based on the inherited rules, can strategically choose which direction to go within the limits set, and even gradually reshape the rules of the game in order to eliminate the

¹According to Taşan-Kok (2015), a legal document issued at a specific time (e.g. the date a development plan was approved or passing a law related to an issue) is an *event* and the process initiated by these events is the *trajectory* (e.g. the increase in building density due to the zoning plan in a region).

restrictions. The institutional change here arises from “path shaping dependent on a path” (Vincensini, 2001).

Moreover, individual and administrative behaviours allow for a variety in the governance of each city, and although cities are identical in many respects, they may have different historical paths (Woodlief, 1998). In fact, the direction and characteristics of these paths have caused the reactions of New York City and Chicago, two powerful global cities, to the Great Depression to differ (Woodlief, 1998). At this point, the concept of path dependence helps the local to reveal its own context because the supporters of neoliberalism have created a discourse on producing economic policies that “reimagine” the local region itself and its place in the world. After this discourse, the local area ceased to be a political, economic and cultural community but began to be conceived as an “economic” entity to serve neoliberal policies (Broomhill, 2001).

Some institutional regulations brought about by neoliberal policies increase social and economic inequalities, which has caused the modern world to be surrounded by fragmented but often weak local economies (Amin, 1994; Broomhill, 2001). On the other hand, while the reflection of neoliberal policies on the local level provides political superiority and convenience to the right-wing political understanding, it has forced the left political understanding to produce policies to save the day. In this sense, when we consider the cities created by neoliberalism as a whole, it is not difficult to imagine a ragbag because advocates of neoliberalism have focused their attention on restructuring the nation-state and anticipated restructuring state policies at the local level (Broomhill, 2001). During this process, political mechanisms focused on both path dependence and shaping the path dialectically (Vincensini, 2001). In this way, the “variegated capitalism” (Peck and Theodore, 2007) paved the way for each local government to produce its own neoliberal ideology at the local scale.

The concept of path dependence presents an appropriate framework to discuss archaeology and the current situation of neoliberal urbanism in Turkey. Indeed, with the start of the multi-party period in the 1950s, the developmentalist discourse of the right-wing conservative parties came to the fore. The crisis that the Keynesian economy has experienced all over the world since the 1970s has urged capitalist countries to seek a new economic regime. This search has become a precursor of a transformation in which “nature and human will be commodified” (Özkazanç, 2005) as well as stimulating the economy. On the basis of commodification was the ideology in which “the free market itself is adopted as a value” (Bora, 2017).

Especially through the supreme institutions under the control of strong states such as the USA and the UK, liberal policies have been transformed into neoliberal policies where the free market was more intensely included and unlimited exploitation utopia was imposed, and a new imposing hegemony was initiated in underdeveloped and developing countries (Özkazanç, 2005). Turkey, which underwent a new political, economic and social transformation process after the 12 September 1980 military coup, was affected by this wave as well in parallel to the developments all over the world (Özkazanç, 2005).

Events based on creative and destructive moments show that the course of neoliberal urbanisation in Turkey was not independent of the world. Taşan-Kok’s (2015) study on the Levent-Maslak axis revealed that change has been the result of the organisational and institutional processes that emerged in Turkey. In this study, Konya offers a similar result. However, interestingly, Eskişehir, which resists “despite the neoliberal wind”, presents a result similar to Konya in the same trajectory of change even though different events complete its urban development along the way.

RESEARCH PROCESS

The research design of this study is a *case study* that aims to understand a case in depth in its natural environment, taking its complexity and context into account (Berg, 2001; Prasad, 2018; Punch, 2005). We conducted fieldwork in three different time periods in Eskişehir and Konya between 2016 and 2019. During the time we spent in the field, we conducted semi-structured in-depth interviews with municipal officials, independent city planners and architects, non-governmental organisations and city residents, whom we regard as the city’s actors. Therefore, the first data collection technique employed in the research was in-depth interview. Interviews were completed in 45-70 minutes.

Within the scope of the sample selection criteria of qualitative research, we conducted in-depth interviews with 32 people, 17 in Eskişehir and 15 in Konya. In this study, purposeful sampling was used. We interviewed people who had been living in these cities for at least five years, who were expected to have a say in the projects related to the production of urban space (urban transformation, transportation, shopping malls, parks and green areas, mass housing projects, etc.) and who were the active users of these projects. Therefore, we designed four different interview forms to be used with the officials in the metropolitan area administration of both cities, officials in the central district local administration, non-governmental organisations, stakeholders in the private sector, and city residents. In order to analyse the construction of hegemony,



the actors actually involved in the space production process were also included in the sample. We tried to reach the sample that would present the richest linguistic material related to the research questions.

In our study, various documents closely related to the research problem enabled us to diversify the data. In this context, the documents of the media outlets of local governments and NGOs in both Eskişehir and Konya were examined. In particular, the announcements and public service bulletins of the municipalities provided important clues about the production process of the urban space. In addition, visual materials on signboards and billboards in both cities provided information that would contribute to the research. In order to understand the restructuring of neoliberal urbanisation through institutional regulations, Laws No. 5216, 6306, 5162, 6360, 5393 and 3194 were examined in detail. Here, the aim was to understand how the legal dimensions in the production of space were used by the actors.

Two types of analysis were carried out in the study: descriptive analysis and discourse analysis. After the interviews were conducted, the recordings were transcribed and texts were created. The transcribed texts were analysed descriptively. Then, various documents obtained were examined and discourse analysis was performed in order to complete the missing parts of the interviews and the parts that were not answered by the interviewers (especially local administrators) and to understand how the neoliberal urbanisation process was constructed discursively. The findings obtained from the analysis were presented in a descriptive narrative and were discussed and interpreted by including direct quotations from the interviewees. Furthermore, the findings were visualised with three concept maps to make the neoliberal space production processes more understandable. This study was redesigned using the findings of the doctoral thesis completed in 2018. Since the obligation to submit the Ethics Committee report became mandatory after 2020, the ethics committee report was excluded in this study.

THE CONSTRUCTION OF NEOLIBERAL HEGEMONY: ESKİŞEHİR AND KONYA CASES

Events Setting the Path in the Urbanisation of Eskişehir and Konya

The agents that have affected the spatial pattern of the city by determining the creative and destructive moments in both cities are: (1) institutional regulations and laws; (2) actors and

(3) the local-social structure (Table 1²). These agents have also provided the basis for the trajectories of change and the path into which urbanisation will evolve by influencing how and to what extent the city will be articulated into neoliberal regulations.

Turkey entered into a development and consumption-oriented period with the January 24, 1980 decisions and the September 12, 1980 military coup. Özal governments were the real driving force for the deliberalization trajectory (Taşan-Kok, 2015). The Motherland Party, which came to power in both the central and local governments with the elections held after the military coup, initiated the liberal municipalism approach through neoliberal regulations and took steps to accelerate urbanisation (Adigüzel, 2013).

Decisions made during the coup have been revised since the 2000s and re-integrated into the process of urbanisation in Turkey. TOKİ, which was established in 1984 to solve the squatting problem experienced in Turkey since the 1980s, has been given more activity areas and resources during the Erdogan government and was annexed to the Prime Ministry in 2004 with a special law. In the housing sector, public-private sector cooperation was established, and the amount of public land under TOKİ control reached 64.5 million m² in 2004 (Buğra and Savaşkan, 2014).

With its growing jurisdiction, TOKİ also had the right to transfer its lands to the private sector. With the Metropolitan Municipality Law No. 5216 enacted in 2004, the transfer of authority to the local was realised, and the municipalities became important actors by having the right to speak in areas where the central government is the sole authority. In this way, they shared some of the privileges of the central government regarding infrastructure investments, and with the law numbered 5393 enacted in 2005, their responsibilities in infrastructure investments were increased and included in their planning authorities. This paved the way for attracting global capital to cities and areas of urban rent (Bal, 2011; Buğra and Savaşkan, 2014; Çavdar, 2016; Doğan, 2011).

Political Background of the Decision-Making Process on Projects

The city of Eskişehir experiences the production process of the urban space as actor-dependent. The only decision-making mechanism of the process is the Metropolitan Mayor. Although different segments are expected to be included in this production process due to his social democratic identity,

²While preparing this table, we were inspired by Taşan-Kok's paper and recreated this table according to the findings of Eskişehir and Konya in accordance with the research design. See Taşan-Kok, "Analysing Path Dependence", 2190-2193.



almost all the interviewees claimed otherwise, stating that the Mayor of the Metropolitan Municipality was very strict and that there was no collaboration in the decisions regarding the city. The question about the participation of different actors in the space production process received the following responses:

I will use a sentence outside your expectations. All the decisions are taken by the Eskişehir Metropolitan Mayor himself. I think it is enough to say that. The Mayor, I should say, is a man who walks around Eskişehir in his spare time and suddenly takes his ruler in his hand, measures the pavement and says "This is 15 cm longer than it should be" and has it demolished and rebuilt. I think this explains the situation, doesn't it? (Eskişehir, Interviewee 1, Male, 51)

Here, although the interviewee tries to emphasise the perfectionist personality of the Mayor and draws a positive picture, he is in fact dissatisfied with the fact that a single person manages and controls the whole process. Another interviewee in Eskişehir stated the following regarding decision-making and implementation in projects related to the space:

It seems to be participatory, but actually it is not. At the beginning, the Mayor held collective mind meetings, brainstorming sessions, etc. It seems as if the opinion of every non-governmental organisation is taken. Such meetings are held, but eventually in those meetings whatever is desired to be done is imposed on the participants and as a result, the decision made at the end of the meeting is introduced as the agreed-upon decision. In other words, there is nothing like 'We want to do something, let's get together and share our ideas, and put those ideas into practice' (Eskişehir, Interviewee 13, Male, 62).

According to the interviewee, the projects are already planned; however, some meetings that serve no purpose are held and symbolic participation is ensured. The interviewee also emphasised the persuasion ability of the Metropolitan Municipality Mayor and stated that the meetings cannot go beyond the perceptual dimension. The ideas of another interviewee, an urban planner, support these statements:

He determines his team. He determines the members of the city council. The political party or any other thing is not important... [Citizens] do not want to think because we are lazy. Someone thinks and decides for them anyway. I think our citizens will be able to perceive our shortcomings only by experiencing them, but it will

be too late then. In other words, the Mayor does not consult much, I mean, not at all. He only acts ... (Eskişehir, Interviewee 4, Female, 44)

The interviewee emphasises the authoritarian attitude of the Mayor. Authority itself is characterised as the orders that are produced by an actor and which others are expected to obey, and the individual can either follow this order without considering its legitimacy or follow the order even if he believes it to be wrong (Bağbaşı, 2010). In this context, according to what the interviewees said, the only dominant actor in Eskişehir's space production follows an authoritarian attitude, and his followers are not only the voters but also the media. In fact, the local and national media present the space-related projects of the municipality as creative and original³, although these projects are the copy of those in European cities because of modernism (Durakoğlu, 2019).

The analysis of the data obtained from both interview texts and bulletins and reports revealed that an actor-dependent space production model (Figure 1) has emerged in Eskişehir. The only actor in the determination and implementation of the projects is the Mayor of the Metropolitan Municipality. Although none of the questions were directly about individuals in the interview form, especially the interviewees in Eskişehir answered the questions with reference to the Mayor of the Metropolitan Municipality. Some interviewees shared some striking ideas:

We are pleased with the services of the professor [the title of the Mayor among the people]. Maybe people here suffer from traffic. I am a taxi driver, and sometimes there is a traffic jam, but I cannot say anything bad about the professor. I work as a taxi driver in the winter and work at the beach for three months in the summer. I cannot say anything bad because I earn my living thanks to him. The professor came, and the city changed a lot. Every place is well maintained. I did not used to know anything about sculptures, but now at least my child knows that sculptures are nothing bad. (Eskişehir, Interviewee 2, Male, 39)

...The professor is quick-witted. He brought the centre to the fore. He had the Porsuk river cleaned. This made him

³See Deniz Ayhan. 2020 "Doğduğu Kenti Yeniden Yarattı." (He Recreated The City He was Born in), Sözcü, November 8. <https://www.sozcu.com.tr/hayatim/yasam-haberleri/dogdugu-kenti-yeniden-yaratti/>; "Kentsel Dönüşüm: Kendini Yeniden Yaratın Eskişehir'in Turistik Bir Kente Dönüşüm Hikayesi." (Urban Transformation: The Transformation Story of Eskişehir that Recreates Itself into a Touristic City), 29 March 2019. <https://thecityfixturkiye.com/kentsel-donusum-kendini-yeniden-yaratan-eskisehirin-turistik-bir-kente-donusum-hikayesi/>; "Eskişehir Bir Avrupa Kenti." (Eskişehir is a European City), Milliyet, 18 January 2003. <https://www.milliyet.com.tr/cumartesi/eskisehir-bir-avrupa-kenti-300158>

Table 1

Path analysis of the urbanisation of Konya and Eskişehir

	Contingent events		Trajectories of change		
Institutional processes	Creative moment(s)	• Liberal economic model (Özal Government-1984)	For Turkey	For Konya	For Eskişehir
	Destructive moment(s)	• Authoritarian neoliberal economic model (Erdogan Government-2002) • Metropolitan Municipality Law No. 3030 (1984) • Zoning and Construction Law No. 3194 (1985) • Metropolitan Municipality Law No. 5216 (2004) • Municipal Law No. 5393 (2005) • Law on Transformation of Areas under Natural Disaster Risk, Law no. 6306 (2012) • Military coups (1960, 1980) • Economic crises (1982, 1992, 1994, 2001, 2008) • Natural disasters (The Marmara earthquake of 1999; The Van earthquake of 2011)	• Increasing state intervention and increasing international capital • Globalisation • Privatisation • CBD expansion • Changing lifestyles and demanding new residential environments • Shopping malls dominate the urban landscape	• Increasing foreign capital • “A world city” image • Increasing global chain stores • Construction of shopping malls, lifestyle residences, intersection bridges and roads • The formation of a new urban pattern under the domination of the construction/housing sector	• The effort to create its own capital • “A European city” image • Construction of smaller-scale shopping malls and consumption areas
Urban administration and actors	Creative moment(s)	• Stability of liberal conservative local governments in Konya (Welfare Party, Justice and Development Party)	• Acceleration of space production projects in partnership with municipalities and various organisations	• Reshaping the landscape of urban space with more amount of and higher budgets with the strong support of the central government	• A city resisting neoliberalism until 2010
	Destructive moment(s)	• Stability of social democratic local governments in Eskişehir (Democratic Left Party, Republican People's Party) • “Metropolitan” status • Expansion of metropolitan service area borders • Conflict situation caused by Eskişehir's remaining in opposition after 2002	• Moving away from the social state understanding • Privatisation of municipal public services	• Creation of a prototype of the neoliberal urbanisation in Turkey	• An urban pattern represented by an increasing number of transformation projects, consumption areas, and restoration of historical buildings and lifestyle residences since 2010

Source: We benefited from Taşan-Kok's (2015) work while re-preparing these tables

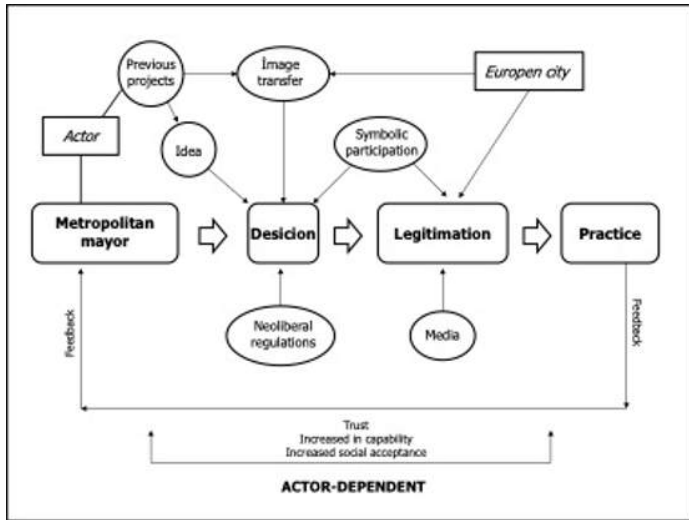
successful. Things are made for the public, so there is no personal gain here, only a few cafeterias. He will continue to serve as long as he is with us...His existence depends on the services he provides. He will remain in office for a long time. In other words, people are voting for the professor, not for his party. (Eskişehir, Interviewee 1, Male 51)

Both interviewees attributed leadership qualities to the Mayor of the Metropolitan Municipality, and when talking about the mayor, they addressed him as the “professor” and expressed

their trust in his academic identity. According to the interviewees, the mayor will not make a mistake because he is a “professor” and every activity he does will definitely be applauded. In this context, it is possible to say that the interviewees, especially the inhabitants of the city, are loyal to the Metropolitan Mayor with unconditional obedience and they respect him. Direct acceptance of policy prescriptions produced by policy makers by the public also reinforces the power of hegemony to reproduce itself (Moulaert et al., 2007).

Figure 1

Space production model in Eskişehir



In Konya, there is more than one actor and the process is structure-dependent (Figure 2). In the city, the decisions taken by the government (mainly the President and the Prime Minister of the period in the second place) are important in the production of urban space. With a path-dependent political tradition and the continuation and even the modernised version of the National Vision,⁴ the government has a strong authority over the city. As emphasised frequently by the interviewees, the city of Konya is the first place where the government won a local government and thus, it has a special value. The harmony between the central government and local governments in Konya plays a facilitating role in all stages of the projects. Here, the projects that come in the form of a package are implemented by local administrations by taking advantage of both the political/administrative and the financial power of the centre. Therefore, the decisions of Ankara are effective in the production of urban space and unlike Eskişehir, the Metropolitan Mayor, in a way, plays a passive role. It is possible to say that in this case structural variables come into play, and contrary to the situation in Eskişehir, the local administrator “plays the role that history has set for him” (Bayraktar and Penpecioglu, 2008) due to the decisions taken in the form of jacobin. For Konya, the charismatic leader is the President, and this idea has strengthened the link between the centre and the local (Figure 2). A senior administrator from a metropolitan

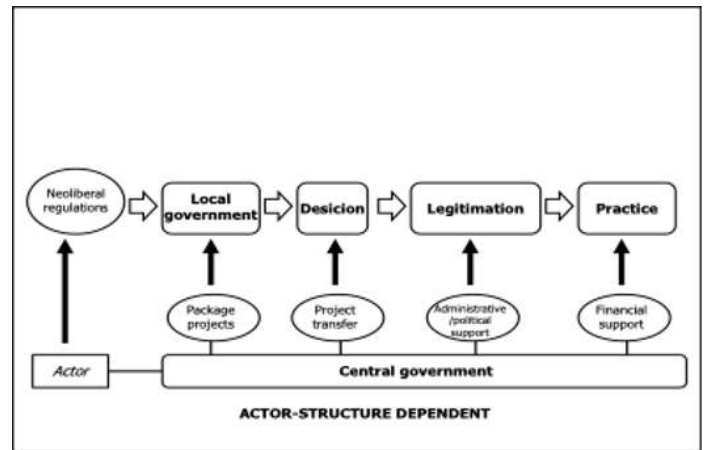
⁴The purpose of the National Vision Movement is to establish a just world order by uniting Islamic countries in the fields of military and economy. It is a political movement that started in 1970 under the leadership of Necmettin Erbakan (see Çaha and Baykal, “Milli Görüş Hareketinin Kuruluşu”). This movement enabled the strengthening of the Islamic political economy (see Bora, 2017). The innovative wing (Abdullah Gül, Bülent Arınç and Recep Tayyip Erdoğan) left the National Vision Movement, which was adopted by the National Order Party, the National Salvation Party, the Welfare Party, the Virtue Party and the Felicity Party, respectively, and founded the Justice and Development Party in 2001.

district municipality in Konya stated the following regarding the harmony between the central government and the local government:

[The harmony between the central government and our local governments] definitely has a contribution. In other words, if a project area to be built is within the framework of the legislation concerning construction or laws, there will absolutely be no obstruction from the government; it is impossible anyway. Let me say that contact and mutual agreement speed up the work. When the government and the local administrations are from the same political party, everything is accelerated. This is very clear. (Konya, Interviewee 20, Male, 39).

Figure 2

Space production model in Konya



The interviewee emphasised that beyond the harmony between the centre and the local government, being from the same political party has an accelerating effect at every stage of the project. Another interviewee expressed his ideas about the relationship between the central government and the local government as follows:

This relationship is a must because Konya is the centre of the central government and because most of the founding members of the ruling party are here. Let me give a sincere answer. There may be a conflict, but I have never heard of any. I believe there is no conflict. If there were, we would not have done this much work. I have never heard a minister say to the mayors here “Why are you doing this here?” I have not encountered such a situation. I cannot because there is nothing like that. (Konya, Interviewee 21, Female, 36)

Other actors in the space production process in Konya can be listed as TOKI, which is largely a government-dependent unit, and the capital and property owners. In fact, the legal ground

needed in the neoliberal urbanisation process was prepared by the laws numbered 5216, 6306, 6360, 5393, and 3194, which emerged as the parts that created the structure especially after 2004.

The rapid and uninterrupted implementation of the urban transformation projects in Konya, which are also intended to be implemented by the Metropolitan Municipality in Eskişehir but allegedly prevented by the Council of Ministers, shows that the process progresses with “favouritism”. In this context, laws that are a part of neoliberal regulations constitute a strong structural basis for Konya. The local participation dimension of the process faces a crisis in Konya as in Eskişehir. When the interviewees were asked about the extent of their participation in the space production process, their responses were as follows:

None. That is, we are nowhere. He has five contractors and accomplishes what he does with them. So he talks about unity here and there, but what he refers to is the contractors, I mean whoever will provide him with the rent. It has nothing to do with the public, nor with the people who vote for him. (Konya, Interviewee 19, Male 60)

We are only invited to the openings; we receive text messages. But they do not ask the public whether they should do this. Those with a higher rank decide what will be done. (Konya, Interviewee 25, Female, 30)

Contractors are mainly involved in this business. The municipality is already a partner. Thus, the municipality obtains rent from them, and contractors already obtain a huge amount of rent. Apart from that, I do not think that many politicians are involved outside the municipality. The provincial presidency may be involved... I mean if even these provincial presidencies are involved, you can be sure that they are also involved in urban transformation works. (Konya, Interviewee 23, Male, 55)

According to what the interviewees stated, the space production process in Konya occurs in a context where the city residents are excluded and the capital is prioritised and privileged. However, in their discourse, senior administrators from the central district municipality insistently emphasised that they take “public interest” and “public demands” into account. In this context, the political power alone cannot determine what the “common good” and “public benefit” principles are because the city dwellers will consider themselves as part of the society and have a sense of belonging to the state, whether at the local or national level, only if common interests are combined (Sabancılar-Eren and Özden, 2014). Otherwise, a process that is disconnected from

city dwellers means a crisis in representative democracy. (Sabancılar-Eren and Özden, 2014). While the capitalist social structure and its production relationships constitute both the foundations and the boundaries of liberal democracy, the contradiction between capitalism and democracy cannot be resolved within the process and results in the crisis of democracy (Keskin, 2017).

In brief, while performing the projects in Konya, the legal dimension of the process is initially deregulated with the “laws produced” and then the projects are implemented as found appropriate by the actors. In Konya, the production of space is realised in complete harmony with neoliberal urbanism through mega-projects, resulting in the urbanisation of capital in parallel to the path-dependent character the developmentalist parties follow in the urbanisation in Turkey.

DISCUSSION and CONCLUSION: SPACE PRODUCTION DISCOURSE and NEW PATHS

The process of political transformation in Turkey has affected the production of urban space. In Lefebvre’s words, this transformation has also necessitated the manifestation of the urban space as “the space of differences” where different actors, social structures, cultural codes, ideologies, and symbols turn into different urban rhythms. In this way, the urban space is now blessed by all scales of government and almost turns into an indispensable tool for the “seat” (for power). In this context, the results of the study can be summarised as follows:

The data obtained from the interviewees revealed that Eskişehir, which has been governed by the same social democratic local administrator in a fairly stable manner since 1999, does not follow participatory democracy in urban administration processes, although there is a “social democratic” political discourse in the city. Spatial production in the city indicates the existence of an actor-dependent mechanism. In addition, there are hints that various visual practices in urban spaces are used as important hegemonic tools in obtaining the “consent” of city residents. Although the neoliberal urbanisation process in Eskişehir includes the dominant discourses concerning the neoliberal urbanisation in Turkey, it differs in terms of the method of application.

Konya was governed by the same local administrator between 2004 and 2018. The city-related projects of the mayor, who was in the administration with more than half of the votes for three terms, were frequently featured in the local and national press. The Mayor won the approval of the public with the transportation services offered in the city, especially the tram line. Recently, projects have been carried out for green

area production in Konya. The website of the Metropolitan Municipality includes the projects for urban transformation, transformation of historical areas, transportation systems, infrastructure and parking areas. Also, the presence of the President and the Ministers in the opening ceremonies of the projects as well as the statements in the municipal bulletins such as “we succeeded together”, “we did it together ...”, and “we govern our city together” are remarkable.

A common model has been developed for the production process of the space with the findings obtained from field studies conducted in both cities. According to the model, in both cities, the urban actor is a person with “leadership” qualities. While the only decision-making mechanism to produce urban space in Eskişehir is the Metropolitan Municipality Mayor, the Central Government is the actor in Konya. This points to the existence of an interlocutor, i.e., a “mediator” in urban politics (Keyman and Lorasdağı, 2010).⁵ This person may be a mayor, a powerful industrialist, or a representative of a powerful family, and his or her presence or absence can be a measure of the success or failure of a city (Keyman and Lorasdağı, 2010).

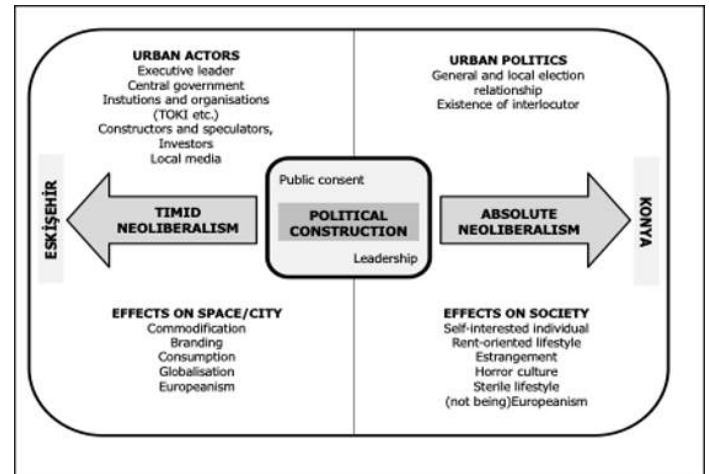
With the relationship between urban actors and politics, the city has now emerged as a place of production, and in this context, both Eskişehir and Konya have undergone a transformation represented by the built environment in a spatial sense. Considering the projects carried out, it can be stated that almost all of them correspond to the designed (cloned) spaces, and the cities themselves have been transformed into an object of consumption by receiving public’s approval through the discourses of “the centre of attraction”, “a brand city”, “employment”, “a European city”, “the capital of culture”, and in this way, the cities in question have been marketed to the capital more easily by local governments.

