ZfWTVol 16, No 3 (2024) 277-306 // **DOI:** 10.46291/ZfWT/160316

Zeitschrift für die Welt der Türken
Journal of World of Turks

THE RELATIONSHIP OF LOCAL ENDEMIC PLANT DISTRIBUTION WITH ENVIRONMENTAL CONDITIONS: A GIS BASED APPLICATION IN MALATYA PROVINCE, TURKIYE*

LOKAL ENDEMİK BİTKİ DAĞILIMININ ÇEVRESEL KOŞULLAR İLE İLİŞKİSİ: MALATYA İLİNDE CBS TABANLI BİR UYGULAMA, TÜRKİYE

Enes KARADENİZ ✉ **, *Zeki BOYRAZ****, *Reşat GEÇEN*****

Abstract

It is critical to comprehend the impact of the physical environment on the spatial patterns of endemic plant species in order to be considered in the development of conservation strategies, especially in areas with semi-arid climatic conditions such as Malatya Province, Turkey. The research uses the GIS-based spatial evaluation and zonal statistics techniques to discuss the influence of elevation, slope, aspect, geology, soil, temperature, and precipitation on the occurrence of 36 local endemic plant species. The results indicate a distinct peak of endemicity at moderate environmental extremes—in particular, in mid-range altitude (1000m–2000m), between 15° and 25° slopes and limestone units. It was noted that the soil properties of Nitrogen 201-300 cg/kg and moisture retention properties of 301-310 units, plus the hydrological variable (stream density of 0.2-0.3) influence species expansion a lot. Also, these findings depend on the interrelations of different factors-forming topography, soil, water, and rock layers. The research points out the need to include physical environmental parameters into conservation plans in order to preserve endemic species effectively despite the impacts of climate shifts and human activities. Where such species exist, this work aids in conservation development since it identifies the particular conditions that are conducive to the existence of endemic species and why they are important in improving interactions between organisms and the environment in semi-arid regions.

---

* Araştırma Makalesi: **Geliş tarihi:** 18.11.2024; K**abul tarihi:** 12.12.2024
Kaynak gösterilme: KARADENİZ, E.- BOYRAZ, Z. - GEÇEN, R. (2024): The Relationship of Local Endemic Plant Distribution With Environmental Conditions: A Gis Based Application in Malatya Province, Turkiye, *Zeitschrift für die Welt der Türken,* 16 /3, s. 277-306 .

** Araş. Gör. Dr., İnönü Üniversitesi Fen-Edebiyat Fakültesi Coğrafya Bölümü Malatya / TÜRKİYE*enes.karadeniz@inonu.edu.tr* https://orcid.org/0000-0003-0757-8553

*** Prof. Dr. İnönü Üniversitesi Fen-Edebiyat Fakültesi Coğrafya Bölümü Malatya / TÜRKİYE *zeki.boyraz@inonu.edu.tr* https://orcid.org/0000-0002-3333-2402

**** Doç. Dr. İnönü Üniversitesi Fen-Edebiyat Fakültesi Coğrafya Bölümü Malatya / TÜRKİYE *resat.gecen@inonu.edu.tr* https://orcid.org/0000-0002-4144-6645

Keywords: Local Endemics, Species-Environment Relationship, Spatial Distribution, Zonal Statistics, GIS

Özet

Malatya ili gibi yarı kurak iklim koşullarına sahip bölgelerde koruma stratejilerinin geliştirilmesinde dikkate alınmak üzere, fiziksel çevrenin endemik bitki türlerinin mekânsal örüntüleri üzerindeki etkisinin anlaşılması kritik önem taşımaktadır. Araştırma, yükseklik, eğim, bakı, jeoloji, toprak, sıcaklık ve yağışın 36 yerel endemik bitki türünün oluşumu üzerindeki etkisini tartışmak için CBS tabanlı mekansal değerlendirme ve zonal istatistik tekniklerini kullanmaktadır. Sonuçlar, orta dereceli çevresel noktalarda, özellikle de orta dereceli rakımlarda (1000m-2000m), 15° ve 25° eğimler arasında ve kireçtaşı birimlerinde belirgin bir endemisite zirvesine işaret etmektedir. Azot 201-300 cg/kg ve nem tutma özellikleri 301-310 birim olan toprak özelliklerinin yanı sıra hidrolojik değişkenin (0,2-0,3'lük akarsu yoğunluğu) türlerin yayılımını çok etkilediği kaydedilmiştir. Ayrıca, bu bulgular topografya, toprak, su ve kaya katmanlarını oluşturan farklı faktörlerin karşılıklı ilişkilerine bağlıdır. Araştırma, iklim değişiklikleri ve insan faaliyetlerinin etkilerine rağmen endemik türlerin etkili bir şekilde korunması için fiziksel çevre parametrelerinin koruma planlarına dahil edilmesi gerektiğine işaret etmektedir. Bu türlerin bulunduğu yerlerde, çalışma, endemik türlerin varlığına elverişli özel koşulları ve yarı kurak bölgelerde organizmalar ve çevre arasındaki etkileşimlerin iyileştirilmesinde neden önemli olduklarını tanımladığı için korumanın geliştirilmesine yardımcı olmaktadır.

Anahtar Kelimeler: Lokal Endemikler, Tür-Çevre İlişkisi, Mekansal Dağılım, Zonal İstatistik, CBS

1. INTRODUCTION

The distribution of local endemic plant species is intricately linked to a myriad of physical environmental factors, including climate, soil composition, topography, and geological substrates. Endemic plants, confined to specific geographic regions, often exhibit narrow ecological niches that reflect their adaptation to unique environmental conditions (Crave and Gascuel-Odoux, 1997; Thuiller et al., 2006; Işik, 2011). Found predominantly in areas with distinct climatic regimes, such as Mediterranean climates or alpine regions, these species rely on precise temperature and precipitation patterns to thrive (Lennon and Turner, 1995; Gaston, 2013). Soil properties, including nutrient availability and pH levels, further influence their distribution by determining the suitability of habitats for growth and reproduction (Vila et al., 2006; Sardans and Penuelas, 2013). Additionally, topographical features like elevation and slope play critical roles in shaping microhabitats, which in turn affect the spatial distribution of endemic flora (Lan et al., 2011). Foundational studies in ecology and biogeography have consistently demonstrated that these physical factors contribute to niche specialization, thereby restricting endemic species to limited geographical ranges and underscoring the delicate balance between organisms and their environments (Gaston, 2009; Rapoport, 2013).

Understanding the significance of endemic species extends beyond mere distributional patterns; these species serve as vital indicators of the health and uniqueness of their ecosystems. Research has highlighted the role of endemic plants in maintaining ecosystem functions and contributing to overall biodiversity

(Stachowicz et al., 2002; Srivastava and Vellend, 2005). High-impact studies emphasize that endemic species often possess unique genetic traits and ecological interactions that are essential for the resilience and stability of their habitats (Thompson et al., 2009). Moreover, endemic species are increasingly recognized for their importance in global biodiversity conservation, as their limited distributions make them particularly vulnerable to environmental changes and anthropogenic pressures (Brooks et. al. 2002; de Lima et. al. 2020). Seminal works in conservation biology have underscored the intrinsic and ecological value of these species, advocating for targeted conservation strategies that prioritize habitat preservation and restoration to sustain biodiversity (Mittermeier et. al. 2011). By focusing on endemic species, researchers can gain deeper insights into the unique ecological conditions of specific regions, thereby informing broader conservation efforts and enhancing our understanding of biodiversity patterns (Hermant et. al. 2013).

Building on the understanding of endemic plants' ecological dependencies, this research focuses on Malatya Province, Turkey, a region distinguished by its diverse geological formations, soil types, and climatic variability (Yazgan and Chessex, 1991). These characteristics create a mosaic of microhabitats, supporting unique plant communities and fostering conditions favorable for endemic flora (Gunduz et. al. 2011; Altıngoller et. al. 2024). Additionally, the topographical diversity of Malatya, encompassing both elevated mountainous areas and lower plains, further contributes to the habitat heterogeneity necessary for niche specialization (Karadeniz et. al. 2022). Previous studies on the regional ecology of Malatya have documented the presence of several endemic plant taxa, highlighting the area's potential as a hotspot for biodiversity research (Mutlu and Karakus, 2012; Karakus and Mutlu, 2019). These ecological and physical attributes make Malatya an ideal setting for investigating the interplay between environmental factors and the distribution of endemic flora.

To rigorously analyze the spatial distribution of endemic plant species, this study employs the zonal statistical method in conjunction with GIS-based spatial statistics. The zonal statistical method facilitates the aggregation and analysis of environmental data within defined spatial units, enabling precise assessments of how specific factors influence species distribution (Zhang et. al. 2015). GIS-based spatial statistics, on the other hand, provide robust tools for modeling and visualizing the spatial relationships between environmental variables and biological patterns (Zhou et. al. 2003). These methodologies are particularly relevant in ecological research, where understanding the spatial dimensions of species distribution is crucial for identifying habitat preferences and predicting potential changes under varying environmental scenarios (Brown, 2014). By integrating these statistical approaches, the study ensures a comprehensive and nuanced analysis of the factors driving the distribution of endemic plant species in Malatya, thereby enhancing the accuracy and reliability of the findings.

The primary objective of this study is to analyze the influence of various environmental variables-specifically geology, soil properties, temperature, precipitation, elevation, slope, soil nitrogen content, and surface temperature-on the distribution of 36 endemic plant species in Malatya Province. Each of these environmental factors has been identified in prior research as critical determinants of plant distribution and ecological preferences (Bornett and Puijalon, 2011; Gaston, 2013; Zhang et. al. 2021) Geology and soil properties influence nutrient availability and root development, which are essential for plant growth and survival (Antonelli et. al. 2018). Temperature and precipitation patterns dictate the suitability of habitats for different species, affecting their physiological processes and reproductive cycles (Araujo and Pearson, 2005). Elevation and slope determine microclimatic conditions and water runoff patterns, which in turn influence soil moisture and stability (Tromp-van Meerveld and McDonnell, 2006). Soil nitrogen content is a key indicator of soil fertility, directly impacting plant health and productivity (Tateno and Takeda, 2003). Surface temperature variations can affect evapotranspiration rates and overall plant metabolism, thereby shaping species distribution (Ashcroft and Chisholm, 2008). By examining these variables, the study aims to elucidate the complex interactions between endemic plant species and their physical environments, providing a nuanced understanding of the factors that underpin their spatial distribution.

