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RESEARCH ARTICLE

Soil Conservation Strategies for the Reduction of Biodiversity in Mountain Soils: Example of Uludağ National Park/Türkiye

Hüseyin Sarı[1]✉ • Bahadır Atmaca[2]

[1]Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition Tekirdağ/Türkiye
[2]Giresun University, Department of Food Technology, Şebinkarahisar School of Applied Sciences, Giresun/Türkiye

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ABSTRACT

Uludağ National Park in Türkiye is famous for its rich biodiversity. The park serves as an essential habitat for a wide variety of flora and fauna and contributes significantly to the conservation of various species. This study examines biodiversity conservation strategies in Uludağ National Park. Soil samples were taken from 17 locations near the summit where endangered endemic plants grow. Analyses of the soil samples reveal the relationships between elevation and soil texture components. According to the soil analysis results, there was a weak positive correlation between elevation and silt content (r = 0.414) and a weak negative correlation between elevation and sand content (r = -0.375). These findings indicate that silt content tends to increase and sand content tends to decrease with increasing elevation. The geomorphological features and soil structure of Uludağ National Park were also an essential part of the research. The region's metamorphic mica schists, granites and marbles affect the soil's physical properties. For example, soils are generally sandy and permeable in areas where granite parent material is present. In contrast, areas where mica-schist parent material is distributed are less resistant and more susceptible to erosion. As a result, effective soil conservation strategies must be implemented to protect biodiversity in Uludağ National Park. These strategies are essential to reduce soil erosion, increase organic matter accumulation and minimise the impacts of climate change. Furthermore, community participation and adaptive management strategies must be adopted for sustainable development and resource management. This study provides essential information for biodiversity conservation in the Uludağ region and contributes to developing conservation strategies.

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1. Introduction

Mountains are vital ecosystems that support a significant part of the world's biodiversity, especially in the tropics, where they act as hotspots of exceptional richness (Rahbek et al., 2019). The complex topography of the mountains creates diverse habitats that harbour a wide variety of species, facilitating isolation and speciation (Lu, 2021). These ecosystems are crucial for biodiversity conservation against species losses caused by climate change and provide opportunities for species to move over short distances through various micro-environmental conditions (Körner, 2014).

Soil conservation in alpine regions is crucial for ecosystem health and sustaining biodiversity. Several studies have emphasised the importance of implementing effective soil conservation measures to reduce soil erosion, increase soil fertility and maintain ecological sustainability in mountainous areas.

✉ Correspondence
E-mail address: hsari@nku.edu.tr

Conservation efforts in mountainous regions are essential for biodiversity conservation. Studies show that protected areas are fundamental for the long-term conservation of mountain biodiversity, especially in tropical regions where human activities affect diversity patterns (Gebert et al., 2019). Furthermore, the spatial relationship between different types of mountainous areas and land use is also essential for sustainable development and resource management (Zhao & Li, 2016). Effective conservation policies, such as those that optimise the conservation of landscape resources in national parks, are vital to maintaining ecological integrity and promoting positive social interactions (Liu & Sun, 2023).

In mountain conservation, it is crucial to assess the impact of human activities on these sensitive ecosystems. Integrating topography and human pressure assessments is vital to accurately assess species vulnerability to climate change and guide conservation strategies (Elsen et al., 2020). Furthermore, understanding the interconnected mechanisms of human-land systems in mountain watersheds can inform land use policies for sustainable development (Wu et al., 2022).

National parks play a crucial role in biodiversity conservation and ecosystem preservation, providing refuge for various species and sustaining essential ecological processes (Siraj et al., 2017). The success of conservation efforts in national parks is influenced by several factors, including monitoring programs tailored to the specific needs of protected areas (Sathyakumar et al., 2014). For example, a case study conducted in the Khangchendzonga National Park and Biosphere Reserve in Sikkim, India, highlights the importance of developing effective monitoring protocols to ensure the long-term conservation of mammals in Himalayan regions (Sathyakumar et al., 2014).

Studies conducted in Türkiye have provided valuable information on the country's biodiversity conservation and ecosystem management. For example, research focusing on mapping ecoregions under climate change in Türkiye highlights the need for large-scale studies to understand and address the impacts of climate change on the country's ecosystems and biodiversity (Ergüner et al., 2018). This study highlights the importance of understanding how climate change affects Türkiye's diverse ecoregions and biodiversity.