Although the path-dependent character of neoliberalism shows that developmental and conservative administrations adopt this understanding more easily, the example of Eskişehir indicates that the social democratic ideology is also caught in the wheel of the capitalist system and is under the influence of this wind. In this sense, a neoliberal understanding of urbanisation is applied in Eskişehir primarily by obtaining public consent and in a more gentle manner. Within the scope of this study, the practices in Eskişehir enable us to define the process as “timid neoliberalism” (Figure 3). In fact, all the projects regarding the production of urban space—whether they support the actor

or not—have been glorified by almost all the interviewees, and when asked about the relationship between the city and capitalism, the impossibility of such a situation was emphasised in Eskişehir.

Figure 3

The political construction of space production



On the other hand, in Konya, neoliberal urbanisation policies have been implemented in a very harsh and “due manner” without the need for any public consent, thanks to the power accorded by the path-dependent character. For this reason, in our study, the space production process of Konya was defined as “absolute neoliberalism” (Figure 3). In Konya, the change in the spatial pattern created by capitalism has taken place more strongly and rapidly as in other capitalist countries in the world.

Each urban condition is abstracted from the real development trajectory and is embedded in its own concrete institutional environment (Moulaert et. al., 2007). In this context, the fact that each city writes its own story in the neoliberal restructuring process shows that there is a radical break in universal neoliberalism (Piore, 2009; Peck, Theodore and Brenner, 2009b). While some cities directly obey path-dependence, as in the case of Konya, a process dependent on the path but progressing in different trajectories may emerge in a city such as Eskişehir, where localities prepare the environment for new trajectories.

Ethics Committee Approval: The data for the study were obtained from a section of the doctoral thesis completed in 2018, and the theoretical discussion section was rewritten. Since the requirement for ethics committee approval started after 2020, there is no ethics committee document.



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⁵This concept is defined by the authors as an actor who is effective in city administration during the transformation process and who has vision and leadership capacity.



for ethics committee approval started after 2020, there is no ethics committee document

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Assessing the Interaction Between Agricultural, Hydrological, and Meteorological Droughts in the Tigris River Basin



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Abstract

Drought is a common meteorological phenomenon that can result in a range of adverse outcomes. The Tigris River Basin (TRB) is located in the arid and semi-arid regions of southwestern Asia, where drought conditions have been observed to intensify. This research aims to understand the relationship between agricultural, hydrological, and meteorological droughts in the basin. To examine meteorological, agricultural, and hydrological droughts, the study employed three indicators: the Standardised Precipitation Index (SPI), derived from Terraclimate precipitation data; the Tasseled Cap greenness index, calculated from Terra-Moderate Resolution Imaging Spectroradiometer (MODIS) multispectral imagery; and surface water area fluctuations based on the MODIS Terra Daily normalised difference water index (NDWI). Our analysis of monthly SPI data from 2003 to 2022 indicates that approximately half of the months experienced meteorological drought conditions. The occurrence of agricultural drought was found to be associated with both 6-month and 21-month accumulation periods of SPI values, underscoring the intricate interrelationship between precipitation deficits and other influential factors in the context of agricultural drought. Hydrological droughts demonstrated significant correlations with meteorological droughts over accumulation periods of 1, 3 and 15 months, indicating a rapid onset but prolonged impact on water resources. Our findings indicate that although the various types of drought are interconnected, their relationships are not straightforward. Further research is required to explore the factors driving these patterns.

Keywords

Drought • Remote sensing • Tigris River basin



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Introduction

Drought, defined as a water deficit relative to normal hydroclimatic conditions, is a common meteorological phenomenon, and its duration is expressed in years, months, or weeks (Mishra & Singh, 2010). Droughts can lead to significant environmental challenges, including water and food crises (Mdemu, 2021), forest loss (Knutzen *et al.*, 2023), and threats to socioeconomic security (Yang, Liao, Di, & Shi, 2023). According to the World Meteorological Organisation (WMO) and the United Nations Convention to Combat Desertification (UNCCD), weather-, climate-, and water-related hazards have accounted for 50% of all disasters and 45% of all deaths worldwide since 1970 (Douris & Kim, 2021). As climate change continues to persist and intensify, many regions worldwide are anticipated to encounter more frequent and severe droughts, with irreversible consequences for both human and natural ecosystems (Bolorani *et al.*, 2024a). These developments underscore the critical importance of drought as an extreme event.

Drought is classified into four principal categories based on its impact: meteorological drought (relating to precipitation anomalies), agricultural drought (affecting soil moisture and crop yields), hydrological drought (impacting surface and groundwater resources), and socioeconomic drought (influencing human water needs and communities) (Svoboda, Hayes, & Wood, 2012). These categories are interrelated, and their definitions are linked to their specific impacts and measurement methods (Zeng *et al.*, 2022). It is noteworthy that the majority of drought effects correspond to agricultural or hydrological droughts, as human communities and ecosystems rely more heavily on water reserves such as soil moisture, aquifers, lakes, and rivers than on direct precipitation (Van Loon & Laaha, 2015). Thus, a comprehensive understanding of drought types and their interrelations is crucial for developing effective drought management and mitigation strategies.

From the beginning of the 21st century, there has been a notable global increase in both the frequency and duration of drought events, with a reported 29% increase worldwide (Douris & Kim, 2021). This trend is particularly evident in the Middle East and Southwest Asia, where the intensification of droughts has resulted in a cascade of environmental challenges. These include the desiccation of lakes and wetlands, the abandonment of agricultural lands because of reduced soil moisture and water availability, and the subsequent formation of dust emission sources (Bolorani *et al.*, 2024a). The interconnected nature of these effects underscores the complex and multifaceted challenges of

increasing drought frequency and persistence in vulnerable regions.

In recent years, the Tigris River basin (TRB) has experienced significant impacts from reduced rainfall and increased evaporation, leading to persistent water shortages in both river flows and groundwater reserves (Chang & Niu, 2023). The TRB's diverse geography and climate contribute to an imbalanced distribution of water resources across the region (Köle, 2017). This inherent disparity in water availability is further exacerbated by human activities, including the construction of dams and the implementation of water diversion schemes, which intensify the natural imbalance in water distribution throughout the basin (UNESCWA, 2013).

Despite the significant implications of drought in the TRB for the environment, agriculture, and human populations, this critical issue has not received sufficient attention. The lack of focus on drought in this region is particularly troubling considering its far-reaching and multifaceted impacts across various sectors. Understanding the process by which meteorological drought evolves into other forms of drought—a process referred to as drought propagation—is essential for mitigating the negative impacts of ensuing drought conditions (Xu, Wu, Shao, He, & Guo, 2023). This knowledge enables the formulation of more effective preparedness and response strategies to address the various consequences of prolonged dry periods (Bolorani *et al.*, 2024a). To achieve this, this study employs multi-temporal and multi-sensor remote sensing data to assess the interaction between agricultural, hydrological, and meteorological droughts in the TRB.

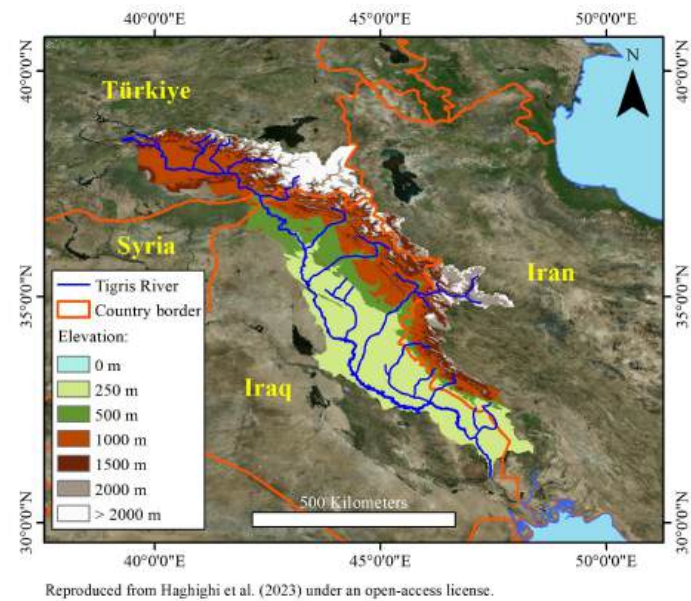
Study Area

The Tigris River, a major waterway in the Middle East, traverses a basin shared by four countries. The distribution of the river course is as follows: Türkiye (24.5%), Syria (0.4%), Iraq (56.1%), and Iran (19%). The basin covers an area of approximately 221,000 square kilometres and is situated within the following coordinates: 30° 59' to 38° 44' North latitude and 39° 8' to 48° 24' East longitude. The region is confronted with significant challenges pertaining to water resources, including concerns regarding quantity, quality, and biodiversity (Bachmann, Tice, Al-Obeidi, & Kılıç, 2019). Furthermore, climate change projections for the TRB indicate a troubling trend, with anticipated reductions in precipitation and river flow, coupled with rising temperatures (Al-Taei, Alesheikh, & Darvishi Bolorani, 2023). [Figure 1](#) shows the location map of the TRB.



Figure 1

Location map of the TRB



Source: Haghighi et al. 2023

Materials and Methods

Satellite-based drought monitoring

Satellite-based drought monitoring is a valuable and effective tool for assessing and monitoring drought conditions over extensive areas with high spatial and temporal resolution. This approach employs remote sensing indices and data products to quantify vegetation, soil moisture, and water storage (Behifar, Kakroodi, Kiavarz, & Azizi, 2023). Satellite-based drought monitoring techniques offer several benefits, including consistent coverage of remote or inaccessible regions and the ability to provide near-real-time data (Alahacoon, Edirisinghe, & Ranagalage, 2021). Consequently, satellite-based drought monitoring represents a fundamental component of drought warning systems and agricultural management strategies.

Assessing meteorological droughts

A prolonged shortage of rainfall is typically defined as a meteorological drought. In this study, we use the standardized precipitation index (SPI) (McKee, Doesken, & Kleist, 1993) to quantify and monitor the spatial and temporal patterns of meteorological drought. In our analysis, we used the Terra climate precipitation dataset (Abatzoglou, Dobrowski, Parks, & Hegewisch, 2018) to collate rainfall data from 2001/01 to 2022/12. Subsequently, precipitation accumulation was calculated for accumulation periods of 1, 3, 6, 9, 12, 15, 18, 21, and 24 months. Given that precipitation is typically distributed according to a gamma distribution (Martinez-Villalobos & Neelin, 2019), the data were normalised by fitting it to a

gamma probability distribution function, as introduced by Laimighofer and Laaha (2022). Finally, the SPI was calculated for each accumulation period by subtracting the mean value from each pixel and dividing by the standard deviation. (Laimighofer & Laaha, 2022)

Analysing agricultural droughts

Agricultural drought is defined as a condition in which the soil moisture content falls below the critical level required for crop sustenance. This condition can be identified by examining soil moisture characteristics and the physicochemical attributes of crops throughout the growing period (Liu et al., 2016). A soil moisture deficiency can reduce the available water supply, which may be insufficient to meet the essential physiological needs of crops. This can lead to a suppression of crop growth, which in turn can result in reduced yields or even complete crop failure (Bhattacharya & Bhattacharya, 2021).

To evaluate the impact of drought on agricultural production in the TRB region, we employed the "greenness" component derived from the Tasseled Cap transformation, which is based on the Terra-Moderate Resolution Imaging Spectroradiometer (MODIS) multispectral data. This transformation involves applying linear combinations of spectral bands, where each band is multiplied by its specific constant coefficient. For the purposes of our analysis, we utilised the coefficients established by Zhang et al. (2002) for the MODIS bands (Table 1).

Table 1

Modis Nadir Bidirectional Reflectance Distribution Function-Adjusted Reflectance (NBAR) Tasseled Cap coefficients (Zhang et al., 2002)

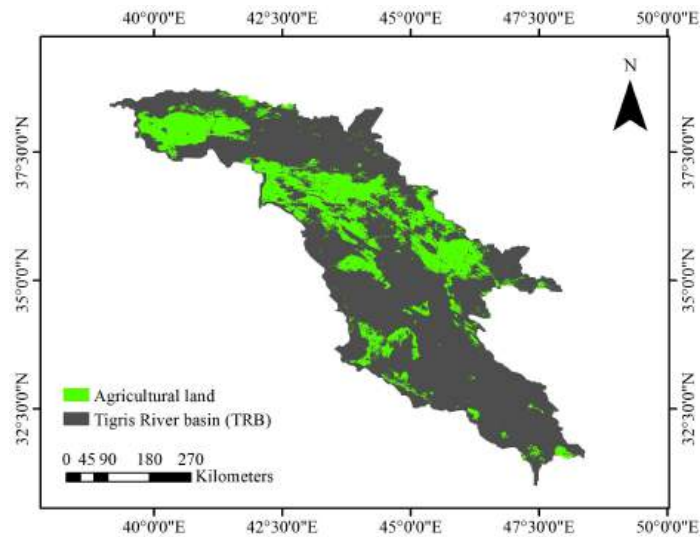
Band	Wavelength (nm)	Coefficient
Nadir_Reflectance_Band1	620-670	-0.3399
Nadir_Reflectance_Band2	841-876	0.5952
Nadir_Reflectance_Band3	459-479	-0.2129
Nadir_Reflectance_Band4	545-565	-0.2222
Nadir_Reflectance_Band5	1230-1250	0.4617
Nadir_Reflectance_Band6	1628-1652	-0.1037
Nadir_Reflectance_Band7	2105-2155	-0.4600

To define the agricultural land boundary, the most frequent value of the LC_Type1 band of the MCD12Q1.061 dataset (Friedl & Sulla-Menasse, 2022) was calculated for each pixel. Subsequently, all pixels identified as croplands within the dataset were selected, provided that at least 24% of the area was classified as cultivated cropland (Figure 2). Once the agricultural land boundary had been defined for the region, the time series of agricultural land greenness between the years 2003 and 2022 (the maximum range of available data)

was calculated using the coefficients from Table 1 and the monthly average of the MCD43A4.061 dataset (Schaaf & Wang, 2021).

Figure 2

Defined agricultural land boundary in the study area



Hydrological drought analysis

A deficiency of water in the hydrological cycle results in hydrological drought, which is primarily caused by climate variability, specifically anomalies in precipitation and temperature. This water shortage is typically evidenced by a number of indicators, including unusually low river flows, reduced water levels in lakes and reservoirs, and depleted groundwater resources (Bolorani *et al.*, 2024a, Kale, 2021a).

Despite the absence of consensus on the optimal method for measuring hydrological drought, there is a clear and direct correlation between precipitation and surface water

flow, as evidenced by (McFeeters, 1996, Kale, 2021b). Considering this relationship, it is feasible to use alterations in the surface water area across the entire basin as a proxy for the assessment and quantification of hydrological drought conditions. To extract monthly surface water areas between 2003/01 and 2022/12, the MODIS Terra Daily normalised difference water index (NDWI) dataset with a pixel size of 463.313 metres was used. In accordance with the existing literature (Ji, Zhang, & Wylie, 2009), each pixel with an NDWI value greater than 0.1 was considered a surface water area.

Analysing drought propagation

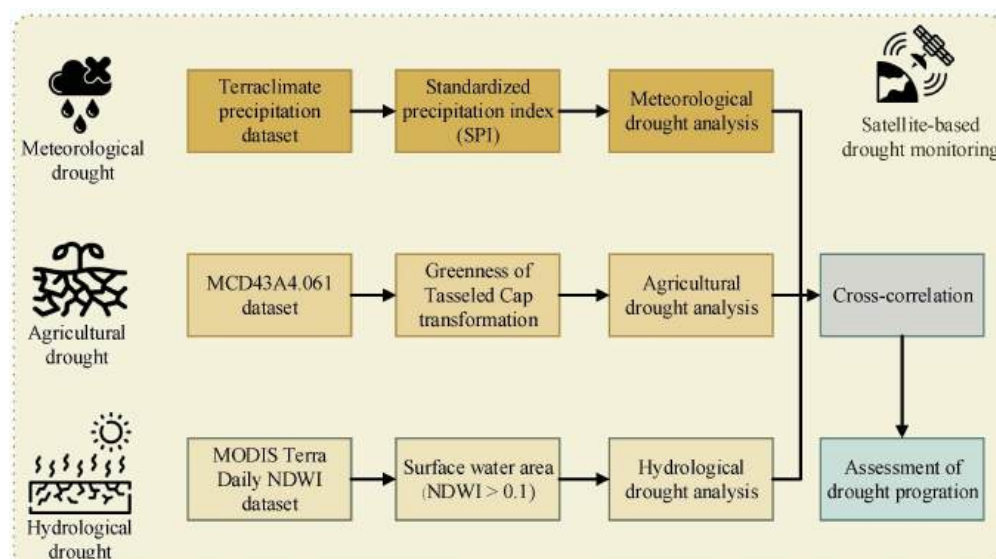
Agricultural and hydrological droughts typically follow meteorological droughts, which are defined by abnormal precipitation and temperature patterns with specific time lags (Bolorani *et al.*, 2024a). To identify the precise point of occurrence of all types of droughts subsequent to the onset of the meteorological drought and analyse their sequential occurrence, the cross-correlation method can be employed (Xu *et al.*, 2023). This approach involves the calculation of the Pearson correlation coefficient between greenness (agricultural drought) and surface water areas (hydrological drought) in conjunction with SPI values (for accumulation periods of 1, 3, 6, 9, 12, 15, 18, 21, and 24 months). To ascertain greenness, the value of each month is added to the value of the previous month, resulting in a value ranging from 1 to 24. Figure 3 depicts the methodology employed in this study for drought propagation.

Results and Discussion

The most severe meteorological droughts, as indicated by the lowest SPI values, occurred in August, July, September, and

Figure 3

Utilised research framework in the study



June. In contrast, the months with the highest precipitation levels, which corresponded to the highest SPI values, were January, March, and February, respectively. Furthermore, the lowest levels of greenness were observed in January, December, and November, whereas April, May, and June exhibited the highest levels of greenness. Finally, the lowest surface water area was observed in July, August, and September, whereas the highest surface water area was observed in February, January, and March. Therefore, an analysis of the monthly drought indicators revealed no significant temporal consistency in the drought types under study. Figure 4 illustrates the monthly values of the measured satellite-based drought indices.

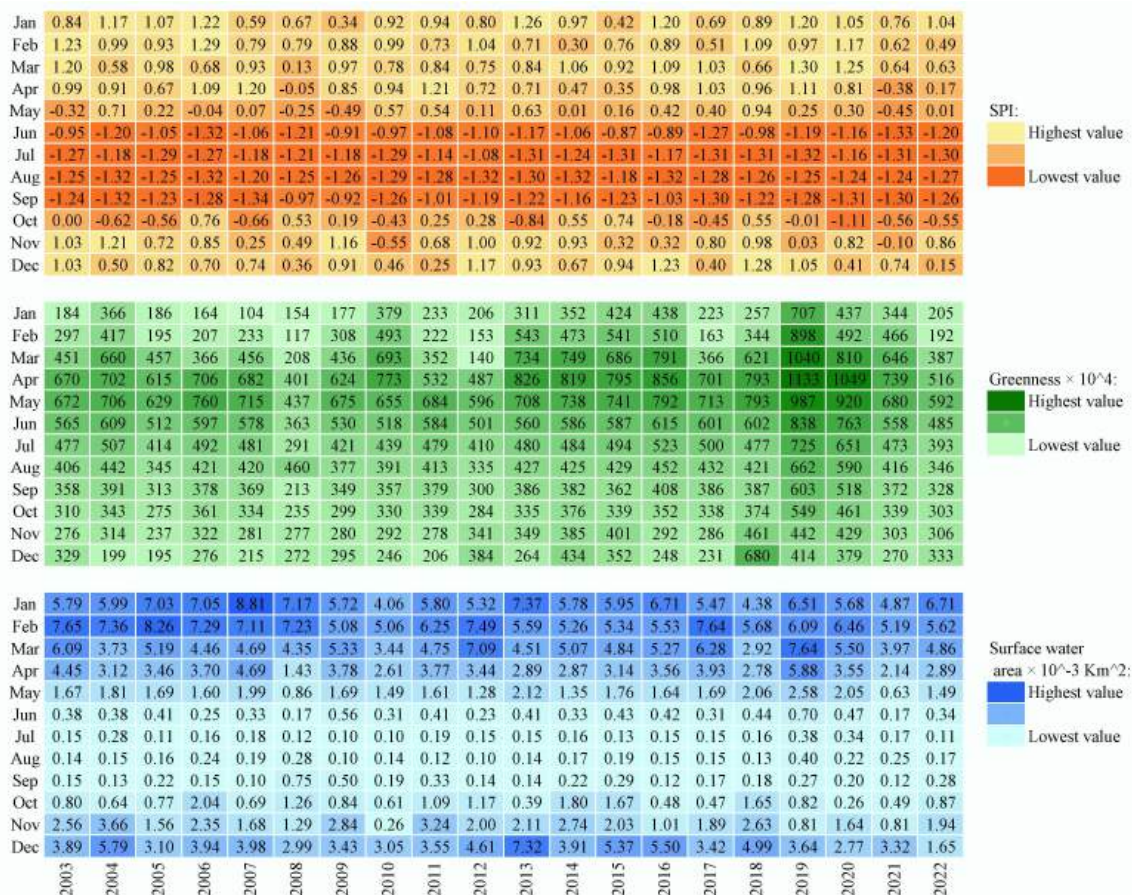
In accordance with the established patterns of monthly droughts, an analysis of the average annual drought indicators demonstrated a notable absence of substantial temporal consistency among the various types of droughts under investigation. On an annual scale, similar to (Boloorani *et al.*, 2024b), the most pronounced drought conditions (based on the SPI) occurred in the years 2021 (-0.327), 2022 (-0.187), and 2008 (-0.164). In contrast, the highest precipitation levels were observed in 2018 (0.214), 2016 (0.130), and 2006

(0.113). Tasselled Cap greenness, which serves as a proxy for agricultural activities, reached its highest point in 2019 (749.8×10^4), followed by 2020 (624.8×10^4) and 2016 (523.0×10^4). In contrast, the lowest greenness values were recorded in 2008 (285.5×10^4), 2012 (344.6×10^4), and 2005 (364.4×10^4). The maximum extent of surface water was observed in 2019 ($2.98 \times 10^{-3} \text{ km}^2$), followed by 2007 ($2.87 \times 10^{-3} \text{ km}^2$) and 2003 ($2.81 \times 10^{-3} \text{ km}^2$). The lowest surface water extents were observed in 2010 ($1.78 \times 10^{-3} \text{ km}^2$), 2021 ($1.84 \times 10^{-3} \text{ km}^2$), and 2022 ($2.24 \times 10^{-3} \text{ km}^2$).

Meteorological drought

The SPI is an efficient tool for gauging meteorological drought. A positive SPI value indicates that precipitation exceeded the median, whereas a negative SPI value signifies that precipitation fell below the median, indicating dry conditions (Khan, Gabriel, & Rana, 2008). In accordance with the SPI thresholds delineated in Table 2 and the mean cumulative SPI values at a 1-month interval from 2003 to 2022, the TRB is subject to moderate drought conditions from June to September. The month of October has mild drought conditions, while the remaining months exhibit mild wet

Figure 4
Monthly drought index values



conditions. Furthermore, drought conditions ($SPI < 0$) were identified in 110 (45.8%) of the 240 months analysed. The prevailing dry condition in the basin may result in various environmental challenges, including the generation of dust storm sources (Al-Taei, Alesheikh, & Darvishi Boloorani, 2024).

Table 2

Meteorological drought categorisation by SPI (Lloyd-Hughes & Saunders, 2002)

SPI value	The drought category
≥ 2.00	Extremely wet
1.50–1.99	Severely wet
1.00 to 1.49	Moderately wet
0–0.99	Mildly wet
0 to -0.99	Mild drought
1.00 to 1.49	Moderate drought
1.50 to 1.99	Severe drought
≤ -2.00	Extreme drought

meteorological droughts affect various water resources in different ways (McKee *et al.*, 1993). For instance, soil moisture conditions respond rapidly to changes in precipitation, whereas groundwater levels, streamlet, and reservoir storage were influenced by longer-term precipitation patterns. Consequently, in the continuation of this work, we assessed the cumulative SPI at multiple time scales and measured its relationship with agricultural and hydrological droughts.

Agricultural drought

Agricultural droughts typically follow meteorological droughts, with the time delay varying based on local climate conditions and ecosystem factors (C.V, Pachore, & Remesan, 2024). Our observations indicate that meteorological and agricultural droughts coincided in 2008, and heavy rainfall in 2019 led to decreased and increased greenery, respectively. However, this pattern did not consistently occur over time.

The results of the cross-correlation analysis are presented in Table 3. Accordingly, the strongest correlation coefficients are observed between the 9-month (0.73), 6-month (0.66), 18-month (0.62), and 21-month (0.60) cumulative SPI and Tasselled Cap greenness. This observation indicates that agricultural drought is not a sole consequence of inadequate precipitation. In other words, the management of water

resources and the implementation of agricultural strategies also play a pivotal role in determining the onset and severity of agricultural drought (Boloorani *et al.*, 2024b; Smith & Edwards, 2021). Factors such as irrigation efficiency, crop selection, soil management, and the utilisation of water conservation techniques also influence how agricultural systems respond to dry periods (C.V *et al.*, 2024). Our methodology for delineating agricultural boundaries relied on MODIS annual land cover maps. This approach may have introduced certain limitations or biases into our results.

Hydrological drought

The surface water area was considered an indicator of hydrological drought. In accordance with the findings of the Tigris-Euphrates Rivers basin (Al-Taei *et al.*, 2023) and precipitation data for Iraq (Al-Muhyi & Aleedani, 2022; Naqi, Al-Jiboori, & Al-Madhhachi, 2021; Rahi, Al-Madhhachi, & Al-Hussaini, 2019), multiple instances of hydrological drought were observed during the period 2003–2022. These instances were characterized by an increasing intensity of drought. The confluence of natural forces, including climate fluctuations, and human-induced factors, such as dam construction, irrigation practices, and inadequate water management strategies, contributes to the alteration of the water bodies of the TRB (Darvishi Boloorani *et al.*, 2021).