This research significantly advances the understanding of species-environment relationships, particularly for endemic plants with restricted distributions, by providing valuable insights into plant biogeography and conservation in Malatya Province, an underrepresented region in ecological studies. Employing advanced spatial statistical methods, the study identifies key environmental determinants supporting endemic plants, establishes a methodological framework for future ecological research, and highlights the importance of prioritizing habitat preservation to mitigate threats from climate change and anthropogenic disturbances. By focusing on ecological gradients and habitat-focused conservation strategies, the findings contribute both to scientific understanding and practical biodiversity management, supporting the resilience of endemic plants in biodiversity-rich ecosystems like Malatya.

2. MATERIALS AND METHODS

2.1. Dataset

This study utilized integrated datasets obtained from multiple institutions and publicly available sources, supplemented by newly generated data layers designed to address the study's objectives. Raw data were processed to create spatial layers suitable for GIS-based analysis. Table 1 summarizes the datasets, their sources, and details such as spatial resolution, scale, and temporal coverage.

The primary datasets included topographic, climatic, hydrological, geological, and biological data. Digital Elevation Model (DEM) and contour data were sourced from the Alaska Satellite Facility and the General Directorate of Mapping, providing high-resolution terrain information essential for generating slope, aspect, and relief maps. Climatic variables, including temperature, precipitation, and surface temperature, were obtained from the Turkish General Directorate of Meteorology and NASA Power Data. These datasets covered long-term periods (1980–2024 and 1990–2024), ensuring robust temporal variability for analysis. Geological data, including lithological layers, were acquired from the General Directorate of Mineral Research and Exploration, while soil properties, such as nitrogen content and water-holding capacity, were derived from SoilGrids and the Central Research Institute for Soil Fertilizer and Water Resources. Additional layers, including hydrological features, settlement locations, and administrative boundaries, were sourced from OpenStreetMap and Natural Earth databases. These datasets were pre-processed to standardize spatial resolution, coordinate systems, and formats, ensuring compatibility for overlay and statistical analyses in GIS environments.

Table 1: Datasets used in the study, their sources, temporal and spatial resolutions.

Dataset	Source	Date	Spatial Resolution (m) Scale
Digital Elevation Model and Digital Contour Line,	Alaska Satellite Facility (https://search.asf.alaska.edu/) General Directorate of Mapping (https://www.harita.gov.tr/)	June 09 2007; 2013	12.5; 5-10
Temperature, Precipitation, Humidity, Surface Temperature	General Directorate of Meteorology (https://mgm.gov.tr/) NASA Power Data (https://power.larc.nasa.gov/)	1980-2024; 1990-2024	Excel CSV; Excel CSV
Roads, Railways, Settlements, Streams	OpenStreetMap (https://www.openstreetmap.org/)	2024; 2024	Vector scale
Country province district village and sea boundaries Water surfaces	Natural Earth (https://www.naturalearthdata.com/) OpenStreetMap (https://www.openstreetmap.org/) GLWD (https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database) General Directorate of Geographic Information Systems (https://cbs.csb.gov.tr/) ArcGIS Hub (https://hub.arcgis.com/)	2023; 2024; 2004; 2024	1:100.000 Vector; Vector scale
Geology-Lithology	General Directorate of Mineral Research and Exploration (https://www.mta.gov.tr/en/)	2019	1:100.000
Soil Properties	Central Research Institute for Soil Fertilizer and Water Resources (https://arastirma.tarimorman.gov.tr/toprakgubre) SoilGrids (https://soilgrids.org/)	2024	250x250
Local Endemics	Noah's Ark National Biodiversity Database (https://nuhungemisi2.tarimorman.gov.tr/) IUCN PhD Thesis (Karakuş, 2016)	2023	Excel CSV; Excel CSV; Vector; Excel CSV
Geographic Names Sheet Index	General Directorate of Mapping (https://www.harita.gov.tr/)	2023	Excel CSV; Vector

2.2. Data Pre-Processing

In order to prepare the datasets for analysis, several pre-processing steps were carried out to standardize, transform, and derive spatial layers that align with the objectives of the study. These steps involved coordinate system standardization, digitization of geological maps, and the application of interpolation techniques to climatic and soil variables. All datasets were first reprojected into the Universal Transverse Mercator (UTM) coordinate system using the World Geodetic System 1984 (WGS84) datum, Zone 37. This process ensured spatial alignment and consistency across all data layers, which is crucial for conducting overlay analyses and spatial statistical calculations. This step also standardized all data into a unified spatial framework suitable for advanced GIS-based analysis. From the DEM data, topographic layers such as slope, aspect, and relief maps were derived using surface analysis tools within GIS. Slope and aspect maps provided essential insights into the gradient and directional orientation of terrains, which are critical factors influencing local microclimates and water runoff. Relief maps, generated from elevation variability, captured the ruggedness of the terrain, which often correlates with habitat heterogeneity and biodiversity.

A lithology map was produced by digitizing geological sheets at a 1:100,000 scale from the General Directorate of Mineral Research and Exploration (MTA). The digitization process involved delineating geological formations and converting them into vector and raster layers for subsequent analysis. The lithology map provided detailed information on the distribution of rock types, which directly affect soil properties such as fertility and water retention, influencing plant growth and habitat suitability. Soil properties, including nitrogen content and water-holding capacity, were extracted and interpolated from SoilGrids datasets at a spatial resolution of 250 m. To overcome limitations in the spatial continuity of climatic data, advanced interpolation techniques were employed to generate seamless and spatially coherent datasets. Climatic variables, including temperature, precipitation, and surface temperature, were interpolated using Radial Basis Function, Spline with Tension and Kriging methods, creating continuous spatial layers. Similarly, soil nitrogen content data were interpolated to produce high-resolution distribution maps, which provided the necessary granularity to assess localized environmental influences on endemic plant distributions. Hydrological data were processed to produce stream density maps, delineating areas with varying levels of water availability. This was achieved by analyzing the network of watercourses within the study area. These hydrological layers were essential for understanding the role of water resources in shaping the habitats of local endemic plants.

The data on local endemic plant species of Malatya Province form the core of this study, providing the essential foundation for spatial and statistical analyses. These data were sourced from the Noah's Ark National Biodiversity Database, the International Union for Conservation of Nature (IUCN), and the study by Karakuş (2016), ensuring a comprehensive and reliable dataset (Table 2). Notably, the geographic coordinates reported by Karakuş (2016) represent the centroids of the areas where the species were observed, providing valuable spatial insights. By integrating these coordinates with environmental variables, the study achieved a high level of precision in analysing species-environment relationship, making this dataset indispensable for identifying habitat patterns and informing conservation planning in Malatya Province.

Table 2: Local endemic species detected in Malatya province (Karakuş, 2016).

Order	**Family**	**Genus**	**Species**	**Local Name**
Apiales	Apiaceae	Pimpinella	***Pimpinella enguezekensis***	engüzek anasonu
Asterales	Asteraceae	Centaurea	***Centaurea malatyaensis***	malatya sarıbaşı
Asterales	Asteraceae	Cousinia	***Cousinia cataonica***	kırkkızan
Asterales	Asteraceae	Cousinia	***Cousinia euphratica***	Fırat kızanı
Asterales	Asteraceae	Klasea	***Klasea bornmuelleri***	yitik topbaş
Asterales	Asteraceae	Taraxacum	***Taraxacum rupiculum***	Malatya pireotu
Lamiales	Boraginaceae	Alkanna	***Alkanna malatyana***	levent havacivaotu
Lamiales	Boraginaceae	Alkanna	***Alkanna viscidula***	yapışkan havaciva
Brassicales	Brassicaceae	Heldreichia	***Heldreichia bupleurifolia***	topaç hardalı
Brassicales	Brassicaceae	Sisymbrium	***Sisymbrium malatyanum***	akçadağ bülbülotu
Asterales	Campanulaceae	Campanula	***Campanula alisan-kilincii***	Levent çanı
Asterales	Campanulaceae	Campanula	***Campanula malatyaensis***	zürbeçan
Asterales	Campanulaceae	Campanula	***Campanula peshmenii***	bey çıngırağı
Caryophyllale s	Caryophyllacea e	Gypsophila	***Gypsophila leucochlaena***	darende çöveni
Caryophyllale s	Caryophyllacea e	Minuartia	***Minuartia aksoyi***	Darende tıstısı
Caryophyllale s	Caryophyllacea e	Minuartia	***Minuartia corymbulosa***	kırk tıstıs
Fabales	Fabaceae	Astragalus	***Astragalus altanii***	meşe geveni
Fabales	Fabaceae	Astragalus	***Astragalus darendensis***	Darende geveni
Fabales	Fabaceae	Astragalus	***Astragalus macrouroides***	cemre geveni
Fabales	Fabaceae	Astragalus	***Astragalus malatyaensis***	malatya geveni
Fabales	Fabaceae	Astragalus	***Astragalus scabrifolius***	gövdesiz geven
Fabales	Fabaceae	Lotus	***Lotus malatayicus***	malatya gazalotu
Fabales	Fabaceae	Onobrychis	***Onobrychis fallax***	yalancı korunga
Malpighiales	Hypericaceae	Hypericum	***Hypericum malatyanum***	malatya kantaronu
Lamiales	Lamiaceae	Phlomis	***Phlomis integrifolia***	özge çalba
Lamiales	Lamiaceae	Stachys	***Stachys cataonica***	bodur karabaş
Lamiales	Plantaginaceae	Chaenorhinu m	***Chaenorhinum cryptarum***	dağ balıkağzı
Lamiales	Plantaginaceae	Chaenorhinu m	***Chaenorhinum semispeluncarum***	has balıkağzı
Brassicales	Resedaceae	Reseda	***Reseda malatyana***	kaya gerdanlığı
Brassicales	Resedaceae	Reseda	***Reseda tomentosa***	havlı gerdanlık