Research on forest communities and ecological differentiation in Elmacık Mountain in Düzce highlights the region's rich floristic and vegetation diversity (Aksoy & Çoban, 2017). By analysing the vegetation-environment relationship using multivariate statistical techniques, this study provides valuable information on the ecological dynamics of mountain ecosystems in Türkiye.

In conclusion, biodiversity conservation in national parks requires a multifaceted approach that integrates effective monitoring programs, adaptive management strategies, community engagement and sustainable economic practices. By addressing these various aspects, national parks can continue serving as vital refuges for wildlife, protecting critical ecosystems and promoting the well-being of nature and people.

This study will examine where endemic plants occur at high altitudes and grow only in certain regions. The aim is to comprehensively analyze the soil structure, landforms and ecological characteristics of these areas. The main objective of the research is to identify the conservation measures necessary for the protection and sustainability of these particular areas. The study also aims to develop strategies for creating similar ecosystems or improving existing ones. Considering factors such as soil chemistry, biodiversity, water management and land use, recommendations will be made to protect the ecological balance of these regions.

2. Materials and Methods

2.1. Study Area

While Uludağ was known as "Bithynian Olympos" and "Monk Mountain" in mythological and Ottoman times, it was officially renamed Uludağ in 1925. This important mountain is located in Bursa province, between 28° 58' - 29° 38' east longitude and 39° 45' - 40° 10' north latitude. Uludağ rises with steep slopes and reaches a height of 2,543 meters. The Nilüfer Stream forms the natural boundaries of the mountain to the west and south and the city of Bursa and the district of İnegöl to the north and east.

Study ares is not a single elevation but a mountain range extending northwest-southeast. It covers an area approximately 40 kilometres long and 20 kilometres wide. Uludağ, the highest mountainous mass in the Marmara Region and Western Anatolia, attracts attention with its height and width. It is also an essential region for natural beauty and nature tourism. (Rehder et al., 1994).

2.2. Method

While selecting sample points for the study area, regions near the summit and where endangered endemic species grow were preferred. The location map of the study area is shown in Figure 1.

In the research area, the soils where endemic plants, especially endangered endemic plants, grow were examined, and textural and organic matter analyses were carried out. Soil samples were taken from the area where the plant was grown. Laboratory analyses: Soil reaction (pH) was determined using a pH meter with glass electrode in soil suspensions diluted 1:2.5 with water and N/50 $CaCl_2$ solution (Jackson, 1958). Grain size distribution (texture) was determined using the hydrometer method (Anonymous, 1993). The texture triangle was used for texture class nomenclature (Anonymous, 1996). Lime and salt were determined by the volumetric calcimeter method (Sağlam, 2008). Salt was determined in soil suspensions using the Wheatstone Bridge concentrator (Richards, 1954). Organic matter content (%) was determined by the modified Walkley Black Wet Burning method (Walkley, 1947). Cu, Mn, Zn (ppm) were determined by (DTPA, ICP), Fe, Mg, Ca, K (ppm) were determined by (A. Acetate, ICP) methods.

Figure 1. Location map of the study area.

2.3. Geomorphological Features

When the geomorphological features of Uludağ are examined, a cross-section from the Bursa Plain to the summit is examined, and it is stated that metamorphic and fragmented mica schists are found first. Since mica schists are weaker than marbles regarding abrasion resistance, they formed low areas. The mica schists have a leaf-like structure in thin layers and continue up to about 1100 meters. Gneisses begin to be seen around 900 meters. Towards 1150 meters, granite-like blocks stand out. These blocks rise to 1250 meters and give way to granite blocks in higher regions. After crossing the ridges separated by widening valleys in Sarıalan, the Kırkpınarlar Region is reached. This is an almost flat area where the surrounding hills to the east and west are composed entirely of granite. In the summit region, the granite is overlain by amphibole schist and a thick layer of marble. It is also stated that the first traces of the glacial period in Türkiye were identified in Uludağ by Philipson. This information emphasises the geological diversity and different rock types of Uludağ. It is seen that mica schists are weak against erosion, and different rocks such as granite, gneiss, amphibolous schist and marble are located in different parts of the mountain. It is also stated that Uludağ was affected during glacial periods, and traces of this period are available (Anonymous, 1994).