To ascertain the relationship between meteorological and hydrological droughts, Pearson correlation coefficients between cumulative SPI values and surface water area were calculated (Table 4). Table 4 demonstrates the existence of robust, direct correlation between hydrological drought and both 1-month (0.83) and 3-month (0.79) cumulative SPI values. Although surface water area is a limited indicator of the severity of hydrological drought, given that the impact of precipitation variations on reservoir levels is minimal (Boloorani *et al.*, 2024a), the aforementioned high correlations indicate a rapid translation of meteorological drought conditions into hydrological impacts. However, a moderate strength direct correlation (0.55) was observed between hydrological drought and 15-month cumulative SPI. This observation demonstrates that the effects of meteorological drought on water resources can persist for extended periods. It is crucial to note that there was a discrepancy in the spatial

Table 3

Pearson's correlation coefficient between cumulative SPI and total assessed cap greenness

	1-month	3-month	6-month	9-month	12-month	15-month	18-month	21-month	24-month
Pearson correlation coefficient	-0.01	0.28	0.66	0.73	0.32	0.36	0.62	0.60	0.30

Table 4
Pearson's correlation coefficient between cumulative SPI and surface water area

	1-month	3-month	6-month	9-month	12-month	15-month	18-month	21-month	24-month
Pearson correlation coefficient	0.83	0.79	0.36	-0.19	0.10	0.55	0.29	-0.11	0.09

resolution between the SPI maps and the delineated water area maps, which could influence the results.

Conclusion

This research examined how agricultural, hydrological, and meteorological droughts interact in the TRB region. To understand this, the study used long-term satellite data and statistical methods. The key findings of this work are as follows:

- During 2003 and 2022, nearly half of the SPI observations were meteorological drought-induced, confirming the general dry conditions in the basin.
- The occurrence of agricultural drought is strongly influenced by meteorological drought conditions over both the 6-month and 21-month accumulation periods, as indicated by the SPI. This demonstrates that agricultural drought in TRB is not solely a result of insufficient precipitation.
- The occurrence of hydrological drought shows a strong to moderate correlation with meteorological drought conditions over accumulation periods of 1, 3, and 15 months. This indicates that meteorological drought conditions can quickly affect water resources, and their effects can persist for extended periods.
- The drought progression analysis indicated that the drought types were not entirely correlated. Hence, further investigations are required to understand the factors influencing these patterns.



Ethics	Committee	Ethics committee approval is not required for the study.
	Approval	
	Peer Review	Externally peer-reviewed.
Author Contributions		Conception/Design of Study- K.V.K., A.K.D., H.A.; Data Acquisition- K.V.K., A.K.D., H.A.; Data Analysis/ Interpretation- K.V.K., A.K.D., H.A.; Drafting Manuscript- K.V.K., A.K.D., H.A.; Critical Revision of Manuscript- K.V.K., A.K.D., H.A.; Final Approval and Accountability- K.V.K., A.K.D., H.A.
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Research Article

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Keeping Memories Alive and Living Again An Evaluation on Nurdağı Open Air Earthquake Museum



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Abstract

One of the most important areas where the dimensions of natural disasters are kept alive and concretised in the memory of the place is disaster-themed museums. Visits to these museums are part of sadness tourism and contribute to raising awareness against natural disasters and keeping public consciousness alive. The aim of this study was to convey the perception of the idea of creating Nurdağı open-air Nurdağı earthquake museum through the eyes of the main actors. In this context, the museum experiences of those who visited the museum and those within the comments on the subject in the electronic environment, the motives that pushed them to this experience, their satisfaction, types of emotions, and their approaches to the opening of an earthquake-themed museum were examined. Semi-structured interviews with 15 people who visited the museum and 113 electronic comments about the museum on social media channels and internet news were analysed. The findings obtained were subjected to content analysis and inductive coding was performed. The MAXQDA 2024 programme was used for content analysis and data coding. In the study, a main theme as "Nurdağı Open Air Earthquake Museum" and six basic categories under this theme were put forward. The points where the perception of the museum differed negatively and positively between the museum visitors and the internet comments and the points where they were in common were determined. In this context, data were analysed and theories were proposed. Accordingly, it was emphasised by the visitors that disaster-themed museums are an important tool in preserving social memory, whereas in social media, it was underlined that it may prevent the long-term preservation of social memory. In this context, it is important that such museums reach a wider audience quantitatively and qualitatively, that they are supported with rich content so that visitors can interact emotionally and intellectually and that they are integrated into educational institutions to raise disaster awareness among students.

Keywords

Earthquake • Nurdağı • Open Air Earthquake Museum • Sadness Tourism.



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Introduction

Events such as wars, natural disasters, epidemics, etc., which have left deep traces in history for societies, are tangibly reflected in places such as monuments and museums and constitute the focus of cultural visits. These visits have an extremely important effect on the transfer of social memory to future generations (Alili, 2017). At this point, an earthquake, which is an important reality for Türkiye, is a disaster that cause great material and moral destruction and create fear. Recently, on February 6, 2023, two earthquakes of magnitude 7.7 and 7.6, the epicentre of which was Kahramanmaraş, occurred in the country and caused great loss of life and damage in 11 surrounding provinces. As with every earthquake, this earthquake caused significant economic and social problems. Considering past and possible future earthquakes in Türkiye, it is thought that studies and spaces that examine earthquakes and their effects are important to raise awareness (Çetinkaya, 2023). Based on this framework, natural disaster-themed museums can be considered prominent places. Visits to such museums are also considered an important part of sadness tourism. The disappearance of the visuals accustomed in daily life and the fact of mortality in the existence of human beings take their place in tourism practices (Biran & Hyde, 2013).

The concepts of sadness tourism and social memory transfer are among the important dynamics that shape the present-day experiences of individuals and social memory. While sadness tourism defines visits to areas where collective or individual deaths have occurred and monumental places, these places also function as places of social memory (Güzel & Atabeyoğlu, 2021). In this context, the relationship between grief tourism and social memory can be addressed by examining how the space shapes social memory and the psychogeographical interactions that individuals establish with these spaces. Spaces are not only physical spaces but also important areas where collective memories, emotions, and identities are embodied (Levent, 2023).

From the perspective of human geography, the concept of "place" should be considered as a dynamic context in which social memory, cultural meaning production and collective identity construction processes come together. The elevation of places to the status of "place" deepens the impact of these places on social memory and reinforces individuals' sense of spatial belonging (Parmaksız, 2019; Dinç, 2024). Museums within the scope of sadness tourism support the processes of remembering and mourning by intensifying the experiential interactions of visitors with the place. By emphasising the experiential dimension of space, these museums contribute

to social mourning processes and strengthen spatial memory (Güzel & Atabeyoğlu, 2021). Concepts such as spatial memory, the intertwining of social traumas with space and "*affective geographies*" offer an important theoretical framework in this field. Spatial memory refers to the meaning and emotional burden that certain places carry in their social and individual memory. This concept means that places remind us of important events, traumas, or social experiences in the past and that these events leave a permanent trace in memory by integrating with the place. For example, battlefields, regions where natural disasters occur, or places where social tragedies occur become the spatial memory of those events (Deniz et al., 2019; Akbulut & Ekin, 2022). Where places bear the traces of the events experienced, these traces shape the identity and meaning of places over time (Yasak et al., 2021; Sungur, 2023). The intertwining of social traumas with space expresses how the spaces where these traumas are experienced play a role in the memory of these traumas. Major events such as war, natural disasters, and genocides leave deep effects not only on individuals but also on the places where they occur (Akbulut & Ekin, 2022). Therefore, these places, while bearing the traces of trauma, become the symbols of trauma over time. Museums, monuments, and other structures, which are called memory spaces, are critical for the preservation and transmission of social memory (Deniz et al., 2019). Such places play an important role in the formation of social identities and collective memory (Parmaksız, 2019; Akbulut & Ekin, 2022). The concept of affective geographies, on the other hand, refers to the emotional relationships that spaces establish with people and the emotional experiences in these spaces. Spaces have not only physical but also emotional dimensions; a space can be peaceful, frightening, or relaxing for a person (Lefebvre, 2014; Bozdoğan & Benek, 2021; Sungur, 2023). Social traumas and collective memories create an emotional bond with places and form the emotional structure of these geographies. In this context, the emotional effects of places are intertwined with individuals' life experiences and social memories (Gürleyen, 2020; Sungur, 2023). Whereas places shape the memories and emotions of individuals, they also become a part of social memory (Abdula & Aygen, 2022; Kolsal & Ulusoy, 2022). While spaces allow individuals to confront their past traumas, they also reveal the effects of these traumas on social memory (Levent, 2023). This framework helps people confront past trauma and understand the relationship between these traumas and space. Therefore, certain spaces carry emotional burdens and play an important role in social memory. This theoretical framework allows us to analyse not only the physical but also the emotional and social dimensions of spaces.

Sadness tourism is a form of alternative tourism that emerges as a result of the reflection of the wishes and demands of people who want to visit such locations in an organised way and is evaluated within the scope of special interest and cultural tourism (Trauer, 2006; Niemela, 2010; Kılıç & Akyurt, 2011; Bozok et al., 2014; Hartmann, 2014; Yıldız et al., 2015; Alili, 2017, Aylan & Kaya, 2021). Sadness tourism empathises with the pain experienced and to keep social memory alive without making material profit. At the same time, the motive of wanting to see the tragic events such as Anıtkabir, Çanakkale, Hiroshima, Chernobyl, Pompeii, and Malazgirt on site (Alili, 2017) shedding light on the past and the present, revealing humanitarian feelings, and determining and visiting the places where such perceptions of traumatic events will be provided. It is described as a type of travel to see areas that have witnessed wars, genocides, political structure of countries, all kinds of disasters in their past, natural disasters, poverty, technological disasters, torture, or deaths of celebrities that have affected societies and world history. With the increasing power of the media, this type of tourism has further developed and shaped people's curiosity to travel to the regions (Kozak & Kama, 2015: 3-6).

By visiting such places, sadness tourism allows individuals to create meaning maps based on their psychogeographical interactions. These maps of meaning are critical for understanding how space mediates collective mechanisms of remembering and remembering (Güzel & Atabeyoğlu, 2021). Therefore, when analysing the relationship between sadness tourism and social memory, concepts such as "social mourning," "place of remembrance" and "spatial meaning attribution" need to be integrated. The process of visiting a place and establishing a psychological interaction with that place requires that these concepts be considered together. Social mourning refers to the collective experience of loss and trauma; place of remembrance refers to the places where these losses and pains are remembered; and spatial meaning attribution refers to how these places are associated with emotional and cultural meanings in people's memories. The integration of these three concepts reveals ways in which a society makes sense of and confronts its past.

Sadness tourism has many components in essence. One such component is the tourism of disaster areas (Eren, 2019). In this context, one of the most important areas where disaster areas can be concretised in space is natural disaster-themed museums. By creating emotional landscapes crystallised in space, such museums offer a "place" image for the construction of individual and social identity and play an important role in the construction of social memory. Therefore, the place turns into a "space of experience" where

the emotional effects of past events or social memories are felt and should be remembered (Eyrek & Çetin, 2022). There are many museums around the world that are subject to sadness tourism. In Türkiye, the number of museums and places in this category is increasing daily. Such places allow visual memory to remain permanent, not to atrophy, and to be revitalised. The transfer of social destruction to the space is important to make it permanent. Societies do not only consist of positive facts, wars, natural disasters, deaths, but also experiences that form social identity. For this reason, preserving the reflections of such phenomena in space and transferring them to the next generations is an important issue in order to exist. At the same time, it is important for local governments to create an area where the memory of space and events is revitalised.

Within the scope of disaster tourism, which is accepted as a part of tourism, it aims to create awareness against natural disasters and to contribute to keeping public awareness alive by emphasising the existence of Gaziantep-Nurdağı open air museum. Nurdağı open air museum, which is the study area, is located in Nurdağı district of Gaziantep province. To build earthquake-resistant structures and not forget the damage left by the earthquake, a 10,000 square metres area, which is considered to be heavily damaged in a part of Nurdağı district, was surrounded by wire fences and turned into an open-air museum. In this study, it has been accepted as an important criterion to draw a framework for the tourism potential of such museums in cities with earthquake risk, especially in the regions affected by the Kahramanmaraş earthquakes on February 6, 2023. In this context, the study measures the perception towards the opening of an earthquake-themed museum. Accordingly, the study begins with the Introduction section where the general introduction and purpose of the subject is explained. In the next section, the collection and analysis process of the relevant dataset is described. The next section presents the analysis of the findings. The study concludes with a conclusion section.

Material And Method

In this study, qualitative research methods were used to evaluate the perception of Nurdağı open air earthquake museum. In this context, within the perspectives of the interviewees and electronic comments from the museum, findings on the subject were sought to be revealed. Data on Gaziantep-Nurdağı open air earthquake museum were obtained from the Gaziantep Metropolitan Municipality. The domestic and foreign literature on the subject has been discussed.

In this study, museum visitors, who are thought to have sufficient experience and knowledge on the subject, and

social media comments in the news about the museum in the electronic environment were examined, and the positive or negative opinions of the interviewees about the opening of such a museum and raising awareness were investigated. To achieve this, semi-structured interviews were conducted with 15 participants. Semi-structured interviews were preferred because they are more open to exploration than structured interviews and easier to control than unstructured interviews (Merriam & Tisdell, 2016: 110; Baş & Akturan, 2017: 85-91; Brinkmann, 2018). In addition, 113 electronic comments shared on social media channels and internet news related to the museum were analysed. A long period was devoted to ensure data saturation. After a while, the data collection process was terminated, considering that the news and comments on the earthquake museum did not find as much space in the media and were not on the agenda as before.

The data collection process within the scope of the study was carried out between 10.04.2023 and 10.12.2023. The semi-structured interview form used as a data collection tool was prepared by the researchers after analysing the relevant literature and preliminary interviews. The interview form included questions about the demographic information of the participants, their professional status, their museum experiences, their motivations that pushed them to this experience, their satisfaction, their types of emotions, their thoughts, and their approaches to opening an earthquake-themed museum. The interviews with the 15 participants were recorded with a voice recorder. The voice recordings were subjected to transcription using Microsoft 365. No one that was not willing to participate in the research was not included in the sample. Necessary permissions were obtained from the interviewees during the research. Interviews were conducted, and ethics committee permission was obtained for the field study. After the solution texts were created, they were proofread by an independent second person. In social media, 113 electronic comments on the subject were analysed and analysed. The obtained data were subjected to coding using the MAXQDA 2024 software (Figure 1).

Table 1

Demographic Information about the Interviewees

Interviewers	Gender	Age	Hometown	Marital Status	Education Status	Profession
G-1	Male	27	Kahramanmaraş	Single	Licence	Security Officer
G-2	Male	53	Gaziantep	Married	High School	Headman
G-3	Woman	21	Gaziantep	Single	Licence	Student
G-4	Woman	22	Gaziantep	Single	Associate degree	Student

Interviewers	Gender	Age	Hometown	Marital Status	Education Status	Profession
G-5	Woman	24	Gaziantep	Single	Licence	Teacher
G-6	Woman	50	Gaziantep	Married	Primary School	Housewife
G-7	Male	20	Gaziantep	Single	Licence	Student
G-8	Woman	26	Gaziantep	Single	Postgraduate	Student
G-9	Male	21	Gaziantep	Single	Licence	Student
G-10	Male	33	İzmir	Single	Postgraduate	Tradesmen-Trade
G-11	Male	24	Adana	Single	Licence	Student
G-12	Male	33	Bursa	Single	Postgraduate	Teacher
G-13	Woman	27	Elazığ	Single	Postgraduate	Student
G-14	Woman	24	Van	Single	Postgraduate	Teacher
G-15	Male	36	Gaziantep	Married	High School	Tradesmen-Trade

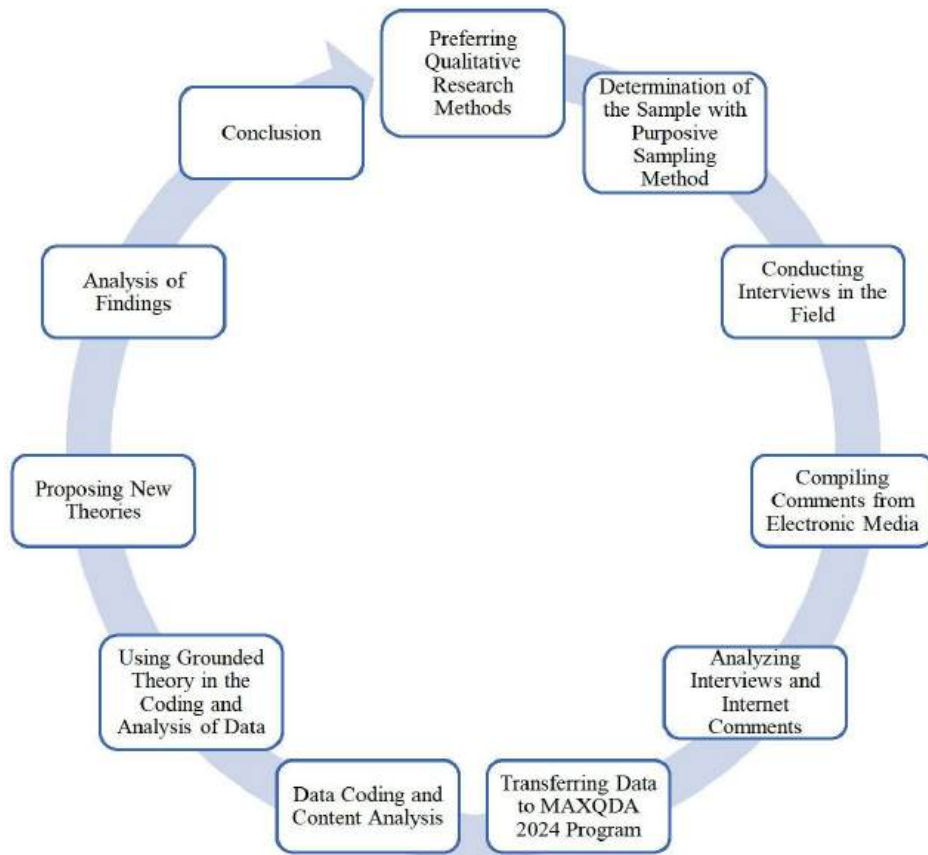
Within the scope of the study, the grounded theory approach was used as the research design. Grounded theory presents qualitative research and inductive theory and consists of interrelated assumptions to explain any phenomenon (Mehmetoğlu & Altınay, 2006; Park et al., 2006; İnanır, 2022). The purposive sampling method was preferred for data collection because the participants did not have equal chances of being included in the sample. The data collection process was continued until all concepts and categories were identified. Therefore, data saturation was taken as the basis. For this reason, no limitation was made regarding the number of samples and data sources, and the interviews were terminated when the answers started to repeat each other (Figure 1). In addition, the Miles and Huberman (1994) model was used to ensure the validity and reliability of the study. According to the coding audit that provides internal consistency, consensus between the coders should be at least 80% (Miles & Huberman, 1994). In this context, the relevant data were coded by the researchers using the MAXQDA 2024 programme and the inter-coder agreement value of the coders for the interviews was determined as 96.79% with 211 related codes-7 unrelated codes and 98.04% with 150 related codes-3 unrelated codes for electronic comments. When the inter-coder agreement results were evaluated, it was determined that the inter-coder agreement percentages were at a sufficient level. After these evaluations, analyses were conducted by evaluating the codes, main themes, and subcategories.

In this study, data collection was conducted using on-site observation, interviews, and electronic comments. In the theory development phase, theories related to the subject were developed through systematic data collection and analysis. In this context, analyses were performed



Figure 1

Work Flow Chart of the Study



using a method expressed as "constant comparative analysis" (Namkung et al., 2007). In this study, the three-stage coding technique proposed by Strauss and Corbin (1990) was used during data analysis from the grounded theory perspective. This technique was determined as open, axial, or selective coding respectively (Şener, 2019). Because of these codings, the main categories and themes that will cover the subcategories obtained were revealed. Theories and findings were presented according to the results obtained. Based on this framework, the findings obtained were subjected to content analysis and inductive coding. The MAXQDA 2024 programme was used for content analysis of the study findings and data coding. The aim was to conduct geographical analyses on the subject by comprehensively and in-depth examining the obtained data. After the interviews, six categories were put forward under the main theme of "Nurdağı Open Air Earthquake Museum" as "Approaches to the Opening of the Museum", "Travel Motivation", "Emotional State", "Tendency to Return", "Location Selection" and "Suggestion".

Findings And Analysis

Nurdağı Open Air Earthquake Museum

Gaziantep Metropolitan Municipality started to work on an open-air earthquake museum to reflect the devastation caused by the earthquakes centred on Kahramanmaraş on February 6, 2020, not to forget the earthquake and to emphasise the importance of precautions. Nurdağı open air earthquake museum was established in an area of 10,000 square metres in the centre of the district that was heavily damaged by the earthquake. The museum includes heavily damaged buildings, materials, and equipment that were recovered after the earthquake. In addition, the museum, which is still under construction, will include an education area, library, research centre, earthquake commemoration and earthquake simulation displays, and on-site experience points (URL-1, 2023).

Before proceeding to the analyses within the scope of the study, a code cloud was created to summarise the general opinion on the findings obtained. It can be seen that the interviewees and internet comments agree on some codes. It is seen that codes such as "keeping the social memory alive, reproaching the authorities, Gaining Consciousness,

Figure 5*Heavily Damaged Houses and Cars in the Museum*

Air Earthquake Museum" and six categories under this theme as "Approaches towards the opening of the museum", "Travel Motivation", "Emotional state", "Tendency to Return", "Site Selection" and "Recommendation" were put forward (Figure 6). In the 113 electronic media comments included in the sample in the study, an evaluation was conducted in parallel with the themes and categories that emerged because of the interviews. At this point, the comments mostly focused on positive or negative approaches to the opening of the museum. According to the code matrix browser, 113 commentators shaped their perceptions predominantly in the category of "Approaches to the Opening of the Museum", "Positive" or "Negative" codes and sub-codes (Figure 4).

Because of the findings, it is revealed that the interviewees and electronic comments are concentrated in some categories and codes. In this context, the predominant categories and codes of the interviewees and comments were analysed one by one according to the code sub-code sections model and the findings were evaluated.

According to the model, the interviewed museum visitors are mostly concentrated in the "Positive" code in the category of "Approaches towards the opening of the museum". In this context, the interviewees perceived the museum's existence as positive. This perception was frequently emphasised with the sub-codes "Keeping the social memory alive", "Take lessons From", "Gaining consciousness", "Gaining empathy". In

addition to this, the sub-codes "Taking precautions, Making the destruction tangible, Transferring to new generations, The idea of real Experience, Reminder of being an earthquake country" were also coded less frequently (Figure 7). At this point, the interviewees frequently emphasised that they welcomed the idea of opening such a museum with the discourse "How will we transfer this destruction?".

According to the code sub-code divisions model, it is seen that museum visitors also draw attention to the "Negative" code in the category of approaches towards the opening of the museum, but to a lesser extent. When evaluated in this context, it is seen that they shaped this negative perception with the codes "Reminder of pain", "Priority" and "Destruction of the memory of the place". It is also seen that the interviewees do not prefer "Reproach to the authorities", "No need" and "Not visited", which are frequently coded in electronic internet comments. The reason for this is considered that the perceptions of museum visitors are more positive tendency (Figure 8).