Rosales	Rosaceae	Rosa	***Rosa vanheurckiana***	muş gülü
Lamiales	Scrophulariacea e	Verbascum	***Verbascum anastasii***	kubbe sığırkuyruğu
Lamiales	Scrophulariacea e	Verbascum	***Verbascum varians***	dilim sığırkuyruğu
Rosales	Urticaceae	Parietaria	***Parietaria semispeluncaria***	malatya fesleğeni
Asparagales	Asparagaceae	Bellevalia	***Bellevalia chrisii***	kubbe sümbülü
Asparagales	Asparagaceae	Bellevalia	***Bellevalia malatyaensis***	Malatya sümbülü
Asparagales	Asparagaceae	Muscari	***Muscari atillae***	Levent sümbülü
Asparagales	Asparagaceae	Ornithogalum	***Ornithogalum malatyanum***	yar sasallı
Asparagales	Iridaceae	Crocus	***Crocus malatyensis***	çiğdem
Asparagales	Iridaceae	Crocus	***Crocus yakarianus***	malatya çiğdemi
Asparagales	Iridaceae	Iris	***Iris pesmeniana***	peşmen navruzu

These pre-processing steps harmonized the datasets, ensuring spatial consistency and sufficient detail to enable a comprehensive analysis of the relationships between local endemic plants and their physical environment. The resulting spatial layers provided a robust foundation for the subsequent analyses.

Spatial Analysis Methods

This research decided to apply spatial statistics with GIS to determine the spatial relationships between local endemic plant species and their physical environment. Informational buffered zones were made to represent more precisely the distribution of 36 local endemic plants in correlation with 12 environmental layers, such as geological, soil characteristics, altitude, slope as well as climatic factors. This method helped the researchers to establish associations between the places of the endemic plants and some environmental characteristics.

A zonal statistical approach was used to calculate descriptive statistics (mean, minimum, maximum and standard deviation) of environmental variables in spatial zones demarcated by species distribution. Through this analysis, we were able to quantify the relative importance of each environmental factor on species occurrence. Spatial density analysis was also used to examine the role of hydrological features (stream density) in controlling localized pattern of densification across endemic plants. All spatial analyses were performed using ArcGIS Pro v.2.7 (ESRI, Redlands, CA) and QGIS (QGIS Development Team 2021) to take advantage of surface modelling tools, interpolation techniques and zonal statistics. By implementing and integrating such GIS tools, a strong framework for quantifying the interaction between endemic plants with their surroundings was formed.

3. RESULTS

The relationship between abiotic environmental factors and the spatial distribution of local endemic plant species in Malatya Province is characterized by substantial variance. This study used several maps of important environmental parameters: topography (elevation, slope, aspect), hydrology (stream distance), climate (temperature, precipitation, surface temperature) and soil characteristics (soil wetness index, nitrogen content in soils and water retention). Finally, lithology and soil type maps are potentially more useful concerning geological and edaphic factors inferring the distribution of species. The cumulative effect of these maps display the spatial heterogeneity of Malatya physical environment and reflects its influence on microhabitats for local endemic plants [39]. When the species distribution data were superimposed in these environmental layers, it demonstrated clear patterns reflecting limitations and preferences between ecological characteristics and environmental conditions. The relationships between each abiotic factor and the observed distributions of endemic flora are explored in subsequent sections providing an understanding of ecological niches (Fig 1).

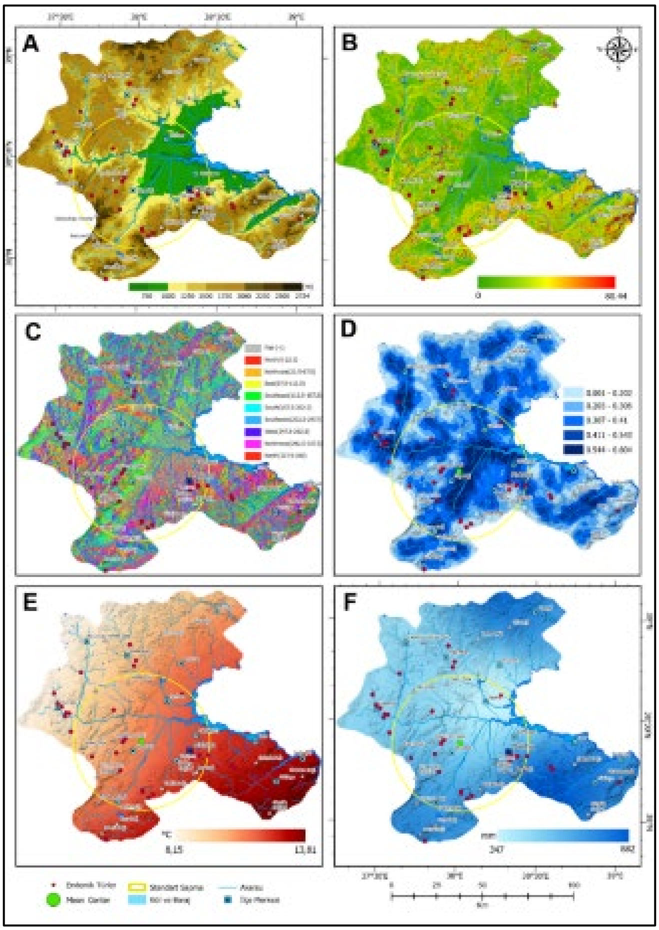


Figure 1: Abiotic Factors: A: Elevation map, B: Slope map, C: Aspect map, D: Stream Density map, E: Temperature map, F: Precipitation map.

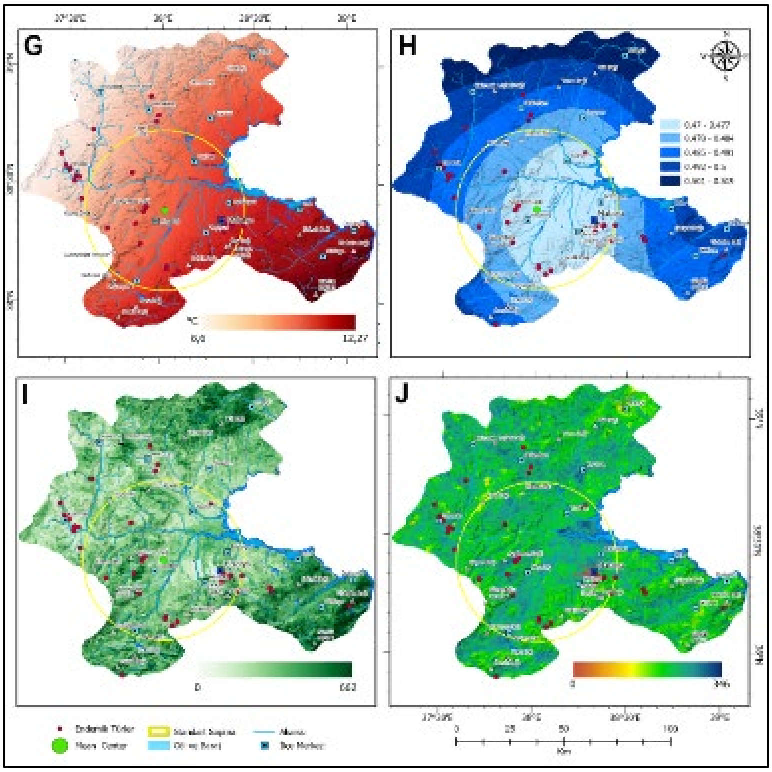


Figure 1 Continued: Abiotic Factors: G: Surface temperature map, H: Soil wetness index map, I: Soil nitrogen content map, J: Soil water retention map.

In Malatya Province, elevation plays a major role in shaping the region's natural environment. The altitude ranges from 676 meters at the Karakaya Dam's water level to over 2,500 meters in mountainous areas like Beydağı in the south and Yama Mountain in the north. Research on local endemic plants has shown that these species don't thrive below 800 meters or above 2,200 meters. This highlights how critical elevation is in determining the right habitats for these plants. Lower areas, such as the Malatya Plain and the Karakaya Dam's shores, lie below 800 meters and are heavily influenced by agriculture. This human activity transforms the landscape, disrupting natural ecosystems and making it tough for endemic species to survive. On the other hand, areas above 2,200 meters are often too harsh for plant life, with colder weather, less fertile soil, and shorter growing seasons creating unfavorable conditions.The sweet spot for most endemic plants is found between 1,000 and 2,000 meters, where environmental conditions strike a balance. These mid-elevation zones offer the right mix of climate, soil quality, and relative freedom from human interference. Interestingly, nearly half of the 45 endemic plant species in the region are concentrated between 1,000 and 1,400 meters, making this range a biodiversity hotspot. Another significant range is 1,400 to 1,800 meters, where many species also thrive, benefiting from favorable ecological niches (Graph 1).