It is stated that the distribution area of the granite ends near the summit at an altitude of 2300 meters and transitions to the contact metamorphic zone formed as a result of internal eruptions of the granite. The main components of this zone include gneiss, mica schist, granodiorite and marble. It is stated that this zone is 2200-2543 meters high and is one of the characteristic features of karst formation. Karst is a process by which water passes through calcareous rocks to form topographic features such as dissolution, cavities, caves and dolines. It is stated that karst formation is present in this contact metamorphologic zone and that rain and snow water pass through the cracks and dolines in this region and exit the foothills of Uludağ and the Bursa Plain. This information explains the components and characteristics of the contact metamorphic zone through which the granite transgressed due to geological processes in Uludağ. It is also noted that karst formation is essential in the water cycle and hydrological processes (Çepel, 1978).

2.4. Soil Properties

The geological structure, climate and landforms in Uludağ greatly influence soil formation. For this reason, terra rosa, a reddish soil, is generally found at low altitudes, while podsolic brown forest soils are found at higher elevations. The main components of the soil are mineral-rich colluvial soils, usually composed of gravel and blocks on deep slopes. This is especially true in the erosion zone. In areas with hard limestones, typically reddish-coloured terra rosa soils are common (Zech & Cepel, 1977).

The fundamental bedrock of the soils commonly found in Uludağ is granite. Soils developed on granite bedrock are generally found at altitudes of 1300-2200 meters, have a coarse structure, and sand content is generally above 60%. In these soils, the thickness of the dissolved granite zone is the most critical factor affecting the depth of the soil. A thick zone of loose granite provides a favourable environment for root propagation and water accumulation. The soils have good permeability but low base saturation rate and cation exchange capacity. Since the soil pH value is between 3.7 and 4.7, it can be called "Brown Forest Soils" (Çepel, 1978). The soils and landforms of the sample locations are given in Table 1.

Table 1. Topography characteristics of soil samples.

Sample No	Soil type	Landforms	Altitude (meters)
Example 1	Colluvial Soils	Slope	2354
Example 2	Colluvial Soils	Slope	2020
Example 3	Colluvial Soils	Slope	2228
Example 4	Reddish Brown Soils	Ridge	2251
Example 5	Red Brown Mediterranean Soils	Ridge	2272
Example 6	Reddish Chestnut Soils	Slope	2265
Example 7	Reddish Chestnut Soils	Slope	2134
Example 8	Reddish Chestnut Soils	Mountain	2114
Example 9	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2090
Example 10	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2000
Example 11	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2233
Example 12	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2242
Example 13	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2282
Example 14	Saline-Alkali and Saline-Alkali Mixed Soils	Ridge	2278
Example 15	Chestnut Soils	Mountain	1912
Example 16	Chestnut Soils	Mountain	2354
Example 17	Chestnut Soils	Mountain	2217

Due to the steep, steep and undulating topography, the soil cover is usually very shallow or shallow. Therefore, a complete soil profile does not develop in brown forest soils without limestone. Generally, AC layer is under the well-developed and acid-characterized A1 layer. The main components of these soils are sandy claystone, clayey, sandy, clayey or gravelly deposits. On bare rock and rubble lands, soil development is impossible as no soil layer exists.

2.5. Climate Characteristics

The annual average temperature drops to 3.8 ˚C at the points where the sample points were taken. While the average temperature in Uludağ falls below zero degrees Celsius in December, January, February and March, there is no month in Bursa where the temperature falls below zero degrees Celsius in monthly average values. The coldest month in Bursa is January with an average temperature of 5.4 ˚C, while in Uludağ, it is February with -4.1 ˚C. In July, the hottest month, the average temperature rises to 24.5 ˚C in Bursa and 13.9 ˚C in Uludağ. In terms of monthly average values, there is a difference of 19.1 ˚C between the hottest and the coldest month in Bursa, while this difference is 18 ˚C in Uludağ. When the average high-temperature values are analysed, it is seen that the effective temperature range in Bursa and Uludağ is widening. The month with the lowest average low temperature in Bursa is February, at 1.7 ˚C, while the month with the highest average high temperature is July and August, at 30.6 ˚C. The month with the lowest average values in Uludağ is February, at -7 ˚C. The month with the highest average values is August, with 18.3 ˚C. As can be seen from the experienced values, according to the average low and average high values, a temperature range of 28.9 ˚C is effective in Bursa, and a temperature range of 25.3 ˚C is effective in Uludağ. Looking at the monthly average temperature differences between Bursa and Uludağ, the highest temperature difference between the two stations is observed in June, while the lowest is in October and November. The difference between the two stations increases in the summer period, mainly due to the overheating of Bursa in the summer months.