One of the most important categories emphasised in the code sub-code section category was measuring the approaches of the electronic comments towards the opening of the museum. According to the model, 113 electronic commenters mostly focused on the sub-codes "Reproach to the authorities", "Reminding the pain" and "Priority". As a result of the findings obtained, users frequently expressed that they reproached the

Figure 6*Nurdagi Open Air Earthquake Museum Theme Code Matrix Browser-Interviews*

Kod Sistemi	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	TOPLAM
Nurdagi Open Air Earthquake Museum																
Approaches to the Opening of the Museum																
Neutral																
Bewilderment																
Negative																
Positive	2,13%	2,53%	1,70%	2,13%	2,13%	1,70%	2,55%	2,55%	0,85%	0,43%	2,98%	2,98%	1,28%	0,43%	1,28%	2,98%
Travel Motivation	1,28%	1,70%	1,28%	1,28%	2,13%	1,28%	0,85%	1,70%	1,70%	0,85%	1,70%	0,85%	1,70%	0,43%	0,85%	19,57%
Emotion State	0,85%	0,85%	0,43%	0,43%	0,43%	0,85%	0,43%	2,13%	0,43%	0,43%	0,43%	0,85%			0,85%	9,56%
Tendency to Return																
Negative																
Positive	0,43%	0,43%	0,43%	0,43%	0,43%	0,43%	0,43%	0,43%	0,43%	0,43%		0,43%			0,43%	0,43%
Site Selection																
Nurdagi																
Wrong Choice															0,85%	0,85%
Right Choice	0,43%	0,43%	0,85%	0,43%	0,43%	0,43%	0,85%	0,85%	0,43%	0,43%		0,43%	0,85%		0,43%	7,23%
New Earthquake Museums	0,43%	2,53%	0,43%	2,40%	2,55%	0,85%	0,85%	0,43%	2,98%	1,28%		1,70%	2,13%	1,28%	1,28%	22,13%
Recommendation	0,43%	0,43%			0,85%	0,43%		0,85%	0,85%	0,43%	0,43%		0,43%			5,11%
TOPLAM	5,90%	8,94%	5,11%	6,09%	8,94%	5,90%	5,96%	8,94%	7,60%	5,11%	5,53%	7,60%	6,81%	4,28%	5,11%	100,00%

Figure 7

Code Sub-Code Sections Model Approaches to the Opening of the Museum Category: Positive Codes-Interviews

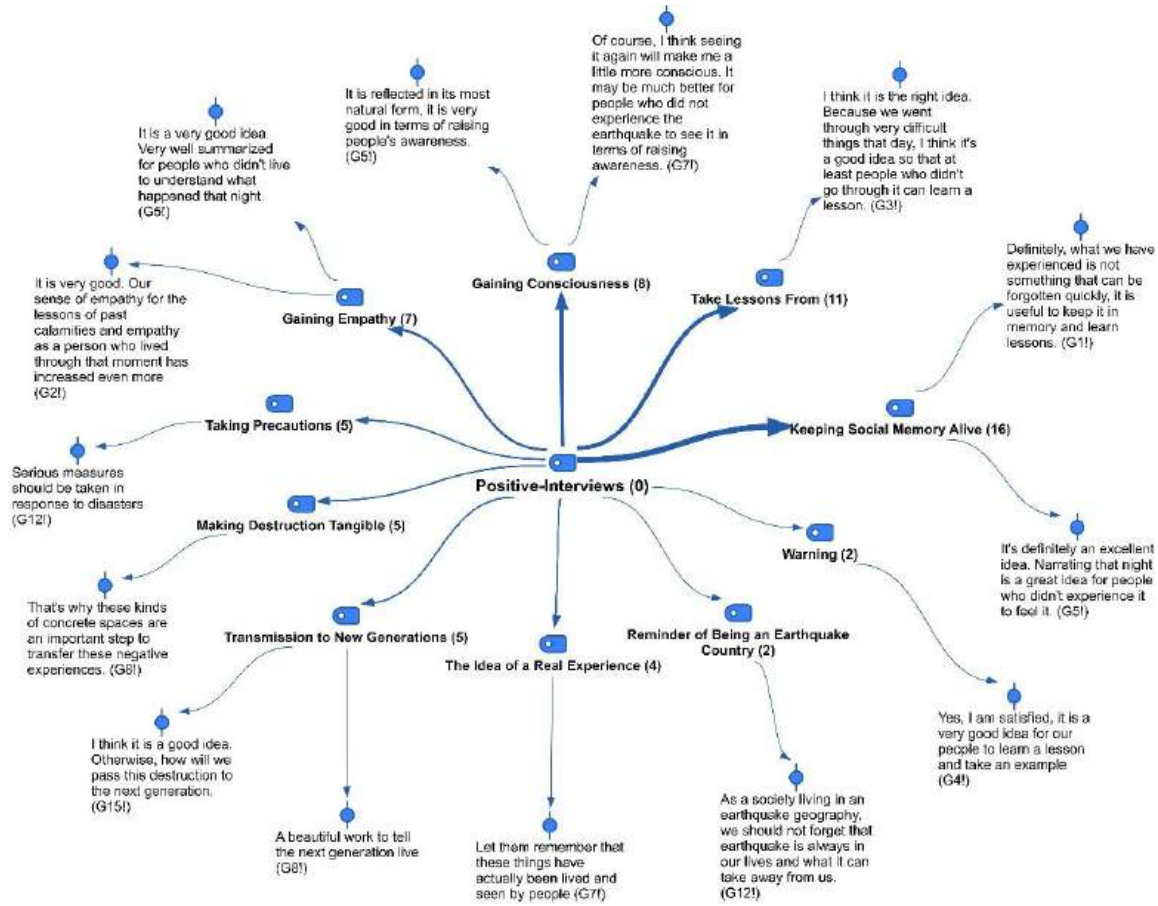


Figure 8

Code Sub-Code Sections Model Approaches to the Opening of the Museum Category- Negative Codes-Interviews

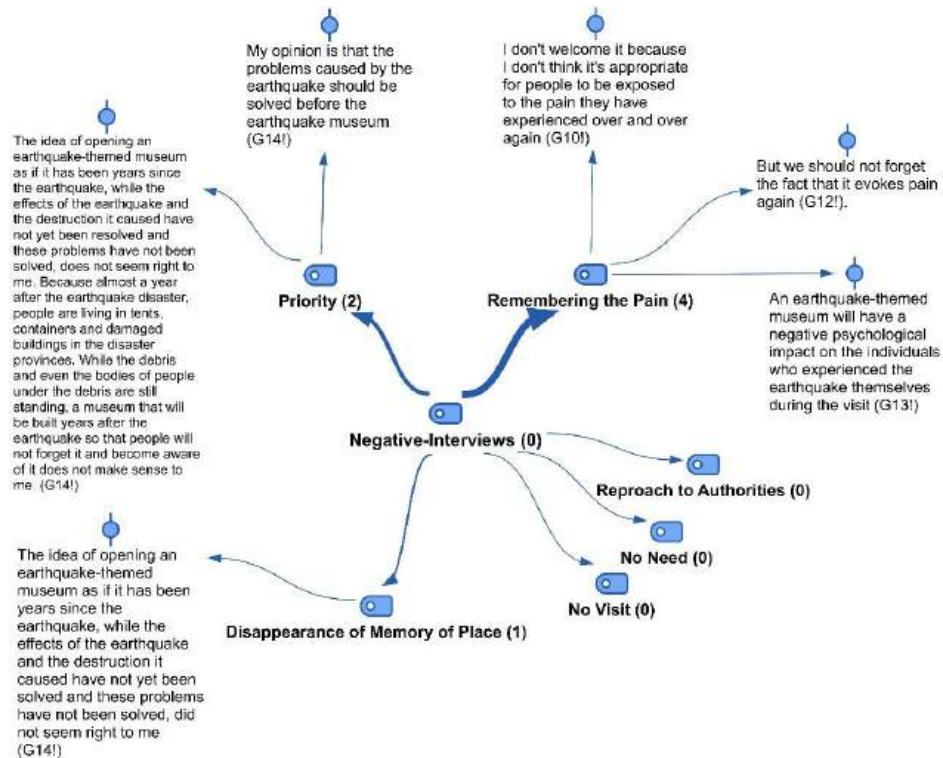


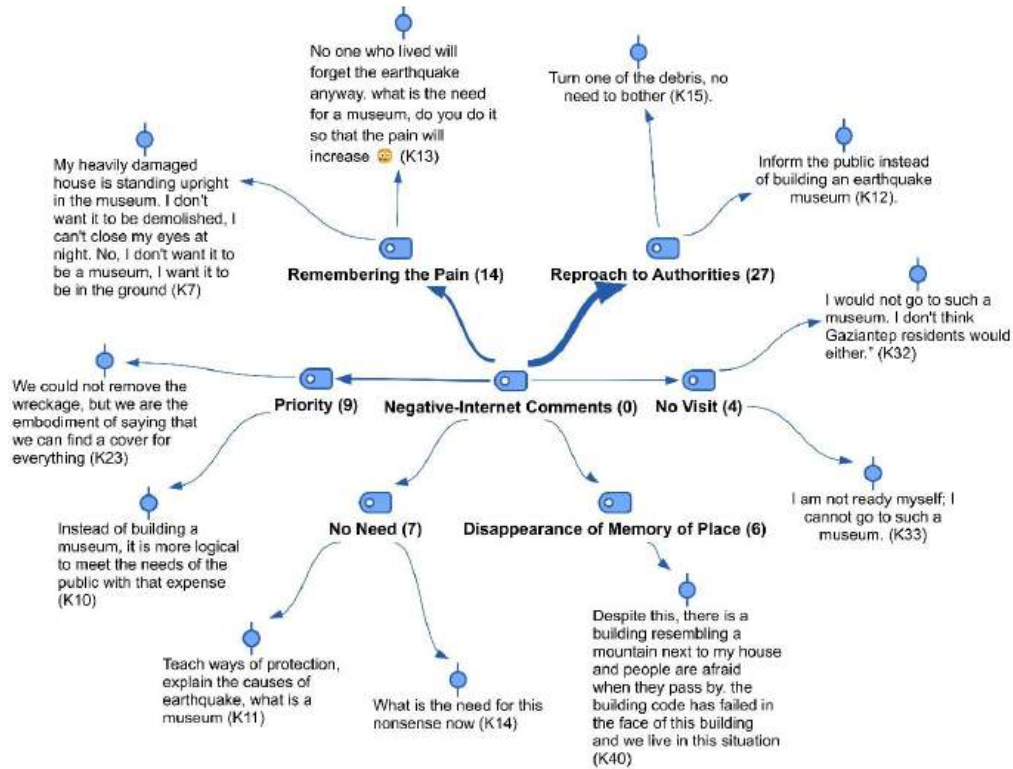
Figure 9

Nurdağı Open Air Earthquake Museum,



Figure 10

Code Sub-Code Section Model Approaches to the Opening of the Museum Category-Negative Codes-Electronic Comments



authorities for reasons such as the destruction of the memory of the place, the negative spatial effects of the earthquake have not yet been eliminated, this is not the priority at the moment, and the situation of reminding the pain. In this context, it can be seen that there is a predominantly negative approach to the idea of opening an earthquake-themed museum. When the results of the code matrix browser are analysed, the commentators coded the sub-codes "Reproach to the Authorities" 27 times, "Reminding the Pain" 14 times, "Priority" 9 times, "No need" 7 times and "Disappearance of the memory of the place" 6 times (Figure 10).

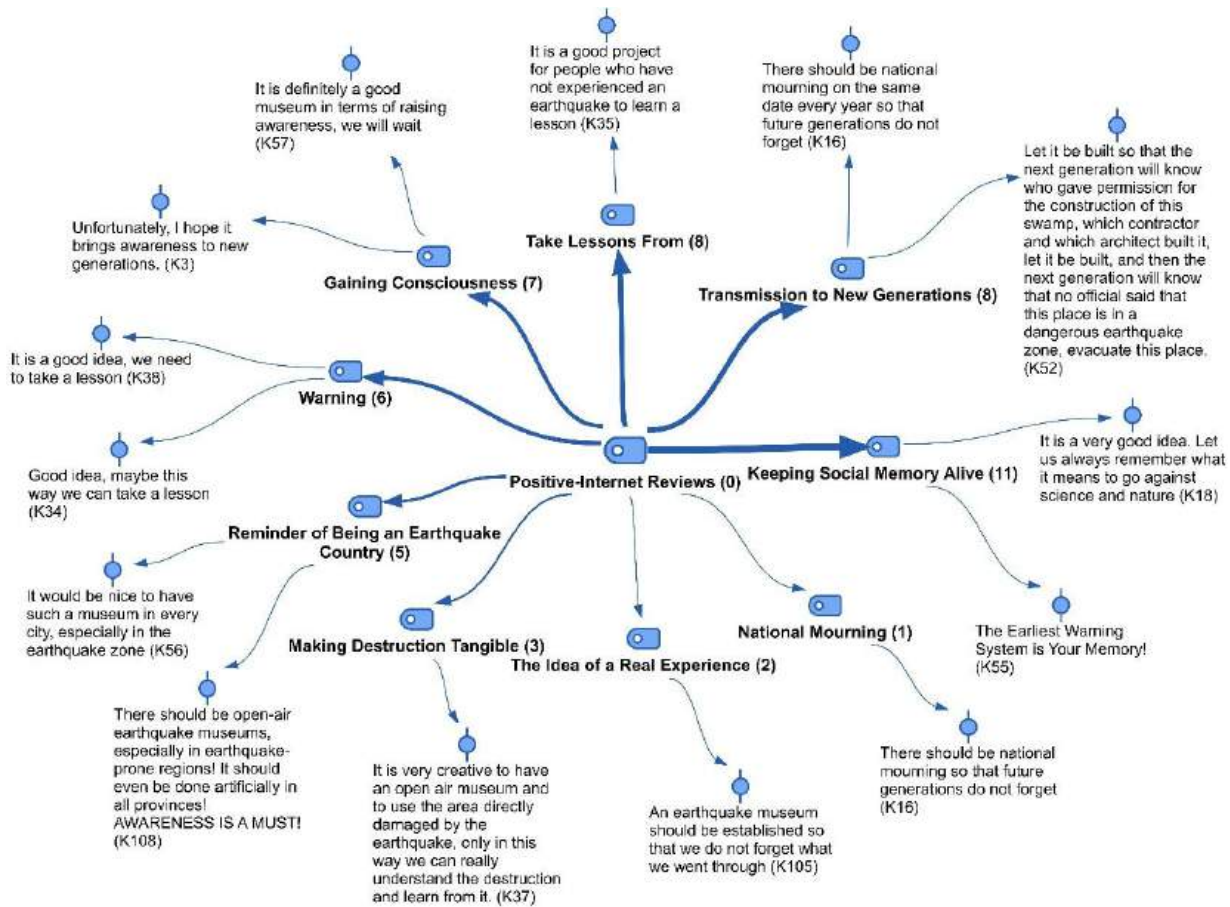
According to the results of the model, among the electronic comments, a group thought that the opening of the museum

was a positive situation. Within the framework of "positive" approaches, the sub-codes "Keeping the social memory alive", "Transmission to new generations", "Take lessons from", "Gaining consciousness", "Warning" were emphasised the most (Figure 11). When the results of the code matrix browser were examined, the sub-code "Keeping the social memory alive" came to the fore with 11 codes in parallel with the museum visitors. In addition, the sub-codes "Take lessons from" 8 times, "Transmission to new generations" 8 times and "Gaining consciousness" 7 times were frequently underlined.

-It can keep the pain fresh for people who have experienced an earthquake, but it is a good project to

Figure 11

Code Sub-Code Sections Model Approaches to the Opening of the Museum Category: Positive Codes-Electronic Comments



take lessons for people who have not experienced an earthquake (K35)

-A excellent idea 🍌🍌🍌🍌🍌 Let's always remember what it is to go against science and nature. (K18)

-The lack of human memory is forgetfulness! (K54).

The "Travel Motivations" category of museum visitors was analysed in the code sub-code section model. In this category, the interviewees expressed the motives that motivated them to visit the museum with the sub-codes "Conscious", "Seeing in Place", "Experience", "Curiosity", "lessoning", "Coincidental" and "Media". At this point, it was revealed that the interviewees made their visits consciously with the desire to see the site (Figure 12).

Another category analysed according to the model was "Emotional State". In this category, museum visitors expressed the emotions they experienced during their visits. As a result of the findings obtained, the interviewees mostly expressed their emotional states with the sub-codes "Sadness", "Unporgetting", "Empathise", "Fear", "Pain" and "Upset" (Figure 13). Among the sub-codes, it is seen that the "Sadness" code is frequently underlined in the discourses of the interviewees.

According to the model, when the tendency of the interviewees to return was evaluated, it was determined that most of them showed a positive tendency (Figure 14). Museum visitors emphasised the existence of the museum positively by expressing their desire to return to the museum often. They also emphasised that their next visit would be with their children, with the idea of raising awareness for the next generation.

In the hierarchical code-subcode model, the category of "Site Selection" was analysed. According to the data obtained from the interviews, perceptions about the idea of creating a new museum in different provinces were first analysed under the sub-code "New Museums". In the second stage, in the "Nurdağı" sub-code, whether the perception about the selection of Nurdağı as an earthquake museum was correct or incorrect was analysed and supported with sub-codes (Figure 15).

According to the code sub-code divisions model, in the "New Museums" sub-code in the "Site Selection" category, the interviewees constantly underlined 11 provinces (Hatay, Malatya, Adıyaman, Kahramanmaraş, Osmaniye, Adana, Şanlıurfa, Elazığ, Diyarbakır, Kilis) affected by the earthquakes

Figure 12

Code Sub-Code Segments Model of Travel Motivation Category-Interviews

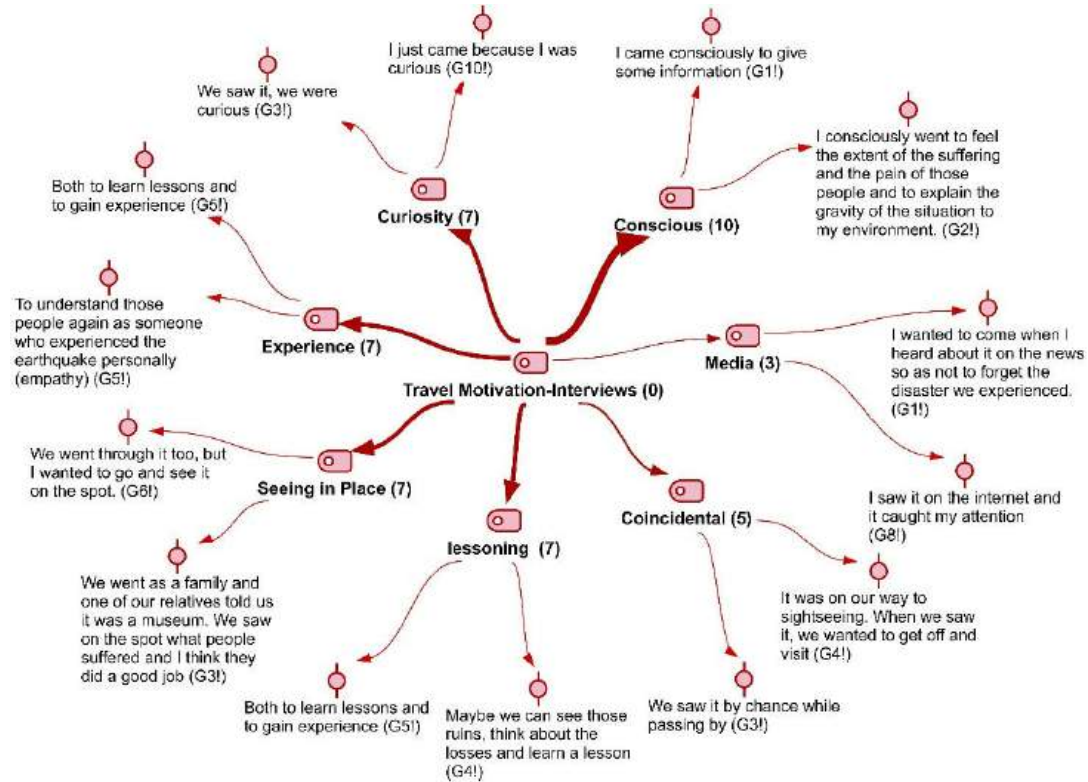
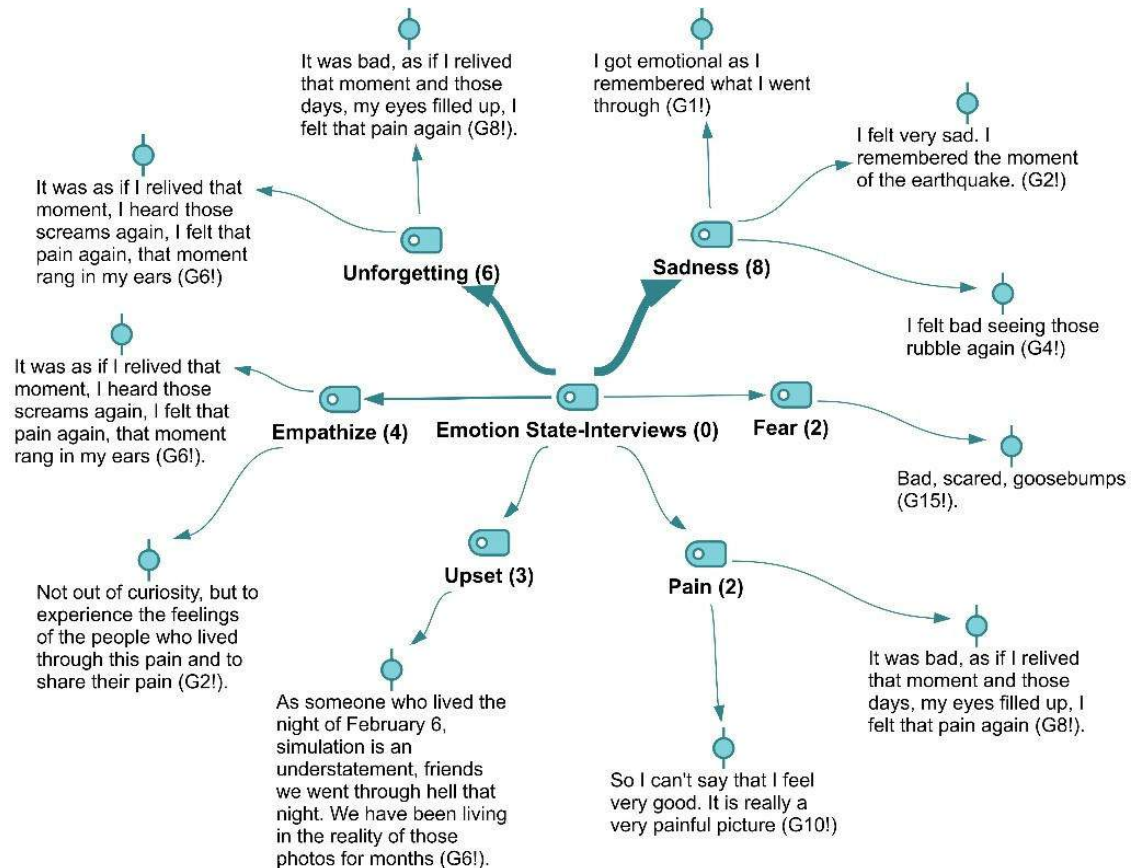


Figure 13

Code Sub-Code Sections Model Emotion-State Category Interviews



of February 6. In addition, the interviewees drew attention to the importance of the provinces with earthquake risk in Türkiye and stated that it would be the right choice of location to create a new earthquake museum in order to raise awareness in the provinces of "İstanbul, İzmir, Yalova, Hakkari" (Figure 16).

"Nurdagi" code and sub-codes in the "Site Selection" category were analysed according to the code sub-code section model. In line with the discourses of the participants, the view that Nurdagi is the right place to open an earthquake museum. The interviewees supported this approach with the codes "Heavy Damage Status, Establishment of the Settlement on the Fault Line, and Many Casualties". According to the model, the fact that Nurdagi was a wrong choice of location was expressed

by only G-14 with the codes "Transportation Challenges and Being on the Periphery" (Figure 17).

The last category analysed according to the model was "Recommendation". Based on the idea of an earthquake museum, the interviewees mostly emphasised the codes "Gaining Awareness Technical Trips, Lesson for Contractors, Earthquake Sensitive Construction, Security". In addition, the codes "Revitalise and Earthquake Memorial" were preferred less in the category (Figure 18).

The Code Relations Scanner model was used to determine the relationships between all categories and codes emerging from the interviews. The interviews and electronic comments were both included in the browser. In the analysis phase,

Figure 14

Code Sub-Code Segments Model Tendency to Return Category-Interviews

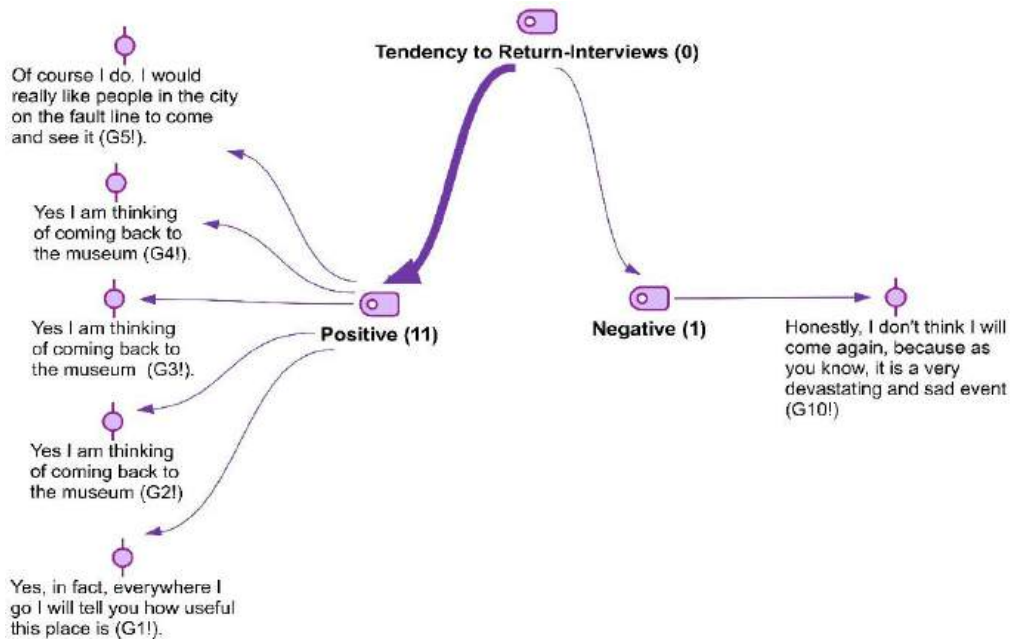
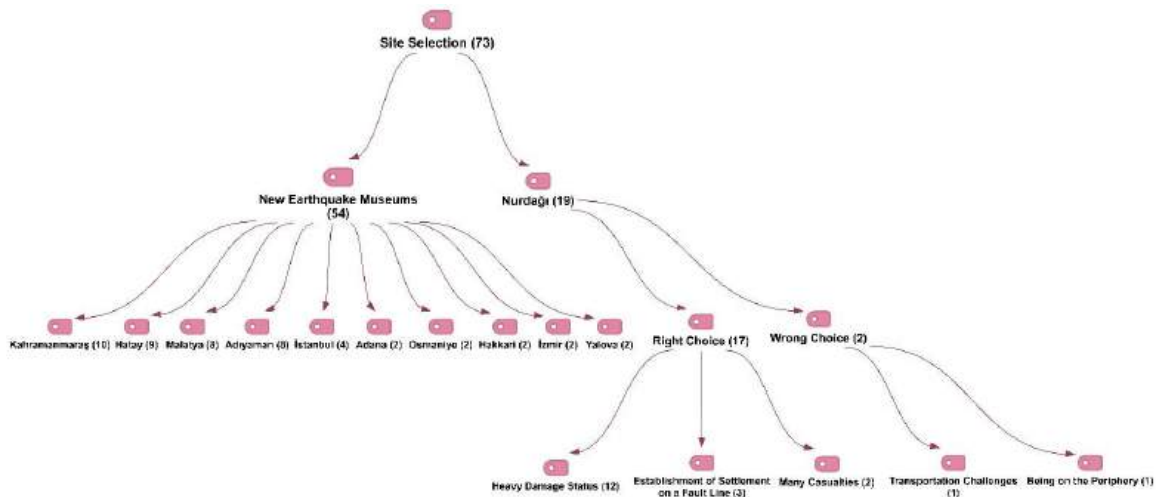