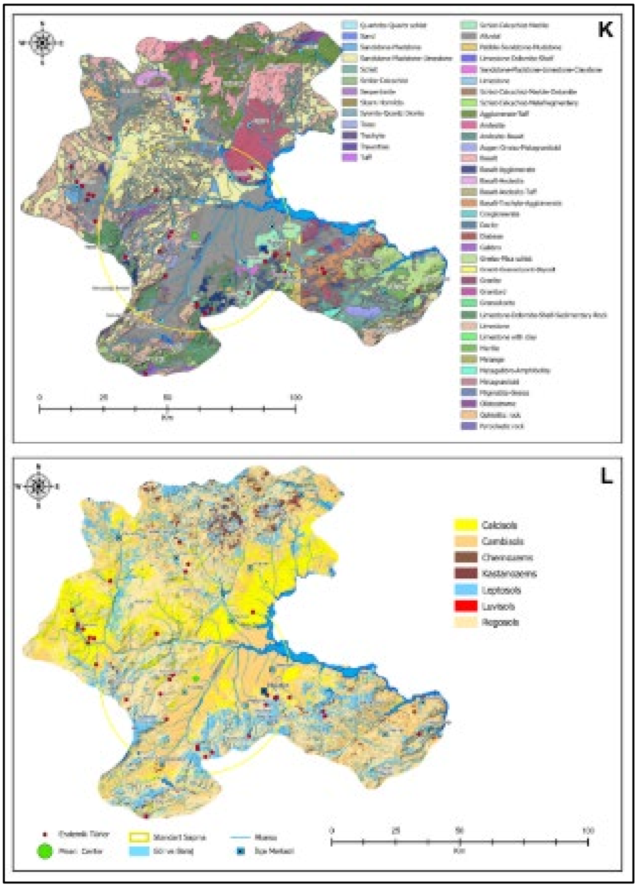
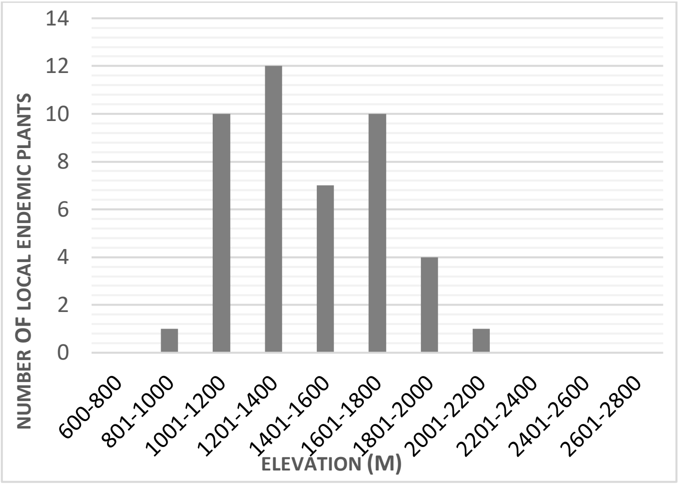


Figure 1 Continued: Abiotic Factors: K: Lithology map, L: Soil map.

When zooming out, the full elevation range for endemic plants spans from a minimum of 853 meters to a maximum of 2,463 meters, covering an impressive 1,610 meters. However, the average elevation for these plants sits at about 1,440 meters, reinforcing the importance of mid-elevation areas as key habitats. These findings underline the powerful influence of elevation on where endemic plants can grow. Both natural factors, like climate and soil, and human activities, such as farming, shape the delicate balance that allows these species to survive.

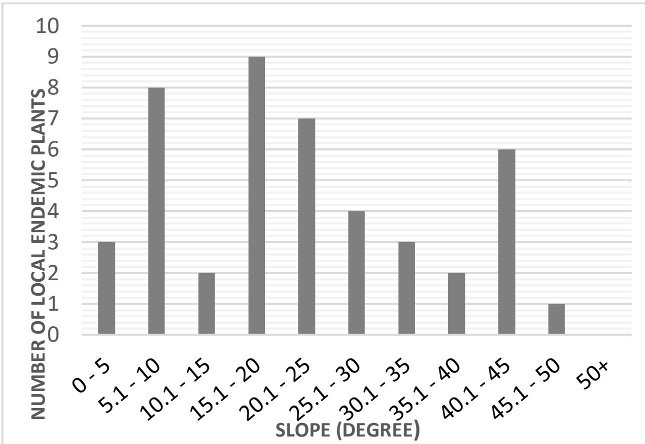


Graph 1: Distribution of local endemic plants according to elevation levels.

Malatya Province showcases diverse topography, with the central Malatya Plain encircled by the Yama Mountain to the north, the Nurhak Mountains to the west, and Beydağı to the south. The region's slopes range from flat areas in the plains to steep inclines in the surrounding mountainous zones. Gentle slopes dominate the central plains, supporting intensive agricultural activities, while steeper slopes characterize the foothills and mountainous areas.

The relationship between slope and the distribution of local endemic plants is intricate and non-linear, with these plants occurring across a broad range of slope values. Analysis reveals that endemic plants are present in nearly all slope categories up to 50°, indicating that slope alone does not restrict their distribution. However, a notable concentration of endemic plants is observed in the 15°–25° range, with the peak density occurring between 15°–20° (as shown in Graph 2). This suggests that moderate slopes offer favorable conditions for the growth and survival of endemic species, likely due to advantageous microhabitat features like optimal water drainage, reduced soil erosion, and partial protection from intense sunlight.

Steeper slopes exceeding 45° are less prevalent in the region and correspond mostly to rocky outcrops and rugged terrains. These areas, with their shallow or absent soil layers and heightened erosion risk, are generally unsuitable for most endemic plants. On the other hand, flat areas with slopes below 5° are predominantly used for agriculture, significantly altering natural habitats and limiting niches for endemic flora. While the minimum slope supporting a dense presence of endemic plants is 1°, the maximum slope reaches 67.61°, spanning a wide range. The average slope associated with the occurrence of endemic plants is 14.81°.

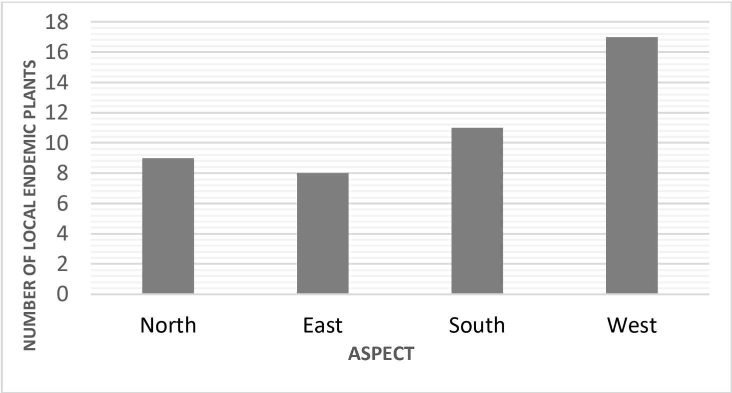


Graph 2: Distribution of local endemic plants according to Slope values.

Aspect, as one of the leading topographical factors, specifies the angle and intensity of the solar radiation impinging on a surface and thus directly affects prevailing microclimatic conditions required for plant growth and development. In Turkey, belonging to the northern hemisphere, slopes that mostly face the south have greater solar radiation since their orientation is perpendicular to the sun's rays. Thus, the resulting slope climate is warmer and drier compared to the other orientated slopes. By contrast, most north slopes are cooler and moister as a result of the limited amount of solar radiation they receive; these greatly differ in microhabitats from other areas, supporting different types of vegetation.

The aspect map of the study area was prepared and then categorized into four cardinal directions, namely north, east, south, and west, to aid the analysis of slope orientation. Overlay analysis indicated a strong inclination toward west-facing slopes, receiving 17 out of 45 endemic plants, while south-facing slopes supported 11. These results portray the western and southern sides of Malatya Province as ecologically significant, most likely because of their balanced solar exposure along with accompanying microclimatic conditions. The west slopes offer a moderate amount of sunlight and temperature conditions that may accommodate a large number of species for plants, while south-facing slopes, most likely, accommodate species adapted to more arid and warm conditions (Graph 3).

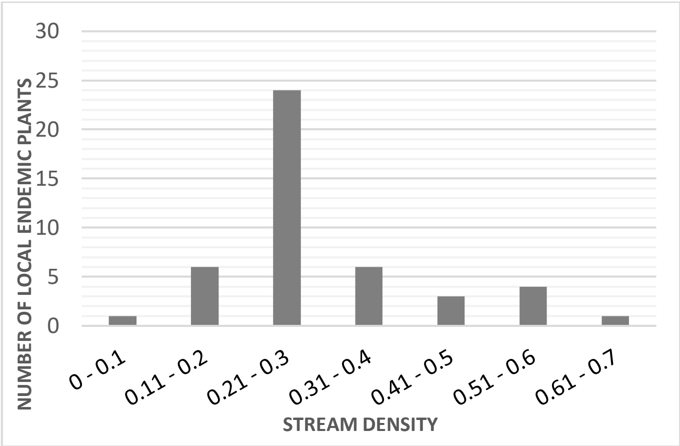
This result is supported by the zonal statistical analysis, with a calculated directional circular mean of 133.45°, which demonstrates a general preference for slopes with an orientation ranging from southeastern to southwestern. Such orientation may be related to the "harmonious" combination of solar radiation, temperature, and moisture, and reduced competition from other vegetation types often associated with such aspects. In complete contrast, east- and north-facing slopes had fewer endemic plants, probably due to cooler temperatures and high moisture levels that might fall outside the ecological requirements of most of the region's endemic plants.



Graph 3: Distribution of local endemic plants according to Aspect.

Starting from the surface and groundwater resources, the Malatya Province has a very rich hydrological network, further lying to the east of its borders with the Karakaya Dam on the Euphrates River. The Tohma River and its tributaries flow from west to east and constitute a large basin in the greater part of the province. A stream density map was generated for this purpose, where values range from 0 to 0.8. Then, overlaying the distribution of local endemic plants with stream density data finds that more than half of the species have inhabitants in areas where stream densities stand at 0.2 to 0.3, suggesting a more favorable hydrological condition for endemic plants in such areas (Graph 4).