3. Results and Discussion

Various geological formations belong to the Paleozoic and Paleocene periods in the higher parts of Uludağ. Rocks such as metagranodiorite, marble, and gneiss microsite from the

Paleozoic period cover most of the region. Granite and aplite pegmatite formations represent the Paleocene period. Looking at the sampling points shown on the map, points 1, 4, 5, 7, 8, 9, 12, 13, 14 and 15 are from meta granodiorite areas; points 2, 3 and 6 are from marble areas; points 10, 11 and 17 are from gneiss marcasite areas; points 15 and 17 are from granite areas and points 16 and 17 are from aplite pegmatite areas (Figure 2). These points were selected to examine the effects of different geological structures on soil properties and, thus, on the distribution of endemic plant species.

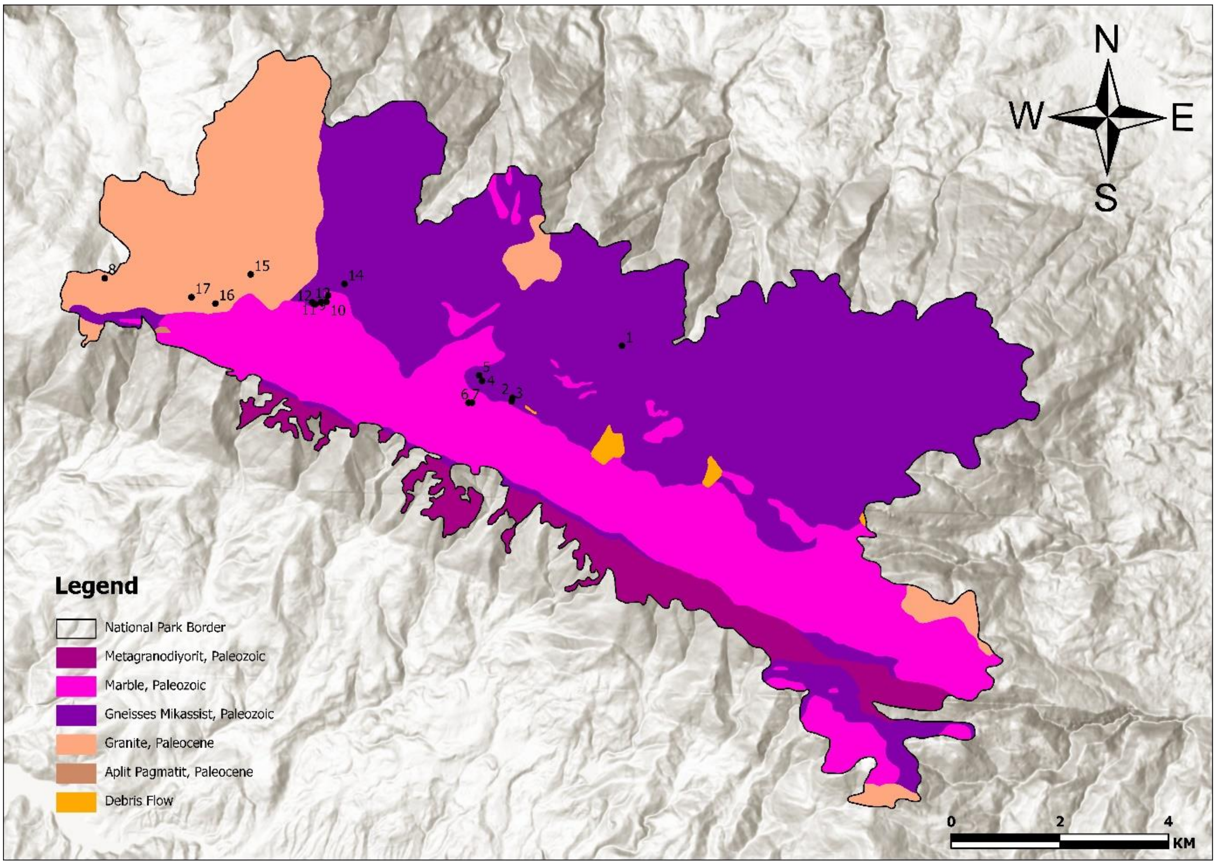

Figure 2. Geological map of study area.

Looking at the landform map of study area (Figure 3), when elevation and slope are considered, the higher regions of study area (high ridges and upper slopes) play an essential role in soil formation. The soils in these regions are generally thinner, stonier, and closer to the bedrock. Therefore, soil formation occurs more slowly.

The mid-slope and upland drainages shown on the map indicate water's flow paths. In these areas, the soil contains less organic matter and is subject to more erosion due to the constant movement of water.