Figure 15

Hierarchical Code-Subcode Model Site Selection Category



Code Sub-Code Sections Model Site Selection-New Museums Category

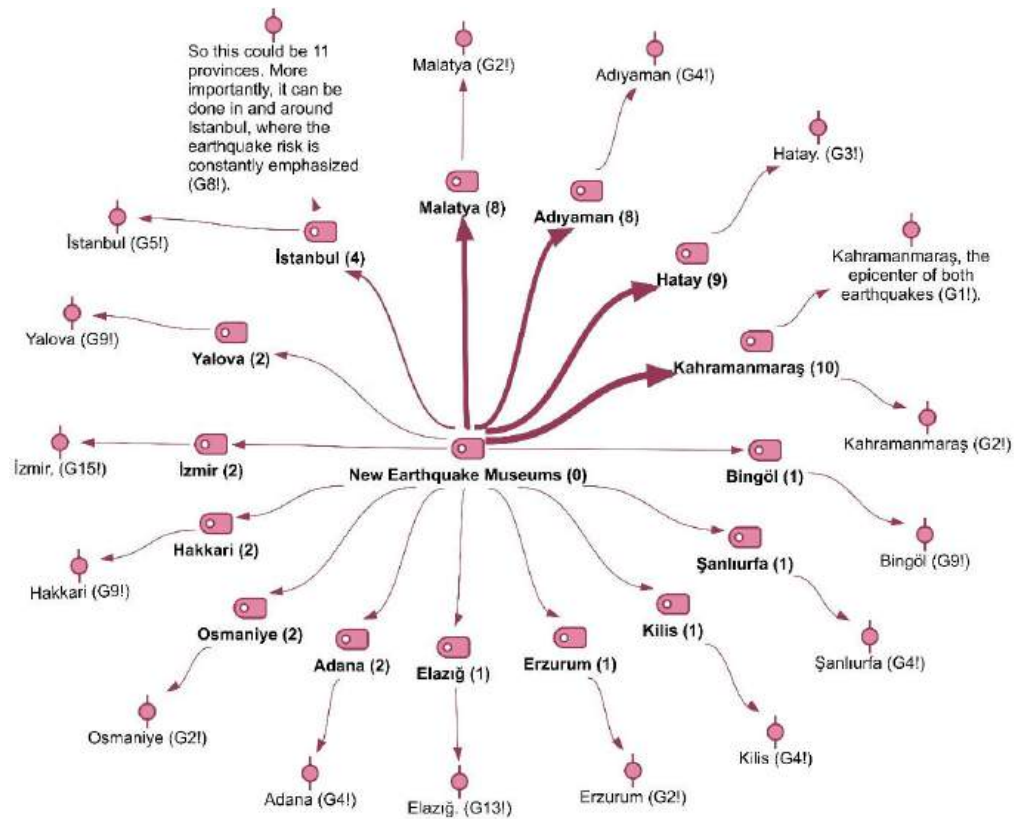
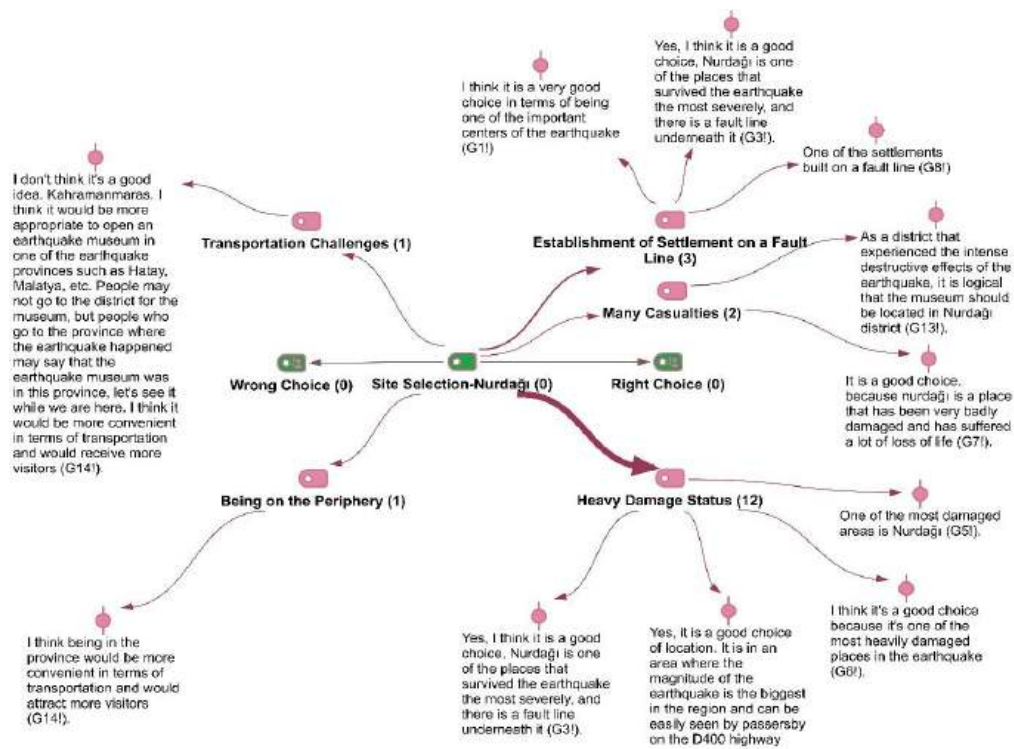


Figure 17

Code Sub-Code Sections Model Site Selection-Nurdağı Category



frequency was determined as 1, cluster as 4, and the results were evaluated. Because of the findings obtained, it was concluded that some codes were frequently preferred by the

interviewees within the 4 clusters formed. At this point, the first cluster consists of the codes "Keeping the Social Memory Alive, Learning Lessons, Warning, Gaining Empathy, Making

Figure 18

Code Sub-Code Sections Model Suggestion Category

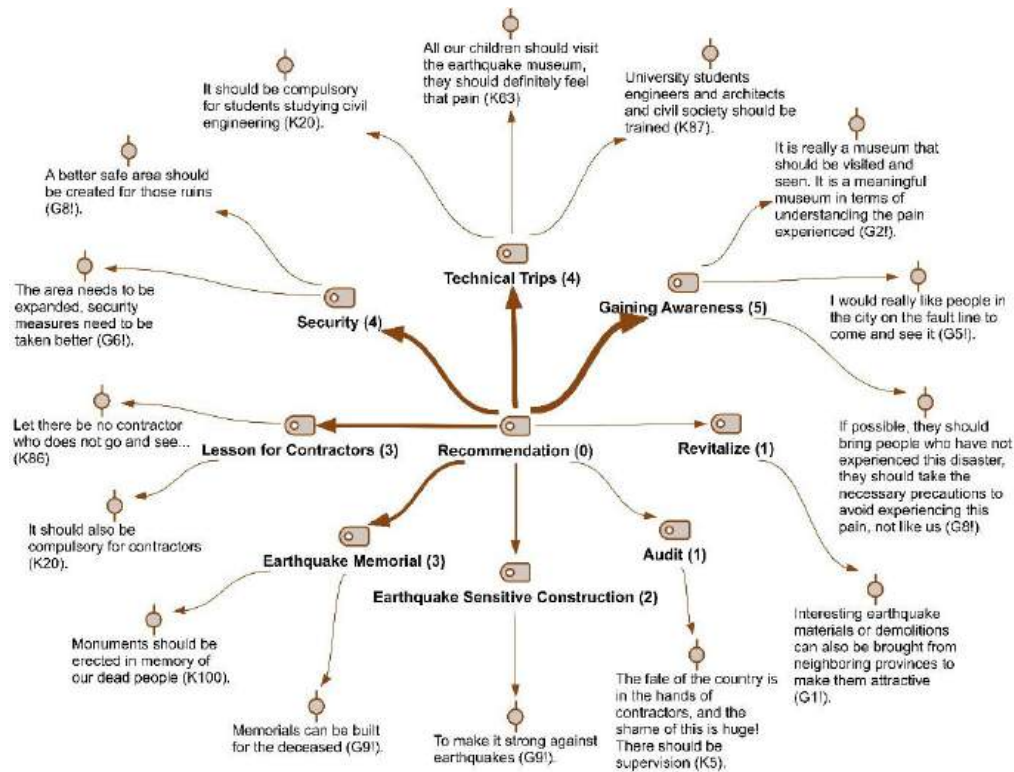
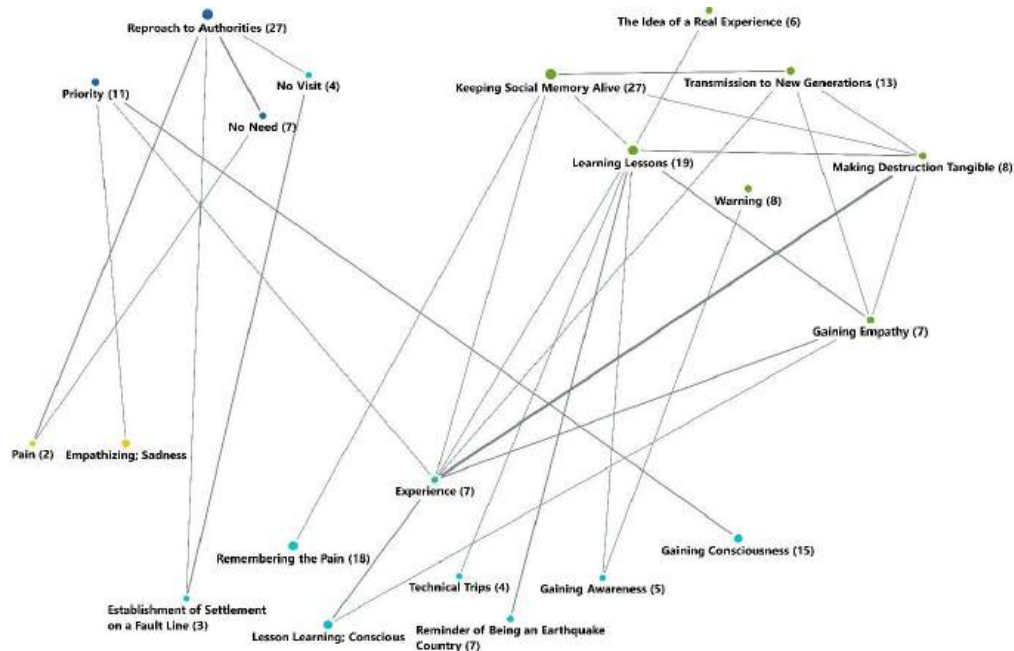


Figure 19

Code Relationship Browser-All Code Intersection (Frequency: 1-Cluster: 4)



Destruction Tangible, Transmission to New Generations, The idea of a Real Experience". The second cluster includes the codes "Reproach to Authorities, No Need and Priority". In the third cluster, "Pain, Empathising and Sadness" codes formed a relationship. In the fourth cluster, it is seen that the codes "Gaining awareness, Reminder of being an earthquake

country, Experience, Technical trips, Gaining consciousness" formed a relational connection (Figure 19).

Discussion And Conclusion

It is of great importance to transfer the negative effects of disasters such as earthquakes, floods, wars, etc., which cause

structural destruction, economic, and social losses in our country as in the whole world, to future generations on behalf of social memory and to raise awareness. The relationship between natural disasters, social memory, and social solidarity is an important topic of discussion in countries with high disaster risk, especially in geographies such as Türkiye. The 6 February 2023 earthquake in Kahramanmaraş left deep traces in social memory and highlighted the necessity of preserving and transmitting these traces to the agenda. In this context, disaster-themed museums such as Nurdağı open-air earthquake museum play a critical role in the transfer of social memory. Such museums allow individuals to face the traumas they have experienced and maintain social memory alive (Abe, 2020; Şener, 2023). In this context, natural disaster-themed museums have become prominent places to make the traces left by natural disasters concrete in spatial memory and within the scope of grief tourism.

This study was conducted to evaluate the Nurdağı open-air earthquake museum, which was created to reveal the effects of the Kahramanmaraş-centred earthquakes of February 6, 2023, which left important traces in Türkiye in the recent period, within the scope of sadness tourism, to raise awareness and to measure perceptions towards the museum. The data collected from museum visitors and electronic comments were analysed from a holistic perspective. During the data collection phase, it was determined that electronic comments and the news in the media were not put on the agenda for a while after the earthquake. It is noteworthy that the earthquake disaster has been replaced by other events before a year has passed. Unfortunately, although such events remain in the memory of the place, they are quickly replaced by other social events in social memory. Events that occupy the agenda of the country may prevent the preservation of natural disasters in social memory. At this point, activating concrete places, such as museums, is one of the most important tasks that can be done in order not to forget these disasters in both social and spatial memory.

The coding during the study revealed some structural findings. Based on these findings, some theories were developed within the scope of the study. The first theory that emerged in this context is that the interviews with museum visitors and electronic comments differ on a perceptual scale. It was revealed that the interviewees' attitudes towards the opening of an earthquake-themed museum showed a more positive trend. In line with the discourses, it is believed that the perceptions of museum visitors are shaped more positively when they find the opportunity to experience on-site in the tourism of sadness. In internet comments, perceptions in social media are shaped negatively depending

on how the process is managed. This perception was constantly supported by users with the codes "Reproach to the authorities, Reminder of pain, No need and priority". In addition, it is seen that both museum visitors and those who think positively in electronic comments support these perceptions with the sub-codes "Keeping social memory alive" and "Taking lessons". In this context, important findings have been obtained regarding the shaping of museum visitors' perceptions and experiences within the scope of grief tourism. Visitors exhibit a more positive tendency towards the opening of an earthquake-themed museum, which strengthens the experiential dimension of grief tourism. In addition, negative perceptions shaped by the influence of social media in electronic comments are emphasised in the relevant literature as a factor that prevents the preservation of social memory (Pereira et al., 2022). While disasters leave permanent traces in social memory, it is also important, in terms of social solidarity practices, to embody these traces and preserve social memory in a sustainable manner. While sadness tourism refers to visits to areas where mass deaths occur and monumental places, such places also function as places of social memory (Lin et al., 2021; Pereira et al., 2022). Nurdağı open-air museum, as a concrete reminder of post-earthquake suffering, supports the practices of remembering and mourning by deepening visitors' experiential interactions with space. Such museums are critical for strengthening spatial memory and revealing the intertwining of social trauma with space (Hwang et al., 2022; Pereira et al., 2022).

The second theory obtained in the study concerned the tendency of museum visitors to return. Because of the analyses, it was determined that most museum visitors positively tend to return. The positive returning tendency of museum visitors is an important factor that contributes to keeping social memory alive (Tarifa-Fernández et al., 2022; Adelan et al., 2023). This theory is associated with the category of "travel motivation", which is another important finding of the study. At this point, it is seen that museum visitors act consciously towards the Nurdağı open-air earthquake museum with the instinct of seeing on-site and curiosity, and this situation shapes their tendency to return with discourses such as transferring the quality experience they have experienced to new generations, raising awareness, and taking lessons. At this point, the interviewees often supported the idea by stating that they would bring their children on their next visit. Based on these findings, visitors' desire to return to the museum with the quality of their experiences and curiosity instinct is considered an effective mechanism for the preservation of social memory in the literature (Tarifa-Fernández et al., 2022; Adelan et al., 2023).

Another theory obtained within the scope of the study is that the code "gaining awareness" in the category of suggestions is frequently underlined by drawing attention to the existence of the museum. In this context, it is thought that the next generation should be made aware of measures to be taken to mitigate the effects of disasters such as earthquakes through technical trips and student visits. The role of disaster-themed museums in the transmission of social memory not only helps individuals to confront the past, but also functions as an important tool in raising disaster awareness in future generations by integrating them into the education system (Vázquez, 2018). The existence of Nurdağı open-air earthquake museum is important in terms of concretising this process. The effects of disaster-themed museums on social memory and the effects of preserving this memory on social identity have a wide place in the literature. While disasters leave permanent traces in the construction of social identity, the embodiment and protection of these traces play a fundamental role in strengthening social solidarity and education (Mutlutürk, 2020; Çelik, 2023). The existence of natural disasters, which is the reality of Türkiye, must be integrated into the education system.

Consequently; During the interviews, it was observed that the visitors learned that the visits they made with these studies conducted by the researchers were included in the scope of sadness tourism. Therefore, it is thought that such studies would create awareness among societies about protecting against natural disasters. At this point, the locations and effective attitudes of authorised institutions and organisations are the key to learn lessons from these disasters and the measures to be taken in this direction. Disaster-themed museums play an important function in the concretisation of social memory and in confronting individuals with past traumas. Such museums allow individuals to maintain social memory by facing the pain and losses they have experienced. Especially Nurdağı open-air earthquake museum draws attention as an example that emphasises the place of natural disasters in social memory and the importance of preserving this memory. Disaster-themed museums and sadness tourism ensure the continuity of social memory by supporting individuals' processes of confronting the past. The existence of these places not only contributes to the preservation of social memory but also plays a vital role in ensuring that the sufferings of the past are not forgotten and that lessons are learned from these sufferings. In this context, the impact of disaster-themed museums on social identity and spatial memory is of great importance.

6 February 2023 The study, which examines the role of the Nurdağı open-air earthquake museum, which was established after the Kahramanmaraş-based earthquakes, in strengthening social memory in the context of grief tourism, interviews with museum visitors and electronic comments revealed the importance of earthquake-themed museums in terms of social memory and social solidarity, and emphasised the function of museums in confronting past traumas and keeping social memory alive. Visitors expressed a positive attitude towards the disaster-themed museum and stated that such places are an important tool in preserving social memory. However, negative perceptions shaped in social media have been identified as a factor that may prevent disasters from gaining a long-term place in social memory. Moreover, integrating such museums into the education system is considered a critical step in transferring disaster awareness to future generations. Disaster-themed museums not only concretise social memory but also play an important role in the construction of social identity by enabling individuals to confront the pain of the past. In this context, it is essential that such museums reach a wider audience quantitatively and qualitatively and that they are supported with rich content that visitors can interact with emotionally and intellectually.



Ethics	Committee Approval	This study was approved by Kahramanmaraş Sütçü İmam University Rectorate Social and Human Sciences Ethics Committee (29.12.2023 / 2023-44)
Informed Consent		Written consent was obtained from the participants.
Peer Review		Externally peer-reviewed.
Author Contributions		Conception/Design of Study- F.T., N.K.; Data Acquisition- F.T., N.K.; Data Analysis/Interpretation- F.T., N.K.; Drafting Manuscript- F.T., N.K.; Critical Revision of Manuscript- F.T., N.K.; Final Approval and Accountability- F.T., N.K.
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Research Article

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An evaluation of the long-term changes in the shoreline of Lake Eğirdir in relation to climate and anthropogenic factors



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Abstract

This study quantifies shoreline changes in Lake Eğirdir between 1984 and 2024 by examining the direction, distance, and rate of change, along with climatic and anthropogenic influences. Landsat satellite images were used to delineate the lake's shoreline using the Modified Normalised Difference Water Index (MNDWI). Shoreline change rates were then calculated using the Digital Shoreline Analysis System (DSAS), employing metrics such as the End Point Rate (EPR), Linear Regression Rate (LRR), and Net Shoreline Movement (NSM). Results indicated the highest EPR value of 61,06 m/yr at transect 2035, while the highest LRR value was 39,78 m/yr. The NSM analysis revealed a maximum positive value of 2444,6 m, indicating significant recession in specific shoreline areas.

The key factors driving these changes include climate change and agricultural irrigation practices. Mann-Kendall trend analysis demonstrated a rising trend in maximum temperatures, although precipitation levels showed no significant variation. The expansion of fruit orchards around Lake Eğirdir has intensified water demand, resulting in a marked decline in water levels. This study highlights the combined impact of climatic shifts and human activities on shoreline dynamics, highlighting the need for sustainable water management strategies to mitigate further environmental degradation.

Keywords

DSAS • Shoreline change • Eğirdir Lake



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Introduction

The rapid increase in global temperatures in recent years clearly demonstrates, based on scientific evidence, that climate change has emerged as an urgent and irreversible threat. Analyses conducted using six comprehensive datasets indicate that the five-year average global temperatures between 2019 and 2023 reached the highest levels in recorded history, with 2023 being the hottest year ever documented (Climate Change Service, 2024). At the same time, according to the IPCC reports (2023), the frequency and intensity of such extreme temperature events are directly linked to the increase in human-induced greenhouse gas emissions. Such events demonstrate that the concept of "**climate urgency**" has reached a level that can no longer be ignored (Steffen *et al.*, 2020). The year 2023 not only experienced a hot summer but also set the stage for an unusually warm winter (Esper *et al.*, 2024; Zheng *et al.*, 2024). According to studies conducted by the WMO, ocean warming accelerates glacier retreat and raises sea levels. Extreme weather-related events adversely impact socioeconomic development, and the cost of inaction on climate change exceeds the cost of taking climate action (WMO, 2024).

Agricultural activities are increasingly dependent on the intensive consumption of surface and groundwater resources due to the changing temperature factors of global climate change. Agricultural activities, driven by the impact of global climate change and shifting temperature factors, contribute to the increased consumption of surface and groundwater resources and further intensification of such practices. As a result of these activities, the rapid depletion of groundwater resources also leads to the rapid withdrawal of water from surface wetlands, and in some areas, it paves the way for their irreversible depletion (Çankal & Alkın, 2024). In Turkey's Konya Plain, which is characterised as a closed basin, studies have shown that the groundwater level has rapidly decreased over time due to agricultural irrigation, accelerating the formation of sinkholes and leading to a significant decline in water levels within these sinkholes (Bozyiğit & Tapur, 2009; Tapur & Bozyiğit, 2015; Yılmaz, 2010). In the Lakes Region, the factors causing changes in the shorelines of lakes, and in some cases leading to the gradual shrinkage of lake surfaces and ultimately the complete disappearance of lakes over time, are similar to those observed in areas of Central Anatolia where sinkholes have formed rapidly due to groundwater depletion.

In summary, lakes are also significantly affected by drought and evaporation, and with the addition of uncontrolled groundwater usage (without considering balance calculations), they have been observed to recede

substantially, starting from their shorelines (Alevkayalı *et al.*, 2023; Aydın & Doğu, 2018; Bahadır, 2013). Today, in our country, particularly in the Lakes Region, some lakes no longer accumulate more water on their surface than what currently exists, or only a minimal amount accumulates. Some of the lakes that no longer retain water on their surfaces today include Yarıklı (Burdur) (Aksoy *et al.*, 2019), Akgöl (Burdur), Karataş (Burdur), and Akşehir (Konya). In addition, lakes that have experienced rapid water withdrawal include Acıgöl (Denizli), Burdur, Beyşehir, Eğirdir, and Salda lakes (Cengiz & Kahya, 2011).

The studies conducted on Eğirdir (Aslan & Koc San, 2021), Burdur (Alevkayalı *et al.*, 2023; Sarp & Özçelik, 2017), and Beyşehir (Yarar & Onüçyıldız, 2009) lakes, which are the largest lakes in the Lakes Region in terms of area, particularly those focused on Lake Burdur, confirm that the decline in water levels in these lakes is not solely due to temperature increases caused by global climate change but is also significantly influenced by the high demand for groundwater usage.

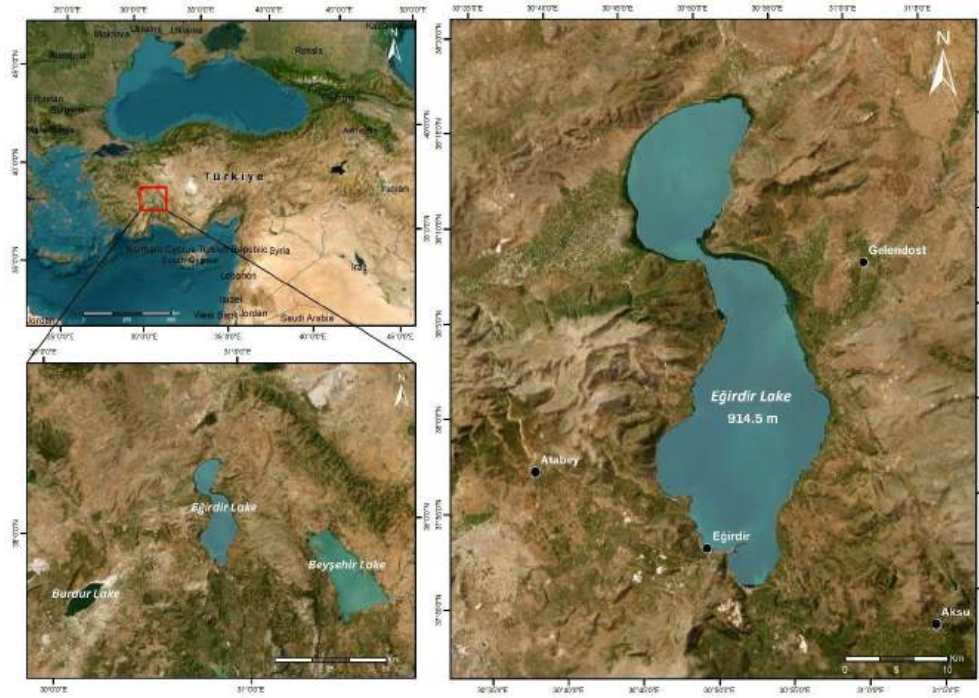
Lake Eğirdir is one of the most significant wetlands in the Lake District, with a freshwater reserve of high ecological and economic importance. This study reveals the long-term shoreline changes in Lake Eğirdir by analysing satellite imagery recorded between 1984 and 2024. In this study, in addition to analysing changes in the lake surface, the temporal and spatial trends of climate parameter datasets and changes in agricultural patterns were evaluated. Based on the findings, the causes of the water level decline in Lake Eğirdir and the potential adverse effects thereof were also assessed.

Method

Study Area

This study was conducted on the surface area of Lake Eğirdir, one of Turkey's significant wetlands located in the Lakes Region, which holds great importance as a freshwater resource for the surrounding area. Lake Eğirdir is located between the coordinates 37° 50' 41"–38° 16' 55"N and 30° 44' 39"–30° 57' 43"E (Figure 1). This open-basin lake drains its waters into Lake Kovada and subsequently into the Aksu River through an epigenic valley and an incised meander. Between Lake Eğirdir and Lake Kovada lies a polje-like plain called Boğazova, through which a canal extends all the way to Lake Kovada. The Kovada Canal provides a surface connection between Lake Eğirdir and Lake Kovada while also draining the plain, making it suitable for agricultural use (Atayeter, 2005). Due to the above-mentioned features, Lake Eğirdir is significantly affected by climate parameters and



Figure 1*Location Map of the Study Area*

anthropogenic factors. This process leads to significant water withdrawal from the lake, particularly during periods that are not supported by precipitation (Figure 2).

Figure 2

Bölük Island, now above water because of the lake's recession at Kemerboğazı location (31.10.2024)



The hydrological system of Lake Eğirdir is largely based on a cycle of groundwater inputs. In the 2000s, the shoreline of Lake Eğirdir was located at an elevation of 916 metres (Atayeter, 2011), whereas recent studies have determined the lake level to be 915.08 metres (Güner & Özgür, 2023). Field studies have determined that the current elevation of the lake is 914.5 m.

Lake Eğirdir has experienced level fluctuations at various times throughout its history (USGS, 2024). Historical records indicate that during the 1960s, marshes and water pools formed in certain areas of the plains surrounding Lake Eğirdir, where groundwater levels were very close to the surface.

These high water levels caused the formation of marshes and water pools, creating unfavourable conditions for agricultural activities. One of these areas is Boğazova, located between Lake Eğirdir and Lake Kovada. In the 1960s, Boğazova was drained and reclaimed for agricultural production through the construction of the Kovada Canal.