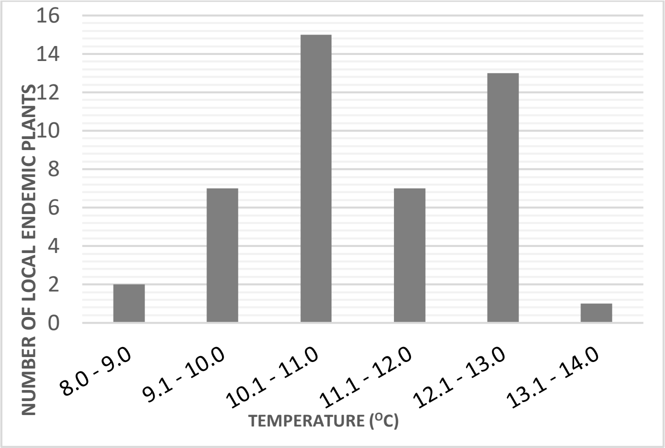
The zonal statistical analysis in the stream density of endemic plants shows a minimum and a maximum of 0.119 and 0.561, respectively, with a mean of 0.293. This indeed points out that locations with a moderate supply of water offer stable microhabitats with adequate moisture levels that may assure growth and endurance in endemic plants. On the other hand, areas of very low stream density may not allow enough water, and highly dense areas are often too saturated or even erosive to be highly suitable in terms of habitat. These results emphasize the role of moderate hydrological conditions in maintaining endemic biodiversity and the importance of consideration of stream density in conservation planning.



Graph 4: Distribution of local endemic plants according to Stream Density.

It is one of the crucial parameters that affect the distribution of local endemic plants directly by influencing physiological processes such as photosynthesis, germination, and growth. According to the Köppen climate classification, Malatya Province has a BSk cold semi-arid steppe climate; the yearly average temperature of the province varies from 8.15°C to 13.8°C. These values are obtained by Spline with tension interpolation method, and this clearly shows the spatial variation of temperature across the province. Higher temperatures are found in the south and southeastern areas where lower elevations are more prevalent, while the western and northern areas are dominated by cooler temperatures due to increased elevation and latitudinal effects. A gradient that is seen across the province as a result of topography and the geographic position.

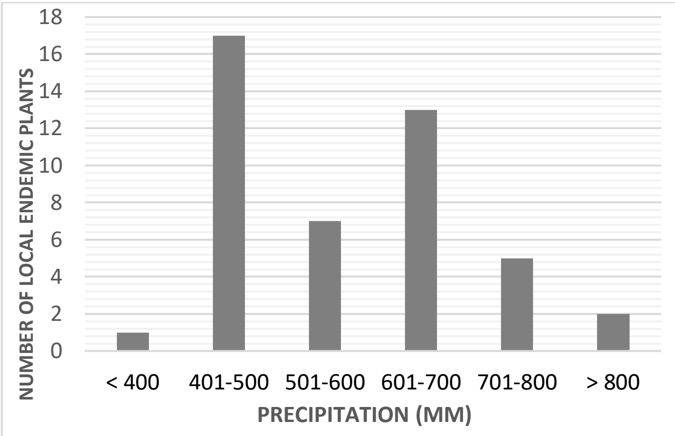
Graph 5 shows that temperature and endemic plants of local origin are interlinked as there is a massive concentration of species between the range of average temperature from 10°C to 11°C. The results further get fortified through zonal statistical result for endemic plants: 10.40°C - 12.31°C, mean - 11.34°C. These results indicate that a moderate thermal condition supports the best microhabitats for endemic plants, as it balances the physiological demands of plants in relation to the avoidance of extreme temperatures. On the contrary, areas with relatively low temperatures (<10°C) and high temperatures (>12.5°C) equally record fewer species, maybe due to the severe climatic conditions which restrict plant growth and reproduction. Results clarified temperature as one of the major environmental factors affecting endemic flora distribution pattern in Malatya Province.



Graph 5: Distribution of local endemic plants according to Temperature Values.

Precipitation controls soil moisture, nutrient availability, and microhabitat conditions, and thus it is one of the most important climatic factors responsible for the local endemic plant distribution. In Malatya Province, annual precipitation shows considerable variation, from 347 mm in the drier parts to 882 mm in the wetter ones. Precipitation is higher in the southeastern and northern parts of the province, possibly due to orographic effects and proximity to water bodies, and relatively low over the west. Overlaying precipitation data on the distribution of the local endemic plants shows the highest density over areas that receive between 400–500 mm of rainfall annually. This moderate range of precipitation provides ample soil moisture without necessarily experiencing adversities in terms of waterlogging or leaching of nutrients, hence providing the best environment for endemic flora (Graph 6).

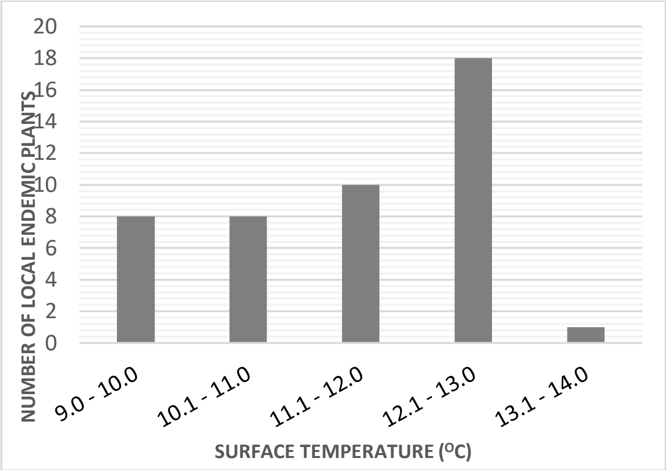
This is further confirmed in the zonal statistical analysis and the precipitation value linked with endemic plants, ranging from a minimum of 462.47 mm - maximum to 759.08 mm, and then averaging at 578.76 mm. Under very low precipitation conditions (<400 mm), the endemic plants decline due to insufficient soil moisture, while in areas with high precipitation (>800 mm), waterlogging and erosion may impede plant growth. These results reveal that Malatya endemic plants are thriving well in habitats whose hydrological condition is in good balance, providing them with a very favorable water level which would satisfy the physiological needs without generating adverse conditions in the soil. These findings highlight the importance of including precipitation patterns in conservation strategies, as conserving areas with moderate rainfall will contribute to ecological niches vital for such endemic plants.



Graph 6: Distribution of local endemic plants according to Precipitation.

Surface temperature is the temperature of the topmost layer of the Earth's crust; it is considered for being an important environmental variable that controls the growth, development, and distribution of plants. Aspect, slope, and elevation are crucial factors in determining the angle of sunlight; hence, the level of radiation a surface receives will directly affect its surface temperature. In this study, annual average surface temperature values were calculated for the area and overlaid spatially in a distribution map of the local endemic plants. The results indicated that the 12 °C-13 °C average surface temperature is optimum for the endemic plants; a total of 18 out of the 45 recognized species, 40% of them, occur within these zones. This means that such moderate surface temperatures are ideal for the development of microhabitats for the proliferation and survival of the collection of flora in question (Graph 7).

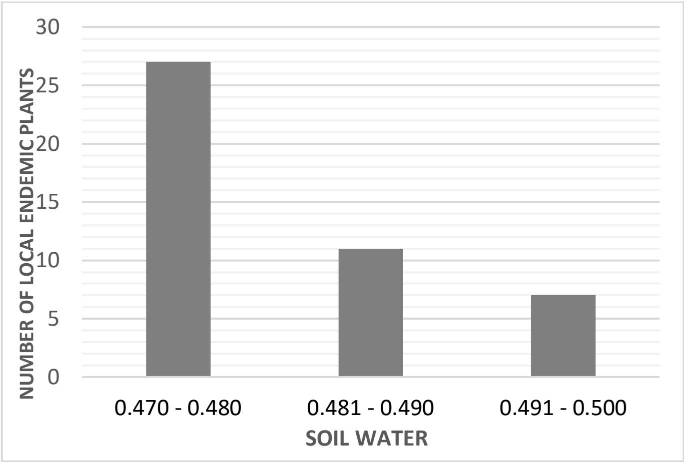
That's the zonal statistical analysis which was calculated just for zones of high local endemic plant massifs, that is why the radar image shows main temperature parameters connected with the species distribution. The surface temperature in these areas varies from 10.78 °C up to 12.71 °C. This narrow range reflects the sensitivity of endemic plants to thermal conditions, since too high or too low temperatures might disturb the vital physiological processes of photosynthesis, respiration, and nutrient uptake that are so important for growth and survival. Areas with lower surface temperatures than this (<10°C) or higher temperatures (>13°C) support fewer species and do so probably as a result of suboptimal radiation levels and resultant moisture conditions. These findings emphasize the vital role played by surface temperature in determining biodiversity patterns and point out the relevance of thermal environments when planning habitat conservation for the endemic flora.



Graph 7: Distribution of local endemic plants according to Surface Temperature.

Soil water content is one of the most important environmental parameters for plant survival because it affects root water uptake directly, nutrient availability, overall plant health, and several aspects of plant performance. In this study, the values of soil water were divided into three classes, ranging from 0.470 to 0.500. From overlay analysis, around 60% of the local endemic plants were enhanced within the range of soil water content from 0.470 to 0.480. This can be regarded as optimal since such soil moisture levels would present the right balance of available water for plant physiological functions without engendering conditions of water saturation that may hinder root function and/or cause anaerobic stress (Graph 8).

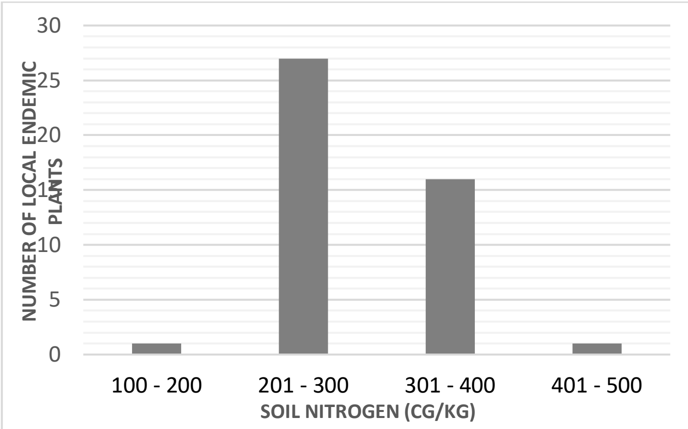
This relationship is emphasized by the preciseness of the zonal statistical analysis conducted for areas with high endemic plants density. For such areas, the minimum, maximum, and mean values of soil water content are all calculated at 0.470—an extremely narrow range. This uniformity underlines the sensitivity of endemic plants to deviations in soil moisture and, for their conservation, hydrological conditions must be maintained in a stable state. This is purportedly because of reduced aeration and lower nutrient availability in soils with water content higher than 0.480, while in soils with lower water content, plants run the risk of drought stress. The findings themselves therefore reinforce the thinking that indeed it may be the moderate levels of soil moisture that are central to the persistence of plant biodiversity in these ecosystems and further emphasize the need for proper land management where habitat preservation is concerned.