Valleys (valleys) and plains (plains) have deeper soils rich in organic matter. In these areas, the density of vegetation and organic matter accumulation is higher.

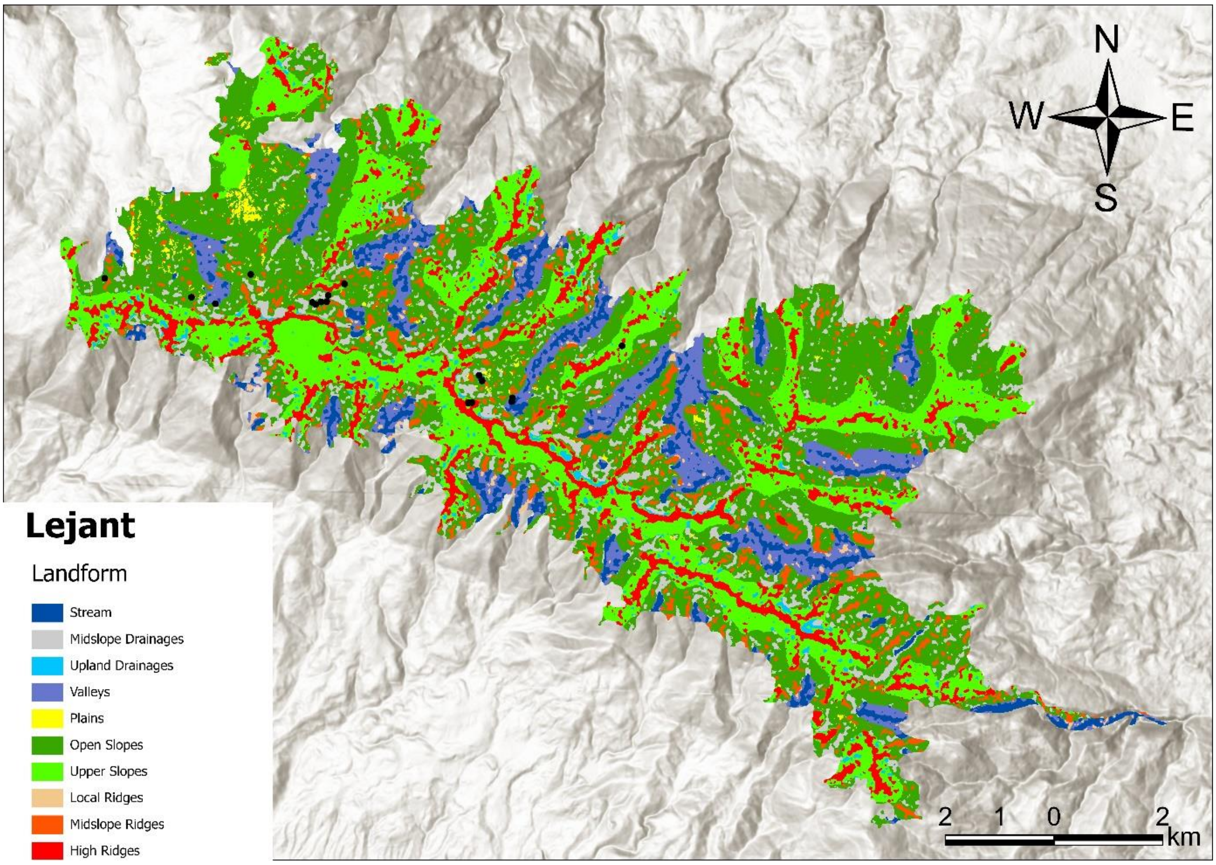

Figure 3. Landform map of study area.

As a result of the analysis of soil samples taken from 17 points in study area, the correlations between elevation and soil texture components were revealed. According to the data, a weak positive correlation (r = 0.414) was found between elevation and silt content and a weak negative correlation (r = -0.375) was found between elevation and sand content. These findings indicate that silt content tends to increase and sand content tends to decrease with increasing elevation. This may reflect environmental conditions favouring the formation of finer-grained soils at higher altitudes.

The literature frequently emphasises that soils' physical and chemical properties change with increasing altitude (Brady & Weil, 2008). Lower temperatures and increased humidity at higher altitudes may affect physical weathering processes and organic matter accumulation, resulting in a change of soil texture in favour of fine-grained fractions (Jenny, 1980). In addition, vegetation is denser in these areas, positively affecting organic matter production and, thus, silt content (Schimel et al., 1994).