Studies on the hydrological and hydrogeological characteristics of Lake Eğirdir have identified various sources of water for the lake. These studies demonstrated that Lake Eğirdir primarily receives water from precipitation, surface water, and groundwater sources. The main surface water sources feeding Lake Eğirdir include the Hoyran Basin, Olukköprü, and Dumanlı karst springs (Değirmenci & Günay, 1992; Sipahi, 1987). Among the significant continuous sources feeding Lake Eğirdir are Pupa (Üyüllü) Creek from the west, Ilgın Stream, which crosses the Kumdanlı Plain and reaches Hoyran, and Öz Stream, originating from the northeastern foothills of the Sultan Mountains with a large catchment area, along with its tributaries Yukarı Çamlıca, Kocaçay, and Keklik Creek. Sarıdris Stream, Kapız Creek, and Koca Creek, located in the southeast of the lake, are among the significant watercourses (Atayeter, 2011).

The surroundings of Lake Eğirdir exhibit diverse geological characteristics across its mountainous and plain areas. Materials eroded from mountainous areas primarily form Quaternary-aged alluvial units that accumulate in the flat and plain areas of the Senirkent, Kumdanlı, Yalvaç, and Gelendost districts. The mountainous areas around the lake

are mostly covered with neritic limestones, dating from Triassic to Cretaceous. The Barla Mountain massif to the west of Lake Eğirdir is predominantly composed of Triassic and Upper Jurassic-Lower Cretaceous neritic limestones. The south side of these limestones contains Mesozoic-aged peridotites is notable. To the east of Lake Eğirdir, limestones are less widespread than in the west, and Pliocene-aged clastic and carbonate units are observed around Yalvaç and Gelendost. In the region between Hoyran Lake and Yalvaç, the presence of Miocene-aged lacustrine deposits indicates the existence of ancient lake environments in this area. These Miocene-aged units consist of lacustrine deposits such as sandstone, marl, and silt. In the southeast, unlike the limestones and lacustrine units, peridotites and occasionally imbricated ophiolites are found (MTA).

Mann-Kendall Trend Test

Temperature and precipitation are the most commonly used climate elements to determine the effects of climate change in a region because these elements continuously vary over time and space. To analyse these changes using long-term data and to understand the increasing or decreasing trends in temperature and precipitation values, the non-parametric Mann-Kendall trend test (Mann, 1945; Kendall, 1975) is widely preferred in many scientific studies due to its reliability (Alahacoon et al., 2018; Alevkayalı et al., 2023; Hirsch & Slack, 1984; Gocic & Trajkovic, 2013; Kahya & Kalaycı, 2004; Kızılelma et al., 2015; Polat & Sunkar, 2017; Şen, 2017; Tağıl & Alevkayalı, 2014; Topuz et al., 2016; Topuz et al., 2018; Topuz et al., 2021;).

As emphasised above, the Mann-Kendall trend test is a nonparametric method used to detect trends in a dataset and does not require data to follow a normal distribution (Onoz & Bayazit, 2003). The Mann-Kendall test is less sensitive to sudden shifts caused by non-homogeneous time series (Taberi, 2011). The primary purpose of the Mann-Kendall test is to determine whether a monotonic increasing or decreasing trend exists in a dataset. According to this test, the null hypothesis H_0 assumes that no trend exists (data are independent and randomly ordered, with no significant trend in the time series) and is tested against the alternative hypothesis H_1 , which assumes that a significant trend exists in the time series (Karmeshu, 2012).

The Mann-Kendall statistical test was performed using the following formulas:

In the Mann-Kendall test, the S statistic is computed using the sign of the difference between two observations. The test evaluates whether each observation value in a time series is greater or lesser than all preceding values for each pair of data points.

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

Here:

- x_i , and x_j are two distinct values in the dataset, respectively.
- where n is the total number of observations,
- the sgn (Signum) function indicates the sign of the difference between two data points and is defined as follows:

$$\text{sgn}(x_j - x_i) = \begin{cases} +1 & \text{if } x_j > x_i \\ 0 & \text{if } x_j = x_i \\ -1 & \text{if } x_j < x_i \end{cases}$$

(Pozitif Trend: $S > 0$, Negatif Trend: $S < 0$, No Trend: $S = 0$)

In this formula, the sign of the difference between each pair of observations is determined and summed for all pairs. When no ties exist in the dataset (no equal observation values), the variance $\text{Var}(S)$ is calculated as follows:

$$\text{Var}(S) = \frac{n(n-1)(2n+5)}{18}$$

If the dataset contains tied values (ties), the variance $\text{Var}(S)$ is adjusted as follows:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum t_p(t_p-1)(2t_p+5)}{18}$$

- t_p , represents the count of repeated observation values for each tie.

The Z-statistic is used to determine whether a trend exists in the dataset. Then, it is calculated using the following formula;

$$z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases}$$

Finally, the calculated Z-value is compared with the critical Z-value obtained from the standard normal distribution table at a specific confidence level (e.g., 95%). This comparison determines whether there is a "trend" in the data.

Satellite images

In this study, Landsat satellite images from different dates over a long period (1984–2024) were used to analyse shoreline changes in Lake Eğirdir (Table 1). These images were obtained from the United States Geological Survey (USGS) database. The selection of satellite images for the study focused on ensuring that they represented different dates, reflected similar periods, and had high image quality. Therefore, data recorded during July, August, and September—when cloud cover is minimal—were preferred (Table 1).



Table 1*Key Characteristics of the Satellite Images*

Satellite	Date	Image ID	Resolution (m)
Landsat 5	16/07/1984	LT05_L1TP_178034_19840716_20200918_02_T1	30
Landsat 5	02/08/1990	LT05_L1TP_178034_19900802_20200915_02_T1	30
Landsat 5	16/08/1995	LT05_L1TP_178034_19950816_20200912_02_T1	30
Landsat 5	29/08/2000	LT05_L1TP_178034_20000829_20200906_02_T1	30
Landsat 5	12/09/2005	LT05_L1TP_178034_20050912_20200901_02_T1	30
Landsat 5	25/08/2010	LT05_L1TP_178034_20100825_20200823_02_T1	30
Landsat 8 OLI/TIRS	07/08/2015	LC08_L1TP_178034_20150807_20200908_02_T1	30
Landsat 8 OLI/TIRS	04/08/2020	LC08_L1TP_178034_20200804_20200915_02_T1	30
Landsat 8 OLI/TIRS	30/07/2024	LC08_L1TP_178034_20240730_20240801_02_T1	30

Determination of Shorelines

Advances in satellite technologies have made it possible to monitor the Earth on a global scale and identify changes on the surface through remote sensing (Lillesand *et al.*, 2015). The images provided by satellite systems consist of channels representing different spectral bands (Richards, 2013). Depending on the study's objective, greyscale single-channel or colour composite images can be created by combining different spectral bands. In this process, the "image rationing" method is used, where spectral reflectance values in one band are compared and divided by those in another band to produce a new image derived from the ratios (Lu & Weng, 2007; Sabins, 1997). The rationing process can vary depending on the characteristics of a specific satellite image and the study area; therefore, researchers often rely on the most suitable band combinations identified in the literature or through trial and error (Alevkayalı *et al.*, 2023). The shoreline, as a dynamic geographical boundary, can be defined as a line formed by connecting points where water meets land in seas, lakes, rivers, and artificial bodies, excluding flood conditions (Turoğlu, 2017). In this study, after obtaining satellite images of Lake Eğirdir, shorelines from different dates were identified. During the determination of the shorelines, image rationing techniques were employed, and the Modified Normalised Difference Water Index (MNDWI) was utilised. In this index, the 2nd and 5th bands are used for Landsat 5 TM and the 3rd and 6th bands are used for Landsat 8 OLI (Sarp & Ozcelik, 2017).

MNDWI is a highly effective method for identifying water bodies by reducing noise from vegetation and soil (McFeeters, 1996; Xu, 2006). When using the Normalised Difference Water Index (NDWI) method, water and built-up areas near water bodies can sometimes mix, particularly in urbanised regions, leading to an overestimation of water bodies. To address this issue, MNDWI is recommended, especially in areas where water and built-up regions overlap, as it minimises noise from

built-up areas (Guha & Govil, 2021). Therefore, the MNDWI method was used in this study to identify the shorelines of Lake Eğirdir on different dates. The raster data obtained by the proposed method were reclassified and converted into vector data.

$$MNDWI = \frac{Green - SWIR}{Green + SWIR}$$

Determination of Shoreline Changes

Landsat satellite images provide spectrally resolved data that are designed to monitor the geophysical characteristics of the Earth's surface. These data are particularly effective in distinguishing between land and water surfaces and offer high accuracy and repeatability for monitoring coastal areas (Dwyer *et al.*, 2018). Since the 1970s, Landsat imagery has been a valuable resource for coastal management and environmental monitoring studies (Moore, 2000; Mishra *et al.*, 2019; Woodcock *et al.*, 2008).

The Digital Shoreline Analysis System (DSAS) is an extension integrated into the ESRI ArcGIS software, enabling the calculation of shoreline change rates based on shoreline data from multiple time periods (Himmelstoss *et al.*, 2021). DSAS uses statistical analysis methods to assess changes in the shoreline, allowing for the examination of trends in coastal erosion, accretion, and stability. These analyses are crucial to gain a better understanding of the long-term impacts of changes in coastal regions.

The primary reason for preferring these methods in shoreline analyses is their complementary features, which enable a more comprehensive examination of coastal changes. MNDWI provides high accuracy in delineating shorelines by distinguishing water from land in satellite imagery. The shorelines obtained through this method can then be analysed with DSAS to determine key parameters such as changes over time (erosion or accretion) and the rates of

these changes. The proposed approach provides detailed insights into both the location of the shoreline and its temporal variations.

In this study, the current state of Lake Eğirdir was evaluated using the DSAS tool, and change rate statistics were calculated for the shoreline data. The DSAS tool requires shoreline and baseline layers for operation. After completing the shoreline extraction process, a shoreline layer was created using the data obtained on different dates (Figure 3a). Three methods can be used to create the baseline layer: generating a line layer at a specific distance from the shoreline, drawing a baseline based on an older shoreline as a reference, or using the buffer analysis method (Yiğit *et al.*, 2022). In this study, we employed buffer analysis, which is considered more reliable than the other methods. This method has been widely used in similar studies (Nassar *et al.*, 2019). In this approach, a 300-m buffer analysis was performed on the shoreline layer, and the boundary facing the lake was designated as the baseline. Using the resulting shoreline and baseline layers, the DSAS tool was run, and transects were generated (Figure 3b).

In the subsequent analysis, statistical methods, including the end point rate (EPR), Linear Regression Rate (LRR), and Net Shoreline Movement (NSM), were applied to monitor and evaluate shoreline changes.

The End Point Rate (EPR) is calculated by dividing the distance (in metres) between two shorelines by the number of years between their respective dates (Ayadi *et al.*, 2016; Dereli & Tercan, 2020; Hwang *et al.*, 2014; Dolan *et al.*, 1991; Hwang *et al.*, 2014; Thieler *et al.*, 2005). This statistical method is widely recognised as a common approach for calculating shoreline change rates and is frequently preferred by many researchers in this field.

$$EPR = \frac{L1 - L2}{t1 - t2}$$

In the equation, L1 and L2 represent the distance between the two shorelines, and t1 and t2 indicate the temporal difference between the two shorelines.

The LRR method examines multiple shorelines to understand how they change over time using a statistical model. The proposed model works by fitting a best-fit line to points along the shorelines. However, to yield accurate results, the shorelines must be precisely delineated. Errors in shoreline identification can significantly impact critical information, such as the rate of erosion or accretion (Dereli & Tercan, 2020; Nassar *et al.*, 2019; Yiğit *et al.*, 2022).

$$D = mt + a$$

In the equation, D represents the distance from the baseline (in metres), t denotes the time variation of the shoreline (in years), m is the slope of the fitted line (in metres per year), and a is the y-intercept.

The NSM statistic represents the distance between the old and new shorelines over the analysed periods (Himmelstoss *et al.*, 2018). Using the NSM statistic, the average, maximum, and minimum values of shoreline changes can be determined for the specified periods (Uzun, 2024).

Results

Lake Eğirdir, one of Turkey's largest freshwater reservoirs, supplies drinking water to the local population and meets irrigation needs for agriculture in the region. However, due to factors such as excessive water usage within the lake and its basin, climate change, and poor watershed management practices, alongside changes in climate data, Lake Eğirdir has experienced significant water recession in recent years, particularly in 2024 (Figure 4 ve Figure 5).

The Digital Shoreline Analysis System (DSAS) was originally developed for use along marine coastlines, and its terminology, parameters, and threshold values are defined

Figure 3
Creation of baseline layer using buffer analysis and generation of transects

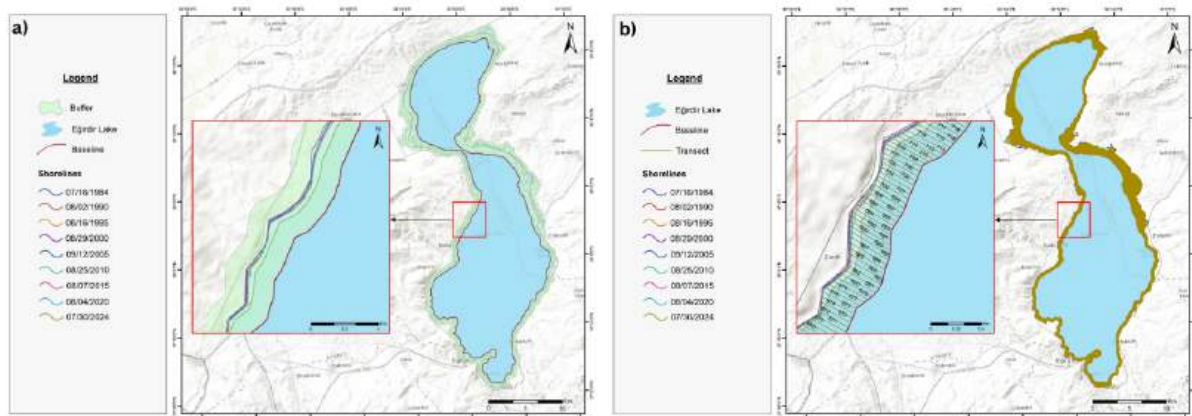
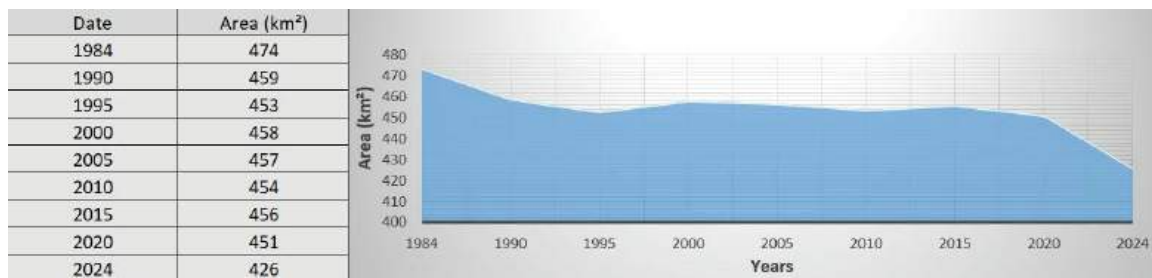
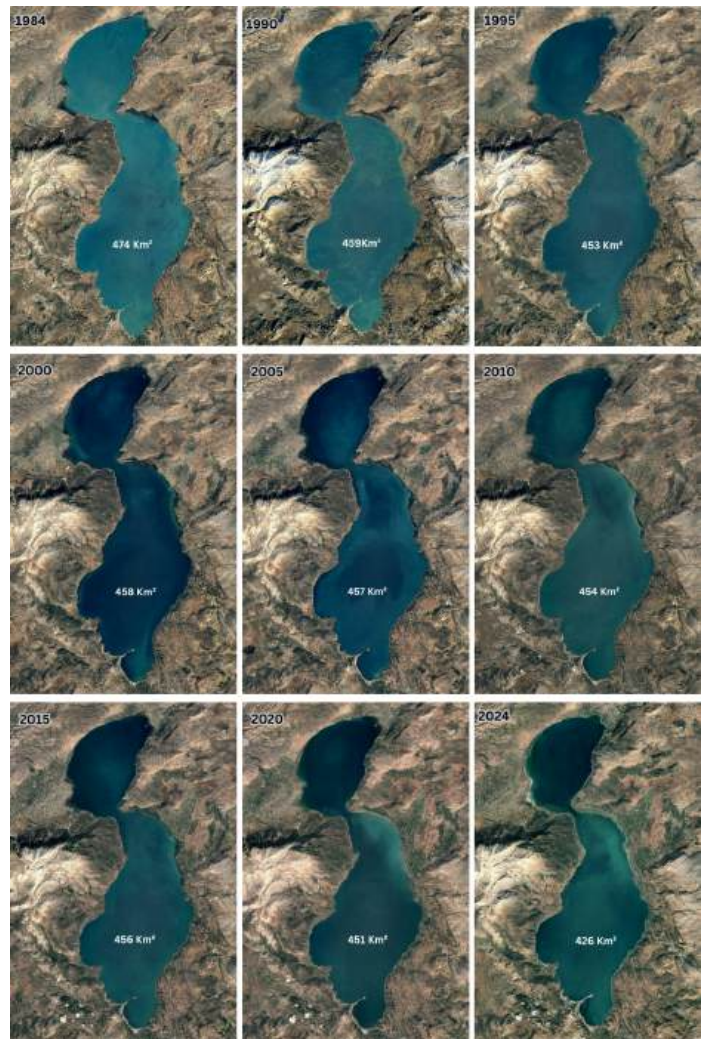


Figure 4*Long-term (1984–2024) areal changes of Lake Eğirdir*

based on coastal marine dynamics. However, this method has also proven to be applicable and effective in studies on lakes and their shorelines, providing meaningful results and guiding the interpretation of shoreline change trends. Nevertheless, processes driving shoreline retreat and advance differ significantly between marine and lacustrine environments. In coastal areas, shoreline advancement generally results from the transport and accumulation of alluvium driven by external forces, whereas retreat is often caused by sea level rise associated with climate change and tectonic activity, which increases coastal erosion. In contrast, in lake environments, the process works in the opposite direction: shoreline retreat is typically linked to sediment accretion, whereas shoreline advancement is associated with rising water levels and the resulting shoreline erosion. Therefore, the terminology and parameters used in the DSAS should be carefully interpreted with respect to the fundamental differences between lake and marine systems.

This recession has caused the narrowing of Kemerboğazi, the point at which the eastern and western shores of the lake are closest to each other (Figure 5). This phenomenon has increased the risk of the lake splitting into two separate bodies of water, named Eğirdir and Hoyran. Such potential changes are expected to have significant impacts on the lake's ecosystem and environmental balance.

Figure 5*Current view of Kemerboğazi location (31.10.2024)***Figure 6***Long-term (1984–2024) areal changes in the surface area of Lake Eğirdir*

Source: Google Earth, 20.10.2024/16:30

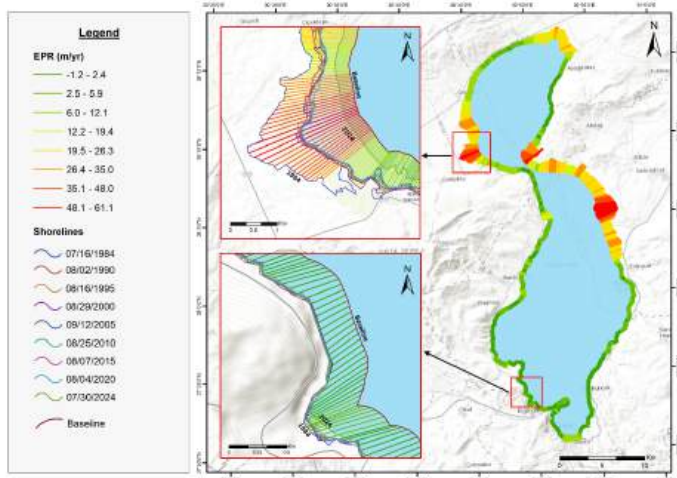
In this study, to obtain concrete findings regarding this recession, statistical analyses of EPR, LRR, and NSM were conducted using the DSAS tool at a 99% confidence level. The results of these statistical analyses are displayed on maps. In the obtained statistical values, negative values indicate erosion and positive values represent accretion. The findings derived from the applied EPR, LRR, and NSM statistical analyses are as follows:

End-point Rate (EPR)

EPR is a statistical method used to quantify the rate of shoreline change at specific locations. The findings from this analysis reveal how quickly the shoreline changes in m/year, whether the change indicates accretion or erosion, and which areas exhibit higher rates of change. The results show that the maximum accretion rate on the shoreline was 61.1% m/year, west of Akdağ (Figure 7). The maximum erosion rate was recorded northwest of Eğirdir, with a value of -1,2 m/year (Table 2).

Figure 7

Long-term (1984–2024) EPR results across the entire shoreline of Lake Eğirdir (2744 transects)

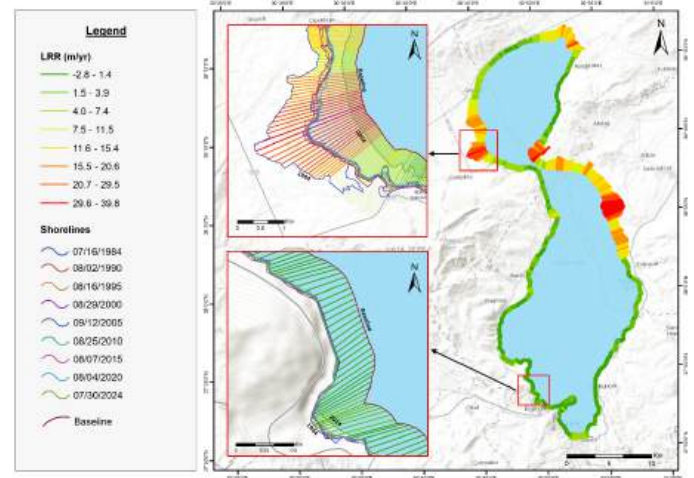


Linear Regression Rate (LRR)

The LRR provides the general trend and temporal rate of shoreline change. According to the results, the maximum rate of shoreline accretion occurred west of Akdağ and was calculated as 39,8 m/year (Figure 8). The maximum rate of erosion was recorded northwest of Eğirdir at a value of -2,8 m/year (Table 2).

Figure 8

Long-term (1984–2024) LRR results in the entire shoreline of Lake Eğirdir (2744 transects)



Net Shoreline Movement (NSM)

The NSM method shows the net movement of the shoreline in metres. According to the analysis, the maximum positive NSM value was calculated as 2444.6 m west of Akdağ. Out of 2744 transects, 2698 (98.32%) exhibited positive displacement, indicating shoreline sediment accretion. The maximum negative NSM value was recorded 47 m northwest of Eğirdir (Figure 9). A total of 46 transects (1.68%) showed negative displacement, indicating shoreline erosion (Table 3).

The analyses performed on the entire shoreline of Lake Eğirdir yielded positive values, indicating a retreat of the shoreline towards the lake. When evaluating the entire shoreline of Lake Eğirdir, the highest EPR, LRR, and NSM values were found on the western side of Akdağ, southwest of the Gelendost district centre (Figure 2a), and along the shores northeast of Garipköy. These areas were observed to have the highest rates and magnitudes of shoreline retreat.

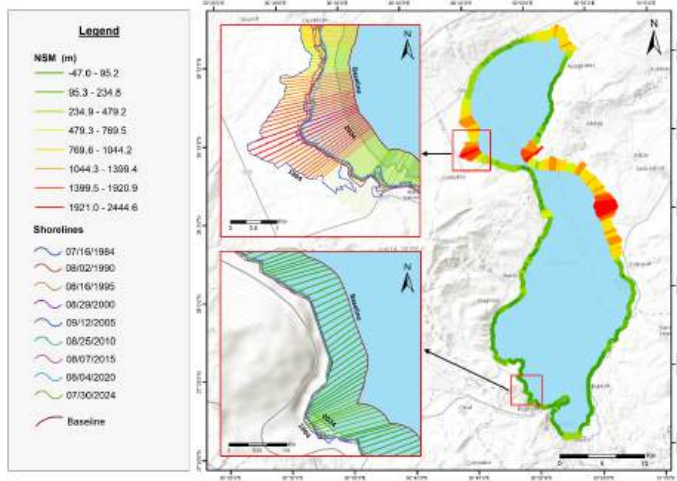
Table 2

EPR (End Point Rate, m/year) and LRR (Linear Regression Rate, m/year) Results

	Analysis Type	EPR (m/yr)	LRR (m/yr)
EROSION	Number of erosional transects	46	101
	percentage of all erosional transects	1.68%	3.68%
	Maximum value erosion	-1.17	-2.82
	Maximum value erosion transect ID	317	167
	Average erosional rate	-0.24	-0.25
ACCRETION	Number of accretion transects	2698	2643
	Percentage of all accretional transects	98.32%	96.32%
	Maximum value accretion	61.06	39.78
	Maximum value accretion transect ID	2035	2055
	Average of all accretion rates	9.45	5.82

Figure 9

Long-term (1984–2024) NSM results in the entire shoreline of Lake Eğirdir (2744 transects)

**Table 3**

NSM (Net Shoreline Movement, m) results

NSM (Net Shoreline Movement, m)	Value
Total transect number	2744
Average distance	372.03
Number of transects with negative distances	46
Percentage of all transects with negative distances	1.68%
Maximum negative distance	-46.96
Maximum negative distance of transect ID	317
Average negative distances	-9.66
Number of transects with positive distances	2698
Percentage of all transects with positive distances	98.32%
Maximum positive distance	2444.6
Maximum positive-distance transect ID	2035
Average positive distances	378.53

The lowest values were observed in the northwestern and southeastern parts of Eğirdir, to the east of Barla Mountain, southeast of Karakuş Mountains, west of Kirişli Mountain, and

along the shores northwest of Sorkuncak Village. In these areas, the rate and magnitude of shoreline retreat were determined to be lower than those in other regions.

Different rates and magnitudes of shoreline retreat have been identified in various areas along the shoreline of Lake Eğirdir. This variation can be attributed to the topographic and bathymetric conditions. In shallow and wide areas, the shoreline retreat distance is greater, whereas in areas with steep slopes, the retreat distance is smaller. This explains why greater retreat is observed along the shores southwest of Gelendost, where the slope is gentle (Figure 10a), and less retreat is observed along the shores west of Sorkuncak Village, where the slope is steep (Figure 10b).

Evaluation of Temperature and Precipitation Trends

In this study, the Mann-Kendall trend analysis, which is frequently used in the literature, was employed to examine the relationship between temporal changes in the shoreline of Lake Eğirdir and climatic parameters. The analysis was conducted using the ± 1.96 critical z-score thresholds of 1.96 at 95% confidence level. For this purpose, long-term monthly average temperature, maximum temperature, minimum temperature, and total precipitation data from meteorological stations closest to Lake Eğirdir (Eğirdir, Isparta, Senirkent Uluborlu, Yalvaç) were used.