Graph 8: Distribution of local endemic plants according to Soil Water.

Soil nitrogen levels are one of the most critical factors affecting plant growth and distribution due to the fact that nitrogen is one of the major nutrients required for photosynthesis, synthesis of proteins, and other metabolic activities in plants. Overlaying the local endemic plants' distribution onto soil nitrogen data clearly outlined a preference for areas containing nitrogen at levels between 201–300 cg/kg. About 27 of 45 endemic plants are concentrated in these zones to suggest that moderate nitrogen availability provides the optimum balance for the growth of endemic plants. This probably shows conditions supporting healthy root systems and nutrient uptake, hence fostering ecological stability for these species (Graph 9).

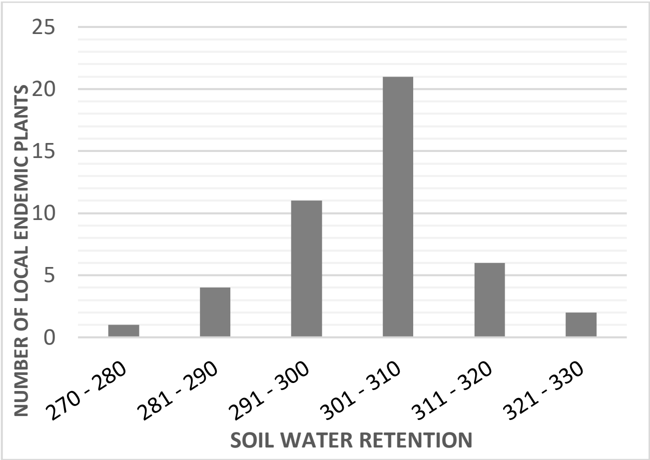
Zonal statistical analysis gives increased magnitude at the soil nitrogen in relation to the distribution of endemic plants in species-dense areas a notch higher. Calculated values also manifest a small range of nitrogen averaging 283 cg/kg of the natives-rich areas. Accordingly, very low (<200 cg/kg) or very high (>400 cg/kg) nitrogen levels support significantly fewer species, suggesting that under these extreme conditions, either nutrient availability is seriously limited or toxicity disrupts plant metabolic processes. This feature of consistency in the level of nitrogen across the endemic-rich zones, unlike any other parameter, throws light on the role of nutrient homogeneity in the shaping of plant communities. These findings emphasize, therefore, a need to keep nitrogen levels in the soil gentle and steady in such conservation cases, as deviations might likely disrupt the ecological niches critical for sustaining endemic plant diversity.



Graph 9: Distribution of local endemic plants according to Soil Nitrogen.

The capacity of the soil to retain water is mainly determined by soil texture and composition. A higher proportion of clay results in higher retention of water by the soil, whereas sandy soils have less capacity since their particles are considerably larger with lesser surface area. Soil moisture availability directly contributes to soil water retention, therefore enabling plants to obtain appropriate amounts of water for maintaining their physiological and metabolic needs. In this study, we estimated volume water content at -10 kPa as an indication of soil water retention capacity and then performed a spatial overlay of the endemic plant distribution with this attribute. The results succinctly suggest that areas where there is high concentration of endemic plants correspond to a value of 301-310 units for soil water retention, with 21 out of 45 endemic plants—or 47% of these—falling in such an area. Also, the general analysis shows that 84% of the species are distributed in the range between 291–320 units, which range is providing the best moisture conditions for endemic flora (Graph 10).

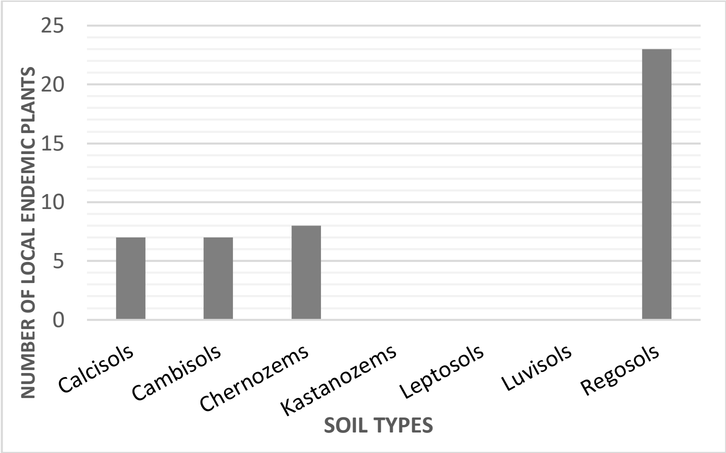
Zonal statistical analysis, focused on the zones of high concentration of local endemic plants, shows the minimum, maximum, and average values of the water retention ranges. These were found to be 270 units as the minimum value and 332 as the maximum, while the mean reached 297 units. We observe how the numbers of species are declining outside of this range from 291 to 320. This shows that such a deviation from the optimum either results in water scarcity or excessive saturation, which may harmfully affect the plant health and habitat suitability. Unlike other parameters, soil water retention is the integral of both physical and chemical properties of soil for creating a stable environment for the growth of plants. The narrow zonal range among site hotspots underlines the sensitivity of endemic-rich areas to any deviation in hydrological soil properties, which necessitates protection and management of such soils for biodiversity conservation.



Graph 10: Distribution of local endemic plants according to Soil Water Retention.

Seven soil types exist within the study area, with varied physical and chemical properties that provide variable habitat suitability conditions for local endemic plants. The discussion on the habitat distribution of endemic plants among these soil types identifies a strong dominance towards the Regosols soil type, which hosts more than half of the recorded species (23 out of 45). Regosols are usually of weakly developed profiles and often very sandy. That considered, they could well have been associated with arid and semiarid conditions whereby vegetation is adapted to a low nutrient supply with rather rapid internal water drainage. This would tend to point out that local endemic plants can be well adapted to the challenging conditions presented by Regosols using their structural advantages such as loose texture for root penetration and moisture retention in microsites.

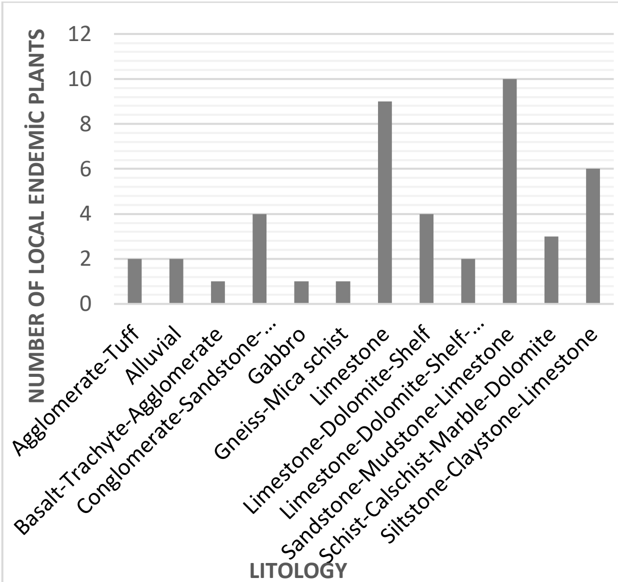
In turn, the area's endemic plants studied do not inhabit other types of soils such as Kastanozems, Leptosols, and Luvisols. Kastanozems, being fertile, are chiefly the soils accompanying grasslands and hence find an intensive application by people in agriculture, with only negligible remains of undestroyed habitats hosting endemic flora. The complete absence of endemic plants in Leptosols and Luvisols, representing respectively thin and very poor soils, further underlines inedibility of these substrates to provide the necessary ecological conditions to host plant species. On the contrary, Calcisols and Cambisols each host seven endemic plants, while Chernozems host eight species. The presence of endemic plants on these soil types underlines their intermediate suitability, which makes a balance between nutrient availability and moisture retention. From the trends observed, it follows that Regosols are vital habitats of endemic plants and must be conserved for habitat diversity in the area to be maintained (Graph 11).



Graph 11: Distribution of local endemic plants according to Soil Types.

A 1:100,000-scale geological map of Malatya Province was digitized and then reclassified into 12 simplified lithological units to suit the aims of the present study. These units represent a great variety of geological formations across the region, ranging from sedimentary to igneous and metamorphic types. By overlaying the distribution of local endemic plants with these lithological units, some important correlations between lithology and plant occurrence could be realized. The analysis indicates that limestone-limestone-complex units are the predominant units of habitats, and most of the flora are found in such lithologies that support it. Such findings complete the groups of ecological significances of carbonate-rich substrates as a roadway to favorable growth conditions for endemic plants.

Of the 45 plants endemic to Malatya, a total of 33 species (73%) are distributed within the areas made up of limestone or dominated complexes such as limestone-dolomite and limestone-mudstone. The origins of the affinity of these lithologies are possibly explained by those unique physical and chemical properties that show high porosity, permeability, and calcium-rich soils and that exert a synergistic effect towards the facilitation of nutrient cycling and root penetration with water retention in semi-arid conditions. Besides that, the weathering of limestones provides microhabitats and niches that also protect the microenvironment from stresses mainly from the environment, increasing their aptness for endemic flora. On the other hand, fewer or non-endemic plants exist in less chemically favorable or more structurally compact lithologies such as gabbro, basalt, and tuff (Graph 12).



Graph 12: Distribution of local endemic plants according to Lithology.