The proportions of silt and sand in the soil samples confirm the influence of elevation-related environmental factors. For example, samples at higher altitudes (e.g. Sample 1, Sample 5, Sample 6) have higher silt contents, while samples at lower altitudes (e.g. Sample 8, Sample 9, Sample 10) exhibit higher sand contents. This demonstrates the role of climate and vegetation factors that change with altitude in soil formation and development (Birkeland, 1999).

The high-altitude areas of Uludağ exhibit unique soil properties influenced by various factors such as geology, vegetation and human activities. Studies have shown that soils in the alpine and subalpine belts of Mount Uludağ are affected by disturbances, leading to differences in mineralisation rates and elemental composition (Güleryüz et al., 2006, 2011). The presence of ruderal species such as Verbascum olympicum in degraded areas indicates high rates of nitrification in the soil and adequate nitrate assimilation capacities (Arslan et al., 2013; Güleryüz et al., 2016). Furthermore, the elemental composition of plants growing in contaminated areas in Uludağ Mountain shows the impact of tungsten mining on soil quality (Erdemir, 2017, Kahraman et al., 2017). Soil properties and soil health are essential in biodiversity conservation (Yanardag, 2022; Yetgin, 2023).

Soil properties in the higher elevations of Uludağ are influenced by factors such as organic carbon content, moisture levels and mineral composition, which play an essential role in determining overall soil quality and health (Stanchi et al., 2012; Unsever & Diallo, 2019). The presence of various elements such as copper, iron, zinc and lead in soil can be attributed to both natural geological processes and anthropogenic activities (Güleryüz et al., 2006). Furthermore, using fly ash and lime for soil stabilisation emphasises the importance of soil amendment in improving soil properties.

Soil structure in the highlands of Uludağ is a complex interaction of geological, biological and anthropogenic factors. Understanding the mineralisation rates, elemental composition and pollution levels in these soils is essential for effective land management and conservation efforts in the region. In addition, it has been determined that water resources have decreased in area, and bare rocky lands have increased in area over time (Özsoy, 2021).

These results are essential for understanding the potential impacts of soils on biodiversity in Uludağ National Park. Higher clay content supports plant root growth by increasing water-holding capacity, while lower sand content may help maintain moist conditions by reducing soil water permeability (Hillel, 2003). This could play a decisive role in endemic plant species' settlement and survival strategies.

The distribution patterns of endemic plants in various habitats have been a subject of interest in ecological studies. Observations show that endemic plant species tend to concentrate on specific microenvironments, especially those inhabiting hillsides. These include hollow areas with colluvial material deposited between stones and soils adjacent to lakes. It was also noted that endemic plants thrive in flat areas created by mining activities, where puddles form and where organic matter content is high. This indicates that the presence and distribution of endemic plants are closely linked to their habitats' topographic and edaphic characteristics. In particular, the preference of endemic plants for flat or nearly flat lands with high organic matter content underlines the importance of soil properties in shaping plant distribution patterns. These findings align with the broader literature on ecological niche specialisation of endemic species and highlight the importance of habitat heterogeneity in supporting endemic plant diversity, emphasising the complex relationships between plant communities and their environment.

These correlations between elevation and soil texture components provide critical information for understanding the dynamics of ecosystems in Uludağ National Park and for developing conservation strategies. These findings support the relationships between elevation and soil properties reported in the literature and provide the basis for sustainable biodiversity management in mountain ecosystems (Walker & Del Moral, 2003). Figure 4 gives field views of some of the places where endemic plants are found in Uludağ.

Figure 4. Field views of some of the sites with endemic plants in study area.

4. Conclusion

Given the biodiversity in Uludağ and the role of soil characteristics in plant diversity, it is essential to address soil erosion and encourage soil conservation practices. In particular, creating flat areas such as terracing near lake formations and other places will contribute to accumulating colluvial material in these areas and forming organic matter over time. Vegetation is critical in protecting soils against erosion and contributes to the accumulation of organic matter, vital for plant growth and ecosystem health in alpine soils. Another issue is grazing activities in the area. Managing grazing activities in these areas is another critical aspect of plant conservation, as seasonal grazing can help maintain species composition and soil texture in these sensitive ecosystems. Consequently, a holistic approach integrating soil conservation, biodiversity conservation and sustainable land management practices is essential for effectively conserving plants in alpine mountains. By considering the complex relationships between soil properties, plant communities and ecosystem functions, conservation efforts can be tailored to maintain alpine environments' unique biodiversity and ecological integrity.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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