According to the Mann-Kendall statistical test applied to the study area, a positive trend was observed in the monthly average, maximum, and minimum temperature values obtained from the Eğirdir station, while no significant increase or decrease was detected in precipitation values (Table 4). Similarly, at Yalvaç Station, a positive trend was identified in the monthly average, maximum, and minimum temperature values (Table 4). Although the precipitation values at this station did not exhibit a significant trend

Figure 10

(a) Changes observed along the shore southwest of Gelendost and (b) west of Sorkuncak Village



Source: Google Earth/10.11.2024, 16:30

in either direction, Yalvaç showed the strongest decreasing trend in precipitation among all stations (-1.69). At the Senirkent station, the maximum and minimum temperature values exhibited a positive trend, while no significant increase or decrease was observed in the average temperature and precipitation values (Table 4). At Uluborlu Station, a positive trend in maximum temperature was detected. Conversely, no significant trend was observed for average temperature, minimum temperature, or precipitation values (Table 4). At Isparta Station, a positive trend was observed for average, maximum, and minimum temperature. However, no significant increase or decrease in precipitation values was identified at this station (Table 4).

Evaluation of the Anthropogenic Impact

Lake Eğirdir has undergone significant changes over the past century as a result of anthropogenic impacts resulting from human activities. These impacts have caused notable alterations in the lake's shoreline and substantial declines in its water level. As a source of drinking water, the intensive use of groundwater for irrigating orchards within the lake catchment area, along with the extraction of water directly from the lake for surrounding orchards, has led to serious issues in the lake's water balance.

According to these findings, disruption of the water balance is a key factor that drives changes in the shoreline. Rising temperatures due to climate change, particularly with 2023 being the hottest year in history, have further increased the pressure on the lake. Excessive water usage for fruit production around the lake is one of the major factors contributing to the rapid decline in the lake's water levels.

The spatial and temporal distribution of fruit orchards around Lake Eğirdir was examined using data from the Turkish Statistical Institute (TÜİK). The analyses were conducted based on fruit orchard area data from the districts of Eğirdir, Gelendost, Senirkent, Yalvaç and Uluborlu from 2004 to 2023.

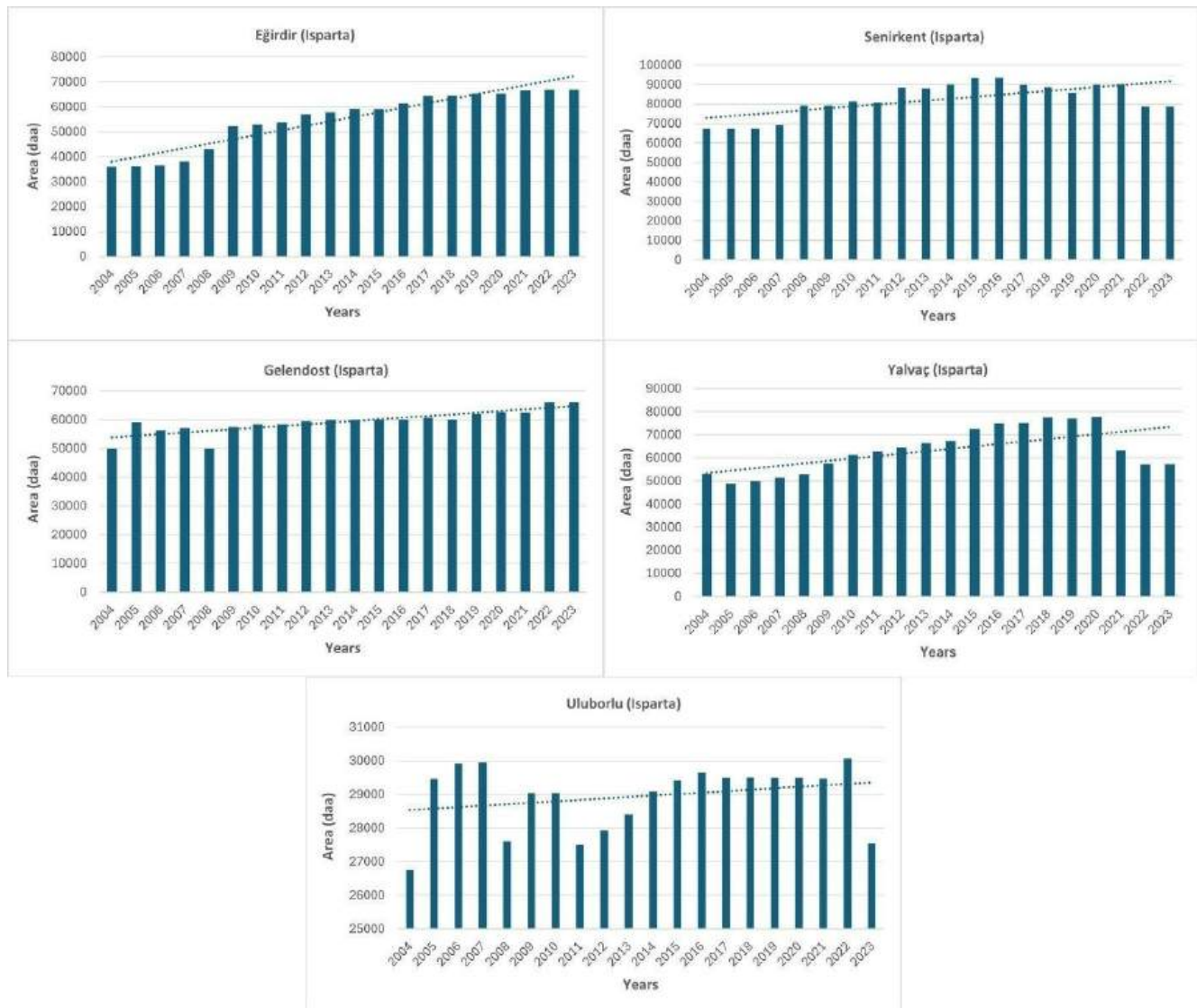
The analysis revealed that between 2004 and 2023, the area of fruit plantations expanded in nearly all districts bordering Lake Eğirdir. Although there were occasional fluctuations in certain years, the overall trend indicates an increase in the area of fruit orchards around the lake from 2004 to 2023 (Figure 11). This upward trend in the area of water-intensive fruit orchards poses a significant threat, contributing to the recession of the lake.

The increasing trend in temperature values, as revealed by climate data, combined with the continued demand for water to sustain the fruit orchards around the lake, has further

Table 4

Mann-Kendall Trend Analysis and Results in the Study Area.

Station	Parameter	Z- Score	Trend Direction	H ₁ Hypothesis	Za/2 (+/-)
Eğirdir (1984-2024)	Average Temperature (°c)	2,33	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Max. Tempt (°c)	2,04	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Min. Tempt (°c)	2,52	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Rainfall (mm)	0,29	No increase or decrease	<i>Reject</i>	1,96
	Average Temperature (°c)	2,46	<i>Increasing Trend</i>	<i>Accept</i>	1,96
Yalvaç (1984-2024)	Max. Tempt (°c)	1,79	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Min. Tempt (°c)	3,97	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Rainfall (mm)	-1,69	No increase or decrease	<i>Reject</i>	1,96
	Average Temperature (°c)	1,78	No increase or decrease	<i>Reject</i>	1,96
	Max. Tempt (°c)	2,52	<i>Increasing Trend</i>	<i>Accept</i>	1,96
Senirkent (1984-2024)	Min. Tempt (°c)	2,11	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Rainfall (mm)	-0,20	No increase or decrease	<i>Reject</i>	1,96
	Average Temperature (°c)	1,83	No increase or decrease	<i>Reject</i>	1,96
	Max. Tempt (°c)	2,59	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Min. sıcaklık	1,40	No increase or decrease	<i>Reject</i>	1,96
Uluborlu (1984-2024)	Rainfall (mm)	-0,75	No increase or decrease	<i>Reject</i>	1,96
	Average Temperature (°c)	2,40	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Max. Tempt (°c)	2,17	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Min. Tempt (°c)	3,19	<i>Increasing Trend</i>	<i>Accept</i>	1,96
	Rainfall (mm)	0,35	No increase or decrease	<i>Reject</i>	1,96
Isparta (1984-2024)	Rainfall (mm)	0,35	No increase or decrease	<i>Reject</i>	1,96

Figure 11*Changes and trends in fruit orchard area from 2004 to 2023*

exacerbated the negative development of the water balance. The convergence of these adverse factors resulted in a significant decline in the lake's water level and a substantial retreat of the shoreline.

Discussion and Conclusion

The reduction in the surface area of Lake Eğirdir has been highlighted multiple times in various studies conducted at different times (Aksoy *et al.*, 2019; Aslan & Koç-San, 2021; Büyükyıldız & Yılmaz, 2011; Göncü *et al.*, 2017; Kale & Erişmiş, 2024). In recent years, the decline in the lake's water level has become a focal point of research. This study examined the changes in the shoreline of Lake Eğirdir between 1984 and 2024 and evaluated the climatic and anthropogenic factors contributing to these changes. To calculate the magnitude and rate of shoreline changes, the Digital Shoreline Analysis System (DSAS), an extension of ArcGIS, was used. Statistical

values for the end-point rate (EPR), Linear Regression Rate (LRR), and Net Shoreline Movement (NSM) were calculated.

The changes in the shoreline of Lake Eğirdir were calculated in m/year using EPR and LRR analyses, while the NSM method was used to determine the direction and magnitude of these changes. The results show that accretion is characterised by shoreline recession, indicating a reduction in lake water levels. Positive EPR and LRR values indicate the continuity of accretion due to shoreline retreat. In particular, the highest EPR value of 61,06 m/yr and the highest LRR value of 39,78 m/yr calculated west of Akdağ highlight the speed and consistency of the retreat. Similarly, the highest positive NSM value of 2444,6 m indicates a significant long-term retreat in this region.

The negative NSM value (-46,96 m) indicates that erosion is effective in limited areas; however, it supports the

overall observation that the shoreline has predominantly experienced retreat. This reflects a long-term trend of declining lake water levels and ongoing changes in shoreline dynamics.

These findings are consistent with similar studies in the literature. For instance, the methods developed by Thieler *et al.* (2003) have been noted for producing reliable results, particularly with the EPR and LRR methods providing consistent outputs for measuring the shoreline change rates. Additionally, previous studies specific to Lake Eğirdir (Büyükyıldız & Yılmaz, 2011; Göncü *et al.*, 2017) emphasised the reduction in the lake's surface area, whereas this study has analysed specific shoreline change rates in greater detail. Furthermore, the effectiveness of the DSAS method in understanding shoreline dynamics has been highlighted by Rio *et al.* (2013) and Oyedotun (2014). In this context, the consistency of results obtained using different analytical methods in this study confirms the accuracy and reliability of the methods. These consistent results indicate a distinct linear trend in changes along the shoreline of Lake Eğirdir.

Mann-Kendall trend analysis was performed on the study area. The results indicate a notable increase in maximum temperatures across all stations. In addition to Uluborlu station, an increasing trend was also observed in minimum temperatures at the other stations. Average temperature trends showed an upward tendency at the Eğirdir, Yalvaç, and Isparta stations. As a general finding, there was no significant increase or decrease in precipitation at any station. The observed increasing temperature trends from the stations contributed to higher evaporation rates in the study area, while the lack of a corresponding increase in precipitation values (ranging from zero to negative trends) emerged as a contributing factor to the retreat of Lake Eğirdir's shoreline. Similar to the findings of this study, an increasing trend in maximum temperature values and a decreasing trend in precipitation values have been observed over the past 30 years, both in the study area (Şen, 2013; Coşkun, 2020) and across Turkey (Demir *et al.*, 2008; Şen, 2013). Data from the Gelendost station were excluded from the trend analysis in this study because recordings at the station only began in 2012. As the number of data points increased, the statistical power of the Mann-Kendall trend test also improved (Yue *et al.*, 2002). Therefore, trend tests were conducted using 40 years of data for the other stations, yielding significant results.

Compared to other lakes, the shoreline change rates in Lake Manyas are relatively lower, with a maximum EPR of 39,82 m/year and an LRR of 33,18 m/year. This study revealed that sediment accretion dominated along the southern shores due to alluvial input from the Manyas Stream, while shoreline

erosion persisted along the northern shores. The observed changes in Lake Manyas can be attributed not only to the sediment transported by the Manyas Stream but also to anthropogenic factors such as agricultural water use and dam construction (Uzun, 2024).

In a similar study conducted at Lake Salda, the EPR and LRR were calculated as 16,35 and 12,91 m/year, respectively, with the primary drivers of change identified as rising temperatures, variations in precipitation, and dam construction (Dereli & Tercan, 2020). In contrast, the shoreline change in Lake Burdur occurred at a much faster rate. Between 2013 and 2023, the maximum EPR and LRR were 543,12 m/year and 610,07 m/year. This rapid change has been primarily attributed to intensive agricultural water use (Baş, 2023).

Compared to these studies, the highest EPR value calculated for Lake Eğirdir was 61,06 m/year, while the highest LRR value was 39,78 m/year, indicating the rate and ongoing nature of shoreline retreat. In comparison to Lakes Manyas and Salda, shoreline change rates in Lake Eğirdir are higher, yet they remain lower than the extreme rates observed in Lake Burdur. The primary drivers of shoreline changes in Lake Eğirdir have been identified as rising temperatures and, in particular, the irrigation demand of water-intensive fruit orchards.

The anthropogenic impacts observed in and around Lake Eğirdir have various effects, ranging from the diversity of flora and fauna to declines in water levels. Although wild irrigation is no longer as prevalent as it once was, agricultural irrigation in the basin, where the water balance has been disrupted, continues to be a factor contributing to the reduction in the surface area of Lake Eğirdir. This claim is supported by the findings of the study.

Land use data extend back approximately six years and do not fully reflect the current situation. Therefore, the distribution and condition of fruit orchards around Lake Eğirdir were examined through observations and field studies. Observations revealed that fruit orchards are highly preferred in the region due to their high economic returns. This finding is also supported by Karatepe's (2004) study, which noted that agricultural activities with high economic returns have caused significant changes in land use around the lake. However, watershed planning in and around lakes is significantly lacking. The current watershed management is insufficient to reduce the pressure of water consumption on the lake. Therefore, re-evaluating and redesigning watershed management practices. Crops to be cultivated in the watershed should be selected based on their water consumption levels, and agricultural activities with high water use should be managed in a controlled manner. These

measures will contribute to both the preservation of the lake's water levels and to ensuring agricultural sustainability.

Water resources around Lake Eğirdir are under significant changes due to the pressure of human activities. Agricultural irrigation, land use, and other anthropogenic impacts at the watershed scale directly contribute to shoreline retreat and water level declines. In particular, the cumulative effects of human activities on river channels and water resources are critical for sustainable river management. Downs and Piégay (2019) emphasised that human-induced activities within watersheds alter the morphology of river channels, and this impact must be integrated into sustainable water management strategies. Similarly, Rybkina (2023) highlighted that the methodological evaluation of anthropogenic pressure on water resources forms the basis for improving water use efficiency and conserving resources. In this context, strategies are needed to reduce water consumption in Lake Eğirdir and ensure watershed management sustainability.



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Adaptation of the Climate Change Curiosity Scale into Turkish



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Abstract

In this study, the Climate Change Curiosity Scale (CCCS) developed by Próchniak and Ossowski (2023) was adapted into Turkish. The research was conducted on three separate study groups consisting of 527 prospective teachers. Of the 349 participants in the first study group, 10 were excluded from the dataset as they were outliers. The confirmatory factor analysis was conducted on the remaining 339 participants and it was detected that the unidimensional structure in the original version of the scale was verified and the factor loadings of the items ranged between .33 and .67. Within the scope of concurrent validity, the hypothesis that there was a positive significant relationship between the CCCS scores and the scores obtained from the Climate Change Worry Scale was tested, and the correlation analysis results performed with the data collected from 99 prospective teachers confirmed this hypothesis. The data from the first study group were used for internal consistency reliability estimates and item analysis, and the McDonald's omega and Cronbach's alpha coefficients were found to be .863 and .859, respectively, while the item correlations varied between .33 and .62. Test-retest reliability was examined on the data of 79 prospective teachers, and the intraclass correlation coefficient calculated for this purpose was obtained as .899. These results indicated that the Turkish version of the CCCS is a valid and reliable instrument.

Keywords

Climate change • curiosity • scale adaptation



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INTRODUCTION

Climate change implies global shifts in climate patterns such as average seasonal temperatures and precipitation rates and considered one of the major challenges facing humanity in the 21st century (IPCC, 2021). Previously explained by natural processes such as reflected energy from the sun (i.e., solar cycle) and large volcanic eruptions, climate change is now associated with anthropogenic factors such as industrialisation, increased greenhouse gas emissions, unsustainable policies in energy and land use, and effects from production and consumption habits (IPCC, 2023; Türkeş, 2008). Human-driven climate change causes intense air pollution, storms, floods, droughts, heat waves, and many extreme weather events in every region of the world, as well as an increase in the frequency and intensity of forest fires (Kumar, 2023). This situation has widespread negative effects on food and water security, human health, economies, and societies (IPCC, 2023). For example, climate change-induced extreme weather events account for more than 80% (618.5 billion US dollars) of the economic damage caused by natural disasters. Moreover, disasters led to the deaths of approximately 90,325 people in Europe between 1980 and 2017 (EEA, 2019). The increase in glacier melting stemming from excessive warming and the accompanying rise in ocean and sea levels have made life difficult for creatures such as penguins and polar bears living in these ecosystems. Also, the increase in sea levels and natural disasters such as hurricanes, storms, and floods have caused the migration of people living in coastal areas and the loss of regional economic livelihoods. Ocean warming and acidification have negatively affected food production from fishing and shellfish farming in some ocean regions. Increasing droughts globally have also generated major economic damage to other climate-sensitive sectors such as agriculture, forestry, and tourism (IPCC, 2023). Beyond its economic and social ramifications, climate change has contributed to a rise in various health problems, including heat stroke, diarrhea, cardiovascular failure, and a range of infectious and pathogenic diseases (Albrecht, 2011; Altizer et al., 2013; Kakaei, 2021; Lafferty, 2009; Mora et al., 2022). Moreover, through its indirect impacts—such as forced migration, drought, and insecurity in water and food supplies—it has triggered the psychological disorders, including distress, depression, anxiety, sleep disturbances, aggression, substance abuse, and suicidal ideation (Bourque & Cunsolo Willox, 2014; Burke et al., 2018; Cianconi, 2020; Clayton, 2020; Kumar, 2015; Manning & Clayton, 2018; Stewart, 2021).

Curiosity about Climate Change

The perception of climate change crises as threats depends on individuals' personal experiences, beliefs, understanding of existing information, and curiosity about environmental disasters (Goodwin et al., 2017). As the acute and long-term effects of climate change become a lived experience for an increasing portion of the world's population, it is specified that the number of people experiencing psychological distress due to the environmental and climate crisis will increase (Ojala et al., 2021; Pihkala, 2020). Despite its clearly visible consequences, numerous people deny climate change, thinking that it is a fad and an artificial agenda put forward by ecologists. However, there are also a considerable number of people who are interested in stopping climate change. These people take care of the causes, consequences and dealing strategies connected with climate change; they wish to inquire into the impacts of climate change. Individuals' curiosity about the subject makes a significant contribution to their efforts to combat climate change (Próchniak & Ossowski, 2023).

Curiosity is the urge to experience, see, or discover that is satisfied by acquiring new information and does not require any external reinforcement (Dyche & Epstein, 2011; Litman, 2007). In the psychology literature, curiosity is handled under two headings: epistemic and perceptual (Berlyne, 1954). Both types of curiosity are critical motives that can impact human behaviour in both positive and negative ways at all stages of the life cycle (Loewenstein, 1994). However, they differ in the inputs that activate them and the behaviours they motivate (Collins et al., 2004). Epistemic curiosity is aroused from the desire to learn new knowledge, eliminate ambiguous and solve intellectual conundrums (Litman, 2008, 2012), and relieved as information gaps are filled (Berlyne, 1957). It leads to epistemic behaviour which includes directed thinking (McGuire & Rowland, 1966) and underlies many decisions in our everyday life, such as asking questions, reading books, browsing the internet, watching movies, or engaging in trivia quizzes (Ligneul et al., 2018). Perceptual curiosity, on the other hand, is a drive evoked by sensory perceptions, namely visual, auditory, tactile, smell or taste stimulus (Litman & Spielberger, 2003) and diminished by continued exposure to these stimuli (Berlyne, 1954). That is to say, in contrast to epistemic curiosity, which is observed for more familiar stimuli, perceptual curiosity typically emerges in the face of highly novel stimuli (Sakaki et al., 2024). Perceptual curiosity provoked the exploratory behaviours such as visual and olfactory inspection or attentive listening (Litman et al., 2005). As can be understood from their listed features, epistemic curiosity is a more developed type of curiosity found only in



humans, whereas perceptual curiosity is a more rudimentary form of curiosity available to humans and animals alike (Litman, 2000; McNary, 2024; Metcalfe et al., 2020; Subaşı, 2019). Based on these explanations, epistemic and perceptual curiosity within the context of climate change can be conceptualised as follows: Epistemic curiosity about climate change pertains to seeking information about the causes and consequences of climate change and ways to cope with this issue. When it comes to perceptual curiosity regarding climate change, it can be remarked that being exposed to heavy rain, prolonged droughts, violent winds, or so hot/cold weather will pique this curiosity. Curiosity motivates a person to explore and investigate perceived stimuli and is seen as a value for environmental adaptation (Próchniak & Ossowski, 2023). Therefore, curiosity about climate change will encourage people to conduct deep systematic research on the subject and develop solutions to eliminate the sources of the problem. This makes it important to reveal individuals' curiosity levels about climate change. To this end, Próchniak and Ossowski (2023) developed the Climate Change Curiosity Scale (CCWS). While previous measurement tools on climate change generally focused on beliefs (Salomon et al., 2017), attitudes (Christensen & Knezek, 2015), knowledge (Dijkstra & Goedhart, 2012), perceptions (Valkengoed et al., 2021), understanding (Libarkin et al., 2018), anxiety (Clayton & Karazsia, 2020), worry (Stewart, 2021) and distress (Searle & Gow, 2010) related to the topic, to the best of our knowledge, there was no scale that captured curiosity about the climate change until Próchniak and Ossowski (2023) developed the CCCS. Yet, curiosity constitutes the basis of the listed cognitive and affective traits and can function as a structure that regulates them. As such, CCCS is an original tool that is different from the prior instruments in the literature.

Climate Change Curiosity Scale (CCCS)

The CCCS is a 15-item scale with a five-point Likert-type rating. During the development of the scale, Próchniak and Ossowski (2023) created an item pool of 47 items. Then, they reviewed the crafted items and 9 redundant items were removed from the pool, and the 38-item form was presented to the five experts in the field of environmental psychology. As a result of the experts' scoring, items with an average score of 4.00 and higher were kept in the form, and 8 items below this value were eliminated. For the remaining 30 items in the scale, the authors anticipated a three-factor structure with 10 items each, namely curiosity about the sources of climate change, the consequences of climate change and mechanisms of dealing with climate change. The validity and reliability studies of the scale were conducted on 306 participants,

including 220 female (71.90%), 79 male (25.82%) and 7 people (2.29%) who identified themselves with a gender other than male or female. The participants' ages ranged between 18 and 83 (Mean: 25.75; Standard deviation: 8.35). Before the exploratory factor analysis (EFA), the researchers assessed the sample adequacy and the data suitability for the factor analysis. They calculated the Kaiser-Meyer-Olkin (KMO) value as .965 and found the Bartlett's test was significant and concluded that the data were factorable.

In the EFA, parallel analysis results revealed a unidimensional structure in contrast to the three-dimensional prescribed construct for the scale, and the items with factor loadings below .70 were removed from the scale. Thus, they obtained a 15-item scale, which was collected under a single factor, explained 60% of the total variance, and had factor loadings ranging between .71 and .82. In the confirmatory factor analysis (CFA), both the one-factor structure that emerged as a result of EFA and the three-factor structure anticipated in the scale development process were tested. The CFA results showed that the fit indices for the three-factor structure did not meet the acceptable criteria ($\chi^2=900.978$, $df=90$, CFI=.653, TLI=.684, RMSEA=.443), while the fit indices for the single-factor model were within the recommended thresholds ($\chi^2=280.14$, $df=90$, CFI=.919, TLI=.926, RMSEA=.044). Próchniak and Ossowski (2023), within the scope of the validity studies of the CCCS, also examined its relationship with a series of scales named as nature curiosity, climate anxiety, environmental identity, curiosity and exploration, need for cognitive closure and generational time perspective; the correlation analysis outputs supported the validity of the scale. The researchers estimated the reliability of the scale via Cronbach's alpha internal consistency coefficient and reported it as .95. They found that the item-total correlations varied between .66 and .80.

Purpose and Significance of the Study

The purpose of this study was to adapt the CCCS developed by Próchniak and Ossowski (2023) into Turkish culture and evaluate its psychometric properties in a Turkish sample. Specifically, the study investigated the factorial structure of the CCCS' Turkish version through CFA and examined its concurrent validity by testing the hypothesis that "There is a statistically significant positive relationship between the CCCS scores and the scores obtained from the climate change worry scale (CCWS)." Two primary considerations informed the selection of the CCWS to establish concurrent validity. First, Próchniak and Ossowski (2023) identified a significant correlation between respondents' levels of climate change anxiety and their scores on the CCCS. Second, the CCWS,

comprised of only 10 items, is a concise tool that can be applied simultaneously with the CCCS without imposing a burden or fatigue on participants. In the study, the reliability of the CCCS scores was assessed through internal consistency and test-retest coefficients, while item discrimination was evaluated by analysing item correlations.

When the Turkish literature was reviewed in terms of measurement tools for climate change, the climate change anxiety scale (Cebeci et al., 2022), the climate change worry scale (Gezer & İlhan, 2021; Özbay & Alici, 2021), the climate change awareness scale (Dal et al., 2015; Deniz et al., 2021), the climate change knowledge test (Gezer & İlhan, 2019), and the climate change hope scale (Gezer & İlhan, 2020) were encountered. The environmental worry index developed by Oguntayo et al. (2023) and adapted into Turkish by İlhan et al. (2024), also contains items to measure climate change anxiety. While the listed tools are valuable, they remain insufficient for capturing the climate change curiosity. Since people's curiosity about the subject is an important determinant of their beliefs, willingness, and efforts to eliminate the effects of climate change, it is thought that it is important to introduce a scale to the Turkish literature to measure curiosity about climate change. To clarify, although curiosity functions as a motivational driver for engagement in climate change challenges, the lack of an instrument to measure this construct in the Turkish literature has paved the way for this paper.