4. DISCUSSION

The outputs of the study provide important information on the relationship between local endemic plant species and the physical environmental factors affecting their distribution in Malatya province. The results of the analyses highlight several key trends, particularly strong associations between endemic species and mid-elevation zones (1,000-2,000 metres), specific slope ranges (15°-25°) and lithological units such as limestone and their associated complexes. These findings underline the complex interactions between topography, soil properties, hydrology and geology in shaping the ecological niches of endemic species.

Endemic species are highly concentrated in areas characterised by moderate environmental conditions. The mid-elevation zones of the site offer a balance between temperature and humidity, which is crucial for plant growth (Gaston, 2003). Slopes with slopes between 15° and 25° provide optimum drainage and soil stability, reducing erosion risks and facilitating nutrient availability (Médail and Quézel, 1997). Areas with moderate soil moisture and nutrient levels, especially soil nitrogen content between 201-300 cg/kg and soil water retention values between 301-310 units, provide the highest local endemic diversity. These findings are in agreement with previous studies emphasising the role of balanced environmental gradients in sustaining endemic plant biodiversity (Harrison et al., 2006; Pausas and Austin, 2001).

The study differs in some aspects from the literature emphasising the importance of extreme environments for local endemic vegetation. Kruckeberg and

Rabinowitz (1985) suggested that endemics generally thrive in habitats with extreme conditions due to reduced competition. In contrast, the unique climatic and geological conditions of Malatya province seem to support more moderate ecological environments. This suggests that endemic species here may be exposed to competition in both extreme and highly favourable environments, thus occupying intermediate niches (Richardson et al., 2005).

The preference for limestone and limestone-complex lithologies in the region underlines the role of substrate properties in determining habitat suitability for endemic species. The high porosity, permeability and calcium-rich soils of limestone increase its ecological importance by supporting specialised plant communities (Chiarucci et al., 2010; Jurado and Westoby, 1992). The formation of microhabitats and niches by the weathering of limestone, which provide protection from environmental pressures, further enhances the occurrence of endemic vegetation. In contrast, the absence of endemic species in certain lithologies such as gabbro, basalt and tuff suggests that these structures may lack the physical or chemical properties necessary to support endemic flora in the field (Proctor and Woodell, 1975). The broader implications of the findings are twofold. The first is the part that contributes to the understanding of how environmental factors shape the diversity of endemic endemic plants in semi-arid regions. This information is important for predicting how ecosystems may respond to environmental changes (Sala et al., 2000). The other aspect of the findings provides a framework for the identification and prioritisation of protected areas. The significant overlap between endemic species density and certain physical parameters emphasises the need to integrate these variables into conservation planning (Margules & Pressey, 2000). For example, areas with moderate stream density (0.2-0.3) and temperatures in the middle range (12-13°C) indicate critical habitats, highlighting priority areas for conservation.

With all these findings, the study has some limitations, especially due to limited fieldwork. Consideration of findings partly based on climate and soil data, whose spatial scale is small, may result in misleading values, especially for areas where sampling points are sparse (Zimmermann et al., 2007). This may lead to an underestimation of environmental variables in some microhabitats. In addition, a spatial distribution does not embrace biotic interactions of competition, predation, or mutualism, which restricts the scope of the studied ecological processes. Because such interactions may dramatically affect the distribution and abundance of species, they may potentially confound any observed relationships with abiotic factors.

Future research should address these gaps by combining higher resolution datasets, field-based measurements and analyses of biotic interactions to provide a more comprehensive understanding of species-environment relationships. Longitudinal studies using remote sensing technology can monitor changes in species distribution over time and thus more effectively assess the impacts of climate change (Turner et al., 2003). Furthermore, studies covering different semi-arid regions may reveal whether the patterns observed in Malatya province are consistent elsewhere. Thus, studies can contribute to broader ecological theories and conservation strategies (Hobbs et al., 2006).

5. CONCLUSION

This study examined the relationship between local endemic plant species and physical environmental factors in Malatya Province, Turkey. Spatial analyses revealed that endemic species are mostly concentrated in areas with moderate environmental trends. These areas have characteristics such as moderate elevations, slopes between 15 and 25 per cent and limestone-dominated lithologies. Key findings emphasise the strong influence of soil properties such as nitrogen content and water-holding capacity, as well as hydrological and topographic factors in shaping flora patterns. The novelty of the study lies in its holistic approach, combining GIS-based spatial analysis and regional statistical methods to understand species-environment interactions in a comprehensive (site-specific parameter) manner. By identifying the specific environmental conditions that favour endemic species, the study provides valuable information for policy makers to develop targeted conservation strategies (Cowling & Pressey, 2003). Conservation of these habitats not only maintains biodiversity but also ensures the continuity of vital ecosystem services for local communities (Daily, 2013).

Integrating physical-environmental variables into conservation strategies is critical to protecting these unique species in the face of climate change and anthropogenic disturbances. For example, the conservation of limestone-rich habitats and areas with temperate climatic conditions can ensure the sustainability of ecological niches of endemic flora (Brooks et al., 2002). Furthermore, sustainable land use practices that take into account soil and hydrological characteristics can reduce the effects of habitat degradation. Future research should build on these findings, exploring temporal dynamics and extending analyses to broader taxonomic and geographic scopes. Incorporating long-term monitoring and predictive modelling processes will improve our ability to effectively conserve and manage biodiversity (Pereira et al., 2010). By adopting a multidisciplinary approach that includes ecological, geographical and social perspectives, more robust strategies can be developed to conserve endemic species and the ecosystems they inhabit.

Yazarların katkı düzeyleri:	Birinci yazar %50, ikinci ve üçüncü yazar %50
Etik komite onayı:	Bu çalışma için etik kurul iznine gerek yoktur.
Finansal Destek:	Çalışmada finansal destek alınmamıştır.
Çıkar çatışması:	Herhangi bir çıkar çatışması bulunmamaktadır.

References

Altıngöller, M., Karakurt, M., Şengün, M. T., Karadeniz, E., & Sunbul, F. (2024). Impacts of Soil Temperature on Apricot Productivity in Malatya, Turkey: A Longitudinal Analysis Using Inverse Distance Weighting. *International Journal of Nature and Life Sciences*, *8*(1), 36-53.

Antonelli, A., Kissling, W. D., Flantua, S. G., Bermúdez, M. A., Mulch, A., Muellner-Riehl, A. N., ... & Hoorn, C. (2018). Geological and climatic influences on mountain biodiversity. *Nature Geoscience*, *11*(10), 718-725.

Araújo, M. B., & Pearson, R. G. (2005). Equilibrium of species' distributions with climate. *Ecography*, *28*(5), 693-695.

Bornette, G., & Puijalon, S. (2011). Response of aquatic plants to abiotic factors: a review. *Aquatic sciences*, *73*, 1-14.

Brooks, T. M., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., Rylands, A. B., Konstant, W. R., ... & Hilton-Taylor, C. (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation biology*, *16*(4), 909-923.

Brown, J. L. (2014). SDM toolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses. *Methods in Ecology and Evolution*, *5*(7), 694-700.

Callaway, R. M., & Walker, L. R. (1997). Competition and facilitation: a synthetic approach to interactions in plant communities. Ecology, 78(7), 1958-1965.

Chiarucci, A., Bacaro, G., & Rocchini, D. (2010). Quantifying plant species diversity in a Natura 2000 network: old ideas and new proposals. Biological Conservation, 143(5), 1180-1187.

Cowling, R. M., & Pressey, R. L. (2003). Introduction to systematic conservation planning in the Cape Floristic Region. Biological Conservation, 112(1-2), 1-13.

Crave, A., & Gascuel-Odoux, C. (1997). The influence of topography on time and space distribution of soil surface water content. *Hydrological processes*, *11*(2), 203-210.

Daily, G. C. (Ed.). (2013). Nature's services: societal dependence on natural ecosystems. Island Press.

de Lima, R. A., Oliveira, A. A., Pitta, G. R., de Gasper, A. L., Vibrans, A. C., Chave, J., ... & Prado, P. I. (2020). The erosion of biodiversity and biomass in the Atlantic Forest biodiversity hotspot. *Nature communications*, *11*(1), 6347.

Gaston, K. J. (2003). The Structure and Dynamics of Geographic Ranges. Oxford University Press.

Gaston, K. J. (2009). Geographic range limits of species. *Proceedings of the Royal Society B: Biological Sciences*, *276*(1661), 1391-1393.

Gaston, K. J., & Spicer, J. I. (2013). *Biodiversity: an introduction*. John Wiley & Sons.

Giam, X., Bradshaw, C. J., Tan, H. T., & Sodhi, N. S. (2010). Future habitat loss and the conservation of plant biodiversity. *Biological Conservation*, *143*(7), 1594-1602.

Gunduz, O., Ceyhan, V., & Bayramoglu, Z. (2011). Influence of climatic factors on apricot (Prunus armeniaca L.) yield in the Malatya province of Turkey.

Harrison, S., Safford, H. D., Grace, J. B., Viers, J. H., & Davies, K. F. (2006). Regional and local species richness in an insular environment: serpentine plants in California. Ecological Monographs, 76(1), 41-56.

Hermant, M., Prinzing, A., Vernon, P., Convey, P., & Hennion, F. (2013). Endemic plants have highly integrated phenotypes, environmental distributions and phenotype–environment relationships. *Journal of Biogeography*, *40*(8), 1583-1594.

Hobbs, R. J., Arico, S., Aronson, J., Baron, J. S., Bridgewater, P., Cramer, V. A., ... & Zobel, M. (2006). Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography, 15(1), 1-7.

Işik, K. (2011). Rare and endemic plants: why are they prone to extinction?. *Turkish Journal of Botany*, *35*(4), 411-417.

Jurado, E., & Westoby, M. (1992). Germination biology of selected central Australian plants. Australian Journal of Ecology, 17(3), 341-348.

Karadeniz, E., Er, S., Boyraz, Z., & Coşkun, S. (2022). Evaluation of potential geotourism of Levent Valley and its surroundings using GIS route analysis. *Geoheritage*, *14*(2), 77.

Karakuş, Ş. (2016). *Flora of Malatya Province* (Doctoral dissertation). Graduate School of Natural and Applied Sciences, İnönü University, Malatya, Turkey.

Karakuş, Ş., & Mutlu, B. (2019). Allium dönmezii, a new species of Allium sect. Melanocrommyum (Amaryllidaceae) from Turkey: morphological and molecular evidence. *Phytotaxa*, *411*(3), 194-204.

Kruckeberg, A. R., & Rabinowitz, D. (1985). Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics, 16(1), 447-479.

Lan, G., Hu, Y., Cao, M., & Zhu, H. (2011). Topography related spatial distribution of dominant tree species in a tropical seasonal rain forest in China. *Forest Ecology and Management*, *262*(8), 1507-1513.

Lennon, J. J., & Turner, J. R. (1995). Predicting the spatial distribution of climate: temperature in Great Britain. *Journal of Animal Ecology*, 370-392.

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. Nature, 405(6783), 243-253.

Médail, F., & Quézel, P. (1997). Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Garden, 84(1), 112–127.

Médail, F., & Quézel, P. (1997). Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Garden, 84(1), 112-127.

Mittermeier, R. A., Turner, W. R., Larsen, F. W., Brooks, T. M., & Gascon, C. (2011). Global biodiversity conservation: the critical role of hotspots. In *Biodiversity hotspots: distribution and protection of conservation priority areas* (pp. 3-22). Berlin, Heidelberg: Springer Berlin Heidelberg.

Mutlu, B., & Karakuş, Ş. (2012). A new species of Ornithogalum (Hyacinthaceae) from East Anatolia, Turkey. *Turkish Journal of Botany*, *36*(2), 125-133.

Pausas, J. G., & Austin, M. P. (2001). Patterns of plant species richness in relation to different environments: an appraisal. Journal of Vegetation Science, 12(2), 153-166.

Pereira, H. M., Leadley, P. W., Proença, V., Alkemade, R., Scharlemann, J. P., Fernandez-Manjarrés, J. F., ... & Walpole, M. (2010). Scenarios for global biodiversity in the 21st century. Science, 330(6010), 1496-1501.

Proctor, J., & Woodell, S. R. J. (1975). The ecology of serpentine soils. Advances in Ecological Research, 9, 255-366.

Rapoport, E. H. (2013). *Areography: geographical strategies of species* (Vol. 1). Elsevier.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions, 6(2), 93-107.

Sajjad, M., Li, Y., Tang, Z., Cao, L., & Liu, X. (2018). Assessing hazard vulnerability, habitat conservation, and restoration for the enhancement of mainland China's coastal resilience. *Earth's Future*, *6*(3), 326-338.

Sala, O. E., Chapin III, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., ... & Wall, D. H. (2000). Global biodiversity scenarios for the year 2100. Science, 287(5459), 1770-1774.

Sardans, J., & Peñuelas, J. (2013). Plant-soil interactions in Mediterranean forest and shrublands: impacts of climatic change. *Plant and soil*, *365*, 1-33.

Srivastava, D. S., & Vellend, M. (2005). Biodiversity-ecosystem function research: is it relevant to conservation?. *Annu. Rev. Ecol. Evol. Syst.*, *36*(1), 267-294.

Stachowicz, J. J., Fried, H., Osman, R. W., & Whitlatch, R. B. (2002). Biodiversity, invasion resistance, and marine ecosystem function: reconciling pattern and process. Ecology, 83(9), 2575-2590.

Tateno, R., & Takeda, H. (2003). Forest structure and tree species distribution in relation to topography-mediated heterogeneity of soil nitrogen and light at the forest floor. *Ecological research*, *18*, 559-571.

Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. (2009). Forest resilience, biodiversity, and climate change. In *Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43. 1-67.* (Vol. 43, pp. 1-67).

Thuiller, W., Midgley, G. F., Hughes, G. O., Bomhard, B., Drew, G., Rutherford, M. C., & Woodward, F. I. (2006). Endemic plants and ecosystem sensitivity to climate change in Namibia. *Global Change Biology*, *12*(5), 759-776.

Tromp-van Meerveld, H. J., & McDonnell, J. J. (2006). On the interrelations between topography, soil depth, soil moisture, transpiration rates and species distribution at the hillslope scale. *Advances in water resources*, *29*(2), 293-310.

Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., & Steininger, M. (2003). Remote sensing for biodiversity science and conservation. Trends in Ecology & Evolution, 18(6), 306-314.

Vilà, M., Tessier, M., Suehs, C. M., Brundu, G., Carta, L., Galanidis, A., ... & Hulme, P. E. (2006). Local and regional assessments of the impacts of plant invaders on vegetation structure and soil properties of Mediterranean islands. *Journal of Biogeography*, *33*(5), 853-861.

Wu, X. B., & Smeins, F. E. (2000). Multiple-scale habitat modeling approach for rare plant conservation. *Landscape and urban planning*, *51*(1), 11-28.

Yazgan, E., & Chessex, R. (1991). *Geology and tectonic evolution of the southeastern Taurides in the region of Malatya*. Turkish Association of Petroleum Geologists.

Zhang, J., You, S., & Gruenwald, L. (2015, November). Efficient parallel zonal statistics on large-scale global biodiversity data on gpus. In *Proceedings of the 4th International ACM SIGSPATIAL Workshop on Analytics for Big Geospatial Data* (pp. 35-44).

Zhang, Q. P., Wang, J., & Wang, Q. (2021). Effects of abiotic factors on plant diversity and species distribution of alpine meadow plants. *Ecological Informatics*, *61*, 101210.

Zhou, Y., Narumalani, S., Waltman, W. J., Waltman, S. W., & Palecki, M. A. (2003). A GIS-based spatial pattern analysis model for eco-region mapping and characterization. *International journal of geographical information science*, *17*(5), 445-462.

Zimmermann, N. E., Edwards Jr, T. C., Moisen, G. G., Frescino, T. S., & Blackard, J. A. (2007). Remote sensing-based predictors improve distribution models of rare, early successional and broadleaf tree species in Utah. Journal of Applied Ecology, 44(5), 1057-1067.

Extended Abstract

Background: *Endemic plants, which are critical components of global biodiversity, often occur in specific geographical regions with unique ecological conditions. These species not only reflect the health of their ecosystems, but also contribute to overall ecological resilience and genetic diversity. Arid-semi-arid regions in Turkey, such as Malatya province, present unique challenges and opportunities for the differentiation of endemic flora due to their climatic characteristics, distinct topography and lithological units. Malatya Province is characterised by its various elevations, climatic differences and lithological diversity, which provide different habitats for a large number of endemic plants. However, significant differences are observed in the distribution of these species over habitats. This study aims to contribute to biodiversity conservation and sustainable land use practices in arid-semi-arid ecosystems by analysing the environmental parameters affecting the spatial distribution of endemic plants.*

Aim of the Study: *The main objective of the study is to analyse the relationships between local endemic plant species and physical conditions in Malatya province. In particular, the study focuses on determining the influence of abiotic factors such as elevation, slope, aspect, soil properties, hydrology and climate on the spatial patterns of 36 endemic plant species. The findings aim to* *inform conservation strategies by identifying priority areas and conditions that support endemic biodiversity.*

Methodology: For the purpose of the study, a comprehensive GIS-based spatial statistics methodology was used using spatial data sets from multiple national and international sources. The data includes topographic (elevation, slope, aspect), geological (lithology), climatic (temperature, precipitation, surface temperature), soil properties (nitrogen content, water retention) and hydrological (stream density) variables. In order to increase the spatial resolution and consistency of the data sets within the scope of field studies, they were pre-processed and their quality was improved and made suitable for spatial statistical analyses. Advanced GIS tools, including ArcGIS Pro and QGIS, were used to map the spatial distribution of physical conditions and overlap them with the occurrence of endemic species. Spatial statistical methods quantified the relationships between species density and environmental factors, highlighting the most important relationships of habitat suitability. By integrating multiple spatial data layers, the study provides a holistic understanding of the ecological requirements of endemic plants.

***Results:** Statistical analyses reveal several main trends in the relationship between the distribution of endemic species and environmental factors: **Altitude:** Endemic plants are predominantly distributed in mid-elevation regions (1,000-2,000 m), with the highest density between 1,000-1,400 m. These regions create ideal habitats by balancing climatic and soil conditions. **Slope** Slopes of 15°-25° were found to be the range where endemic plants are denser. This value provides favourable drainage and soil stability. **Aspect:** The western and southern slopes, which receive moderate solar radiation, favour a greater diversity of endemic species than the cooler and more humid northern slopes. **Lithology:** Limestone-dominated substrates host 73% of the endemic species, attributed to high porosity, permeability and calcium-rich soils that enhance nutrient cycling and water retention. **Soil Properties:** Areas with nitrogen levels of 201-300 cg/kg and soil water retention values of 301-310 units emerge as areas favourable for plant growth, reflecting the importance of balanced soil fertility and moisture. **Hydrology:** Stream densities of 0.2-0.3% support a significant proportion of endemic species by creating stable microhabitats with sufficient moisture. **Climate:** Temperate climatic conditions, with annual temperatures of 10°C-11°C and rainfall of 400-500 mm, created favourable conditions for endemic plants, avoiding extremes that inhibit physiological processes. These findings emphasise that endemic plants prefer moderate environmental conditions, contrasting with studies that emphasise extreme habitats as refugia for endemic species. The results underline the interplay of abiotic factors in shaping biodiversity patterns and emphasise the need for holistic conservation approaches.*

***Conclusions:** By advancing the understanding of species-environment relationships in arid-semi-arid ecosystems, the study provides actionable information for biodiversity conservation in Malatya province. Key outputs emphasise the importance of mid-elevation zones, limestone-rich habitats,*

moderate climate and hydrological conditions in sustaining endemic biodiversity. These results have important implications for conservation planning and sustainable land management for the region.