The current study was designed in a way that would allow the limitations stated by the researchers who developed the original form of the scale to be overcome. The research is expected to contribute to the literature in this respect. First, Próchniak and Ossowski (2023) collected the data online in their study and drew attention to the fact that this may have reduced the data quality. For this reason, they recommended that the scale be administered to the participants face-to-face in further studies. Based on this point, the data of the present study were collected face-to-face (i.e. paper-pencil format). Therefore, this study will be able to contribute to overcoming the just mentioned limitation. Another limitation of the original form of the CCCS was that only the Cronbach's alpha coefficient was calculated as evidence of reliability, and the reliability of the scale in terms of stability was not tested (Fikri, 2023; Próchniak and Ossowski, 2023). Considering this limitation, the test-retest reliability was also calculated in this adaptation study in addition to the internal consistency coefficients. Furthermore, both Fikri (2023), who critically examined the original form of the scale and wrote it in a letter to the editor, and Próchniak and Ossowski (2023) remarked that the evidence on the concurrent validity of the

CCCS should be enriched and suggested that the correlation of curiosity about climate change with different psychological constructs related to the subject should be examined in this context. Given that, the current study investigated the relationship between the CCCS and the CCWS. It can be stated that the research will contribute to the literature in this respect.

METHOD

Study Group

The study group was selected according to the convenience sampling technique owing to practical constraints. Psychometric analyses were conducted on three separate groups. The first group included a total of 349 prospective teachers, 255 of whom were female (73.10%) and 94 of whom were male (26.90%), aged between 17 and 44 (Mean: 21.39, Standard Deviation: 2.87). CFA, calculation of internal consistency reliability and item analysis were performed on the data belonging to this group. The second group comprised 99 prospective teachers, 84 of whom were female (84.80%) and 15 of whom were male (15.20%), aged between 17 and 34 (Mean: 21.39, Standard Deviation: 2.99). The concurrent validity of the CCCS was tested using the data obtained from this group. The third group, from which data regarding the test-retest reliability study was collected, consisted of a total of 79 prospective teachers, 68 of whom were female (86.20%) and 11 of whom were male (13.80%), aged between 17 and 32 (Mean: 21.44, Standard deviation: 2.61). As it requires administering the measurement tool to the same group twice at certain intervals, reaching large groups is challenging in terms of test-retest reliability. Hence, the sample from which the test-retest reliability was calculated was smaller than the other two samples. Nevertheless, since the number of subjects in the relevant sample was greater than 30 (Koçak et al., 2022), it can be posited that the group used to calculate the test-retest reliability was also an adequate size.

Instrument

In addition to the CCCS, the CCWS was also employed to collect research data. The CCWS was developed by Stewart (2021) and adapted to Turkish by Gezer and İlhan (2021). There are 10 items in the scale with the five-point Likert type rating from *Never* (1) to *Always* (5). The original form of the scale has a unidimensional structure that explains 73.60% of the total variance, with factor loadings of the items varying from .73 to .90. Stewart (2021) calculated Cronbach's alpha and McDonald's omega coefficients to estimate the reliability of the measurements obtained with CCWS and reported both coefficients as .95. In the Turkish form of CCWS, a two-

dimensional structure was attained, unlike the original form, and Gezer and İlhan (2021) named the resulting dimensions as anxiety and the feeling of helplessness. According to the EFA results, there were seven items in the anxiety dimension with factor loadings ranging from .49 to .90, and it was determined that this dimension contributed 52.57% to the variance explained by the scale. The feeling of helplessness dimension consisted of three items with factor loadings ranging from .82 to .85, and the contribution of this dimension to the explained variance was established as 11.60%. Gezer and İlhan (2021) applied CFA in addition to EFA and found the fit indices of the two-factor structure as $\chi^2/df=2.06$, RMSEA=.095, SRMR=.062, NFI=.94, NNFI=.96, CFI=.97, IFI=.97, GFI=.90, and RFI=.92. In the Turkish form of the CCWS, Cronbach's alpha coefficients for the anxiety and feeling of helplessness dimensions were estimated as .87 and .83, respectively, while the stratified alpha reliability for the entire scale was detected as .91. In the present study, analyses were performed on the total score obtained from CCWS, and the McDonald's omega and Cronbach's alpha coefficients for the entire scale were found to be .832 and .838, respectively. Özdamar (2011) stated that coefficients between .70 and .90 indicate high reliability and that measurements with this reliability can be used confidently in scientific research. Thus, it was judged that the scores of the CCWS were sufficiently reliable.

Translation Process of the Scale into Turkish

Before the translation procedure, Piotr Próchniak, the responsible author of the article in which the original form of the CCCS was developed, was contacted via e-mail and his permission was requested for the adaptation study. After Piotr Próchniak approved the adaptation of the scale into Turkish, the translation operation was started. Four principal methods are available for translating an instrument from the source language into the target language: (1) judgement-based single translation, (2) judgement-based back-translation, (2) statistical single translation, and (4) statistical back translation. (Hambleton & Bollwark, 1991). In the present study, statistical methods were not used because the authors could not reach a group to which they could administer both the Turkish and English forms of the CCWS. In addition, as the translation process engaged specialised from multiple disciplines and the equivalence of the translated version to the original one was supported by additional experts' evaluations, back-translation was deemed omissible, and a single-translation method was employed in the study.

The scale items were translated into Turkish by three experts, each representing a distinct field: social studies education, geography education, and measurement and evaluation

in education. The selection of the translation team was based on the relevance of their respective disciplines to climate change concepts and the psychometric field. While experts in social studies and geography education ensured the contextual accuracy of climate-related terminology, the measurement and evaluation specialist contributed to the creation of a scale form aligned with psychometric principles. Following the translation of the scale items into Turkish, the independent translations were systematically compared to identify potential discrepancies. In order to resolve any observed divergences, the consensus-based decision-making approach focusing on maintaining conceptual accuracy rather than word-for-word translation was used. Once the most appropriate Turkish equivalent of each item was created, the finalised version of the CCCS was reviewed by two experts from the field of English language education. These experts, who are fluent in both languages, comparatively analysed the original and Turkish forms of the scale and announced that the two versions were linguistically equivalent. Thereby, it was concluded that the Turkish version of the CCCS was ready for administration. A five-point Likert-type rating was adopted in the Turkish version of the scale as in the original.

Data Collection

Before initiating the data collection process, an application was made to Dicle University Social and Human Sciences Ethics Committee regarding the compliance of the study with the current ethical principles. With the approval letter dated 27.08.2020 and numbered 81787, it was confirmed that the study complied with the national and institutional research ethics guidelines (i.e., informed consent, voluntary participation, confidentiality and data protection). Data were collected in December 2024 in the respondents' own classroom environments. In light of the potential data quality concerns pointed out by Próchniak and Ossowski (2023) regarding online data collection, the CCCS was administered in paper-and-pencil form to increase the participants' motivation and response rate (O'Leary & Tennen, 2025), to allow for greater researcher control over the data collection process (Ang, 2021), and to minimise the self-selection bias (Bethlehem, 2010) and likelihood of careless responding (Meade & Craig, 2012).

The prospective teachers in the first study group responded only to the 15-item CCCS. The second study group was presented with two scales simultaneously, with the 15-item CCCS on the front of the data collection tool and the 10-item CCWS on the back. The third study group, where test-retest reliability data were obtained, was administered the CCCS twice with 3 weeks apart. In test-retest reliability, it

Table 1
Univariate Normality Test Results

Datasets	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
Dataset used for CFA, internal consistency reliability and item analysis (n=339)	-.66	.13	1.05	.26
Dataset used for concurrent validity (n=99)				
CCCS	-.73	.24	.80	.48
CCWS	-.48	.24	.16	.48
Dataset used for test-retest reliability (n=79)				
First administration	-.31	.27	-.23	.54
Second administration	-.14	.27	-.40	.54

is not possible to specify anything exact about the interval that should elapse between the two administrations. This is because the ideal duration differs according to the nature of the trait being measured and the developmental characteristics of the target group (Mitchell et al., 2000). Having said that, a period of 2-3 weeks is generally considered sufficient (Atçı & İlhan, 2024; Koçak et al., 2022) in order to prevent the potential impacts arising from the participants' remembering their responses in the first application on the one hand and due to maturation, learning, and personal experiences on the other hand (Crocker & Algina, 1986).

No names or nicknames were requested from the respondents in the first and second study groups other than demographic information, while participants were asked to write a memorable nickname at the beginning of the scale form for test-retest reliability. This procedure enabled the matching of the scale forms responded by the participants in the two applications, resulting in the exclusion of 21 individuals from the final sample who were absent and thus participated in only one session.

Data Analysis

In the first step of the data analysis, each of the three separate data sets was checked for missing values and miscoding. For this purpose, the frequency values for each item were calculated. No missing data or any values outside the range of 1-5 indicating incorrect coding were found. Following this, the data were examined for outliers and the normality assumption. No data with a Z score outside the range of ± 4 (Stevens, 2009) was observed in any data file, showing that there were no univariate outliers in the data sets. The dataset to which CFA was applied was screened not only for univariate outliers but also for multivariate outliers using the Mahalanobis distance procedure. After 10 multivariate outliers were excluded from the data file, 339 participants remained in this dataset. Skewness and kurtosis coefficients were calculated to test univariate normality, and the results are presented in Table 1.

The fact that the skewness and kurtosis coefficients in Table 1 remain within the range of ± 1.5 (Tabachnick & Fidell, 2019) reflects that the research data meet the univariate normality assumption. Accordingly, within the scope of concurrent validity, the Pearson product-moment correlation was exerted to inspect the relationship between the prospective teachers' scores on the CCCS and CCWS. For test-retest reliability, the relationship between the participants' scores from the first and second administration was examined the intraclass correlation coefficient. The guideline published by Koo and Li (2016) was referenced for the intraclass correlation analysis, and the two-way mixed effect for the model, mean of k measurements for the type, and consistency for the definition were selected. While judging the coefficients obtained from the Pearson correlation and intraclass correlation analysis, the ranges suggested by Salkind (2017) were taken as the basis. Correlation coefficients between .00 and .20 in terms of its absolute value were interpreted as very weak, between .20 and .40 as weak, between .40 and .60 as moderate, between .60 and .80 as strong, and between .80 and 1.00 as very strong.

In the study, it was not necessary to apply EFA to provide evidence for the construct validity of the CCCS; it was deemed sufficient to perform only CFA and test whether the unidimensional structure in the main version of the scale was valid in Turkish culture. In order to decide on the estimation method to be used in CFA, multivariate normality was also tested in addition to univariate normality. In this direction, Mardia's test was applied, and the multivariate skewness and kurtosis coefficients were found to be 25.55 ($\chi^2_{sd=680}=1443.79$, $p<.001$) and 311.70 ($z=23.11$, $p<.001$), respectively. The statistical significance of the calculated coefficients indicated that the multivariate normality was violated and that the maximum likelihood estimator based on a normal distribution could be misleading. That's why the robust maximum likelihood estimator that provides corrections to the model-fit statistics and standard errors while undertaking structural equation modelling with non-normally distributed data was operated in CFA (Preston, 2022). Numerous statistical indices are available for judging model-data fit in CFA, and which indices should

Table 2*Criterion Values for Fit Indices Examined for Model-Data Fit in the CFA*

Fit Indices	¹ χ^2/df	² RMSEA	² SRMR	² CFI	² TLI
Criteria values	< 3	< .08	< .10	> .90	> .90

B¹ Schermelleh-Engel et al. (2003), ² Pituch and Stevens (2016)**Table 3***Fit Indices Reported in CFA for the Turkish Form of the CCCS*

Fit Indices	χ^2/df	RMSEA	SRMR	CFI	TLI
Values before modification	2.50 ($\chi^2=224.92$, $df=90$)	.07 %90 CIs (.06 – .08)	.06	.89	.87
Values after modification	2.17 ($\chi^2=193.33$, $df=89$)	.06 %90 CIs (.05 – .07)	.05	.92	.90

be reported remains a subject of ongoing debate. Based on existing literature (Bentler, 2008; Brown, 2006; In'nami & Koizumi, 2011; Kline, 2011) and their personal observations, Ockey and Choi (2015) recommend that the following be reported: two absolute fit indices, the model chi-square statistic along with its degrees of freedom (df) and p -value and the SRMR; one adjusted parsimony fit index, preferably RMSEA and its 90% confidence interval; and one relative fit index, preferably CFI or TLI. From this suggestion, when deciding whether the model in the CFA was supported by empirical data, the fit indices and their corresponding criteria values in Table 2 were considered.

In the study, McDonald's omega and Cronbach's alpha coefficients were calculated to estimate the internal consistency reliability of the measurements obtained via the Turkish form of the CCCS. The rationale for calculating both McDonald's omega and Cronbach's alpha rather than presenting a single internal consistency coefficient was as follows: The fact that it produces more accurate reliability estimates for congeneric measures that violate the tau-equivalence assumption (Yurdugül, 2006) has served as a basis to the calculation of McDonald's omega. Nevertheless, as it was the most frequently reported reliability estimate (Boztunç Öztürk et al., 2015; İlhan et al., 2024; Şahin & Boztunç Öztürk, 2018), it was thought that if there were any researchers who intended to execute a reliability generalisation meta-analysis for the CCCS in the future, these researchers might need the Cronbach's alpha coefficient. Hence, Cronbach's alpha was also estimated, although it is not an optimal measure of reliability relative to its more general form, McDonald's omega (Hayes & Coutts, 2020). Finally, corrected item total correlations were investigated in order to determine the items' discrimination power in the Turkish form of the scale, and item correlations exceeding the .30 lower limit (Erkuş, 2012; Field, 2009) were interpreted as an indicator of

item discrimination. All analyses implemented in the research were performed in the JASP 0.18.3.0 program.

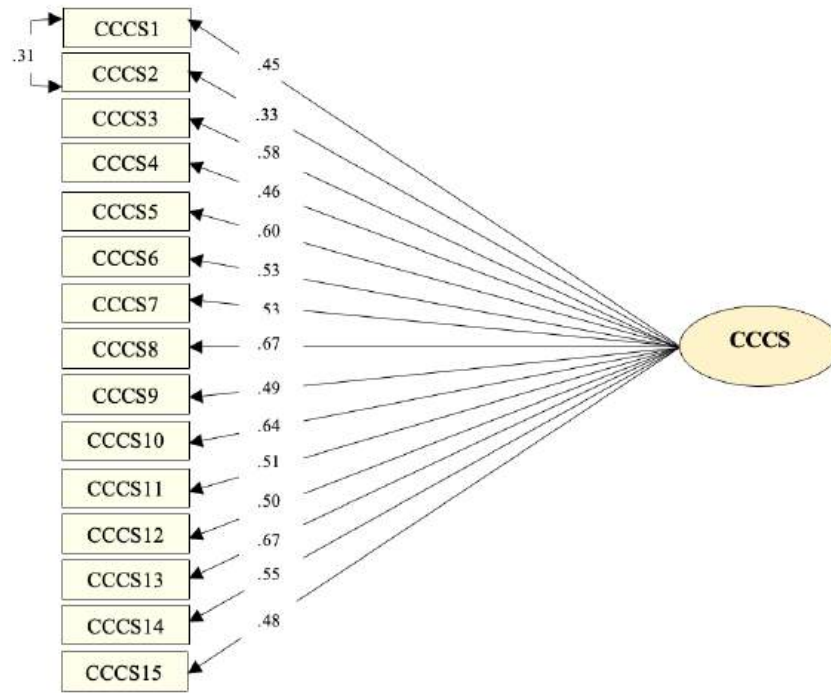
FINDINGS

To assess the psychometric properties of the measurements collected using the Turkish form of the CCCS, the analyses began with a confirmatory factor analysis (CFA), and the fit indices are presented in Table 3. As seen in Table 3, while χ^2/df , RMSEA and SRMR were within the acceptable ranges, CFI and TLI did not meet the recommended thresholds. For this reason, the modification suggestions in the analysis outputs were examined. It was seen that the suggestion that would improve the model-data fit the most was to relate the error variances of the scale's items numbered one and two. Since the two items were similar in terms of their contents and were indicators of the same factor, it was concluded that the modification in question could be explained theoretically. Even so, before making the final decision on the modification, the opinion of an expert who has studies on climate change was also taken, and this expert reported that the statistically proposed modification was theoretically reasonable. With the application of the relevant modification, all of the fit indices considered had acceptable values.

After it was understood that the model-data fit was achieved, the factor loadings were checked over and the reported factor loadings are illustrated in the measurement model in Figure 1. Figure 1 indicates that the items in the Turkish form of the CCCS have factor loadings ranging from .33 to .67.

Subsequent to the CFA, to provide further evidence of the CCCS's validity, the correlation between prospective teachers' scores on the CCCS and the CCWS was calculated. The correlation analysis results revealed a positive, strong and statistically significant relationship between the two variables ($r = .69$ 95% CIs [.57 – .78], $p < .001$).



Figure 1*Measurement Model Acquired from CFA for the Turkish Form of the CCCS***Table 4***Internal Consistency Coefficients and Item Correlations of the CCCS' Turkish Version*

Item Number	r_{jk}	Item Number	r_{jk}	Item Number	r_{jk}
CCCS1	.43	CCCS6	.49	CCCS11	.47
CCCS2	.33	CCCS7	.50	CCCS12	.46
CCCS3	.53	CCCS8	.62	CCCS13	.61
CCCS4	.42	CCCS9	.45	CCCS14	.52
CCCS5	.56	CCCS10	.57	CCCS15	.45
McDonald omega: .863 (95 % CIs [.841 – .884]), Cronbach's alpha: .859 (95 % CIs [.836 – .879])					

Following the validity evidence, internal consistency reliability was calculated and item analysis was performed. The McDonald's omega and Cronbach's alpha coefficients estimated for internal consistency and the corrected item-total correlations (r_{jk}) calculated for item discrimination are presented in Table 4. Table 4 shows that the McDonald's omega and Cronbach's alpha internal consistency coefficients of the measurements obtained with the Turkish form of the CCCS were .863 and .859, respectively, and the corrected item total correlations varied between .33 and .62.

Finally, the test-retest reliability was examined in order to estimate the reliability of the scale in terms of stability. According to the intraclass correlation coefficient (ICC) calculated for this purpose, a statistically significant, positive and very strong relationship was found between the scores that the prospective teachers received from the CCCS in two

administrations carried out three weeks apart ($ICC=.899$, 95% CIs [.842 – .935], $p<.001$).

Evaluation of the CCCS Scores

The CCCS consists of 11 items. A five-point Likert scale was adopted, where scores of 5 and 1 correspond to *Strongly Agree* and *Strongly Disagree*, respectively. Accordingly, the possible scores on the scale range from 11 to 55. There are no reverse-scored items in the instrument. An increase in the CCCS scores reflects a higher level of curiosity about climate change.

DISCUSSION AND CONCLUSION

In this study, the CCCS developed by Próchniak and Ossowski (2023) to determine individuals' curiosity about climate change issues was adapted to Turkish. In the first step of the adaptation process, an attempt was made to reach a Turkish form linguistically equivalent to the original scale, and

experts' opinions were exploited for this purpose. Analyses were conducted to determine the scale's psychometric qualities on the data obtained by applying the created Turkish form to prospective teachers. Analyses were conducted within the framework of the classical test theory.

Validity studies were started with CFA, and it was tested whether the 15-item and single-factor construct observed in the original form of the scale was preserved in the Turkish form. The fit indices reported in the CFA showed that the structure in the main version was verified in the Turkish culture. An examination of the factor loadings revealed that all items, except CCCS2, had loadings exceeding .40. Although the factor loading of CCCS2 was lower than that of the other items, it was retained in the scale based on the following considerations: (1) its loading was greater than the minimum acceptable threshold of .32 (Pituch & Stevens, 2016; Tabachnick & Fidell, 2019), (2) its exclusion did not result in a substantial improvement in model-data fit, and (3) preserving the item supported the goal of maintaining fidelity to the original version of the scale. In the next stage of the psychometric analyses, the relationship between the participants' CCCS and CCWS scores was tested so that the concurrent validity could be identified. A positive, strong, and statistically significant coefficient was obtained in the correlation analysis. This result uncovered that the hypothesis "There is a significant positive relationship between the participants' scores on the CCCS and CCWS" tested in the criterion validity study was confirmed.

After the analyses that provided evidence for the validity of the measurements, the reliability and item analysis were executed. In the reliability analysis, the McDonald's omega and Cronbach's alpha internal consistency coefficients were estimated as .863 and .859, respectively, while the intraclass correlation coefficient reflecting the test-retest reliability was calculated as .899. DeVellis (2017) claims that reliability coefficients exceeding .80 are excellent. Accordingly, it is possible to say that the measurements collected with the Turkish form of the CCCS have high reliability in terms of both internal consistency and stability. When the item analysis results were examined, it was determined that the corrected item total correlations exceeded the .30 cut-off point (Ebel & Frisbie, 1991) for all items in the scale. This hints that there are no items in the Turkish form of the CCCS that do not serve the scale's purpose.

All the findings on the psychometric analyses suggest that the CCCS' Turkish form is a scale that provides valid and reliable measurements on prospective teachers. However, there are some differences between the original and Turkish forms of the scale in terms of their psychometric qualities. Even though

the Turkish form of the CCCS has a single-factor structure with 15 items, which is compatible with the source form, the factor loadings, internal consistency reliability, and item correlations of the Turkish version were relatively lower compared to the original form. This may be attributed to the differences in the demographics of the samples. The group in which the current study was conducted has a composition parallel to that of the original form in terms of the higher proportion of female compared to male, but it is more homogeneous than the sample from which the original scale was developed in terms of age and education level. This may have been reflected in the factor loadings, internal consistency reliability, and item correlations. The variations in the internal structure-based validity and reliability evidence of the original and Turkish versions of the CCCS could also be attributed to differences in the administration methods. To put it more clearly, the administration modes—online for the original version and face-to-face for the Turkish version—may have introduced differences in participants' response behaviours, potentially influencing the scale's psychometric properties. Indeed, Buchanan (2002) emphasised that although there is evidence that online and traditional versions of the same instrument can measure the same constructs, there is also evidence indicating that these instruments are not always identical.

In terms of the concurrent validity results of the original scale and its Turkish form, the situation was in the opposite direction of the psychometric evidence based on internal structure. Both this study and Próchniak and Ossowski (2023) found a significant positive correlation between the CCCS and climate change concern. However, the correlation observed in the current research, was stronger than that reported by Próchniak and Ossowski (2023). This result might be due to the use of different tools to measure climate change concern in the two researches, or it is again related to differences in sample characteristics and administration methods (online vs. face-to-face).

Avenues for Future Research

The study has certain limitations, and these limitations bring with them some suggestions for further research. The first was related to the characteristics of the sample. The research was conducted with participants selected using the convenience sampling method, most of whom were female and relatively homogeneous in terms of age and education level. Although it has obvious advantages in costing, timing, and logistics (Hulley et al., 2013), convenience sampling limits the generalizability of the research results. In this regard, future studies should examine the validity and reliability of

the Turkish version of the CCCS using more heterogeneous samples with respect to gender, age, and educational background to enable for the assessment of measurement invariance across these variables. Second, the relationship between the scores obtained from the CCCS and the CCWS was presented as evidence of concurrent validity in this paper. In further studies, the correlation of the CCCS with different instruments about climate and the environment, such as the environmental/ecological identity scale, climate literacy scale, and climate change knowledge test, can be tested, and supporting arguments for concurrent validity can be provided. Researchers can further enrich the validity evidence for the scale by conducting mixed-method studies that support CCCS measurements with qualitative data. To put it more clearly, qualitative data into individuals' curiosity about climate change can be gathered from a sample to whom the CCCS is administered, using methods such as in-depth interviews or focus group discussions. It can then be questioned whether these qualitative findings coincide with the relevant participants' scale scores.

Moreover, validity evidence based on known-groups can be analysed. To achieve this, the CCCS can be administered to groups that are expected to differ in their curiosity levels about climate change, and it can be tested whether the scale is able to discriminate these groups as anticipated. It may also be advisable to conduct studies that reassess test-retest reliability on datasets where the interval between the two administrations is longer than that employed in the current paper. This would allow for an evaluation of whether the relatively short 3-week duration between the two administrations in this study contributed to the quite high stability coefficient. That is, future research could inspect whether CCWS yields measurements with similar stability as in this study over longer time periods. Finally, studies can be conducted in which the psychometric properties of the CCCS are investigated on the basis of item response theory.



PEthics	Committee Approval	The study's compliance with current ethical principles was approved by Dicle University Social and Human Sciences Ethics Committee (approval letter dated 27.08.2020 and numbered 81787).
	Peer Review	Externally peer-reviewed.
Author Contributions	Conception/Design of Study-	M.G., M.İ.; Data Acquisition-
	M.G.; Data Analysis/Interpretation-	M.G., M.İ.; Drafting Manuscript-
Conflict of Interest	M.G., M.İ.; Critical Revision of Manuscript-	M.G., M.İ.; Final Approval and Accountability-
	M.G., M.İ.	M.G., M.İ.
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APPENDIX

Items of CCCS' Turkish Version

1. Gezegenimizdeki sıcaklık artışını durdurmak için neler yapılabileceğini merak ediyorum.
2. Doğal çevredeki bozulmanın gelecekte Dünya'daki yaşamı nasıl değiştirebileceğini merak ediyorum.
3. Sera etkisinin üzerimdeki sonuçları hakkında düşünürüm.
4. Atmosferdeki fazla karbondioksitin nereden geldiğini merak ediyorum.
5. İklim değişikliğinin insanlar üzerindeki etkilerini sıklıkla düşünürüm.
6. Fosil yakıt tüketimi ile Dünya'daki değişen hava koşulları arasındaki bağlantıları araştırırım.
7. Buzulların neden bu kadar hızlı eridiğini merak ediyorum.
8. İklim değişikliğinin olumsuz sonuçlarını azaltmak için neler yapabileceğimi merak ediyorum.
9. Dünyanın pek çok bölgesinde sıklıkla meydana gelen kasırga, sel ve kuraklıkların nedenlerini araştırırım.
10. Hava kirliliğini azaltmak için fosil yakıtların yerini alabilecek fikirleri/önerileri merak ediyorum.
11. Eriyen buzulların gelecekte Dünya'daki yaşamı nasıl etkileyeceğini merak ediyorum.
12. Doğal çevrenin bozulmasını durdurmak için bir yol sunan her türlü bilgiye dikkat ederim.
13. Sera etkisinin dünyanın farklı bölgelerindeki sonuçlarını merak ediyorum.
14. Ormansızlaşmanın atmosferdeki karbondioksit seviyesini nasıl artıracığını araştırırım.
15. İnsanların doğal çevreye aşırı müdahalesinin Dünya'daki yaşamı nasıl değiştireceği üzerine düşünürüm.