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The Impact Of Environmental Changes On Plant Diversity Of Mount Gara For (2014-2024) A.D. In Dohuk Governorate, Northern Iraq

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ABSTRACT
Climatic, topographical, and soil factors are the main determinants of the distribution and spread of natural trees. Therefore, Mount Gara one of the most prominent landmarks of the Zagros Mountains, stretching between Iraq, Turkey, and Iran which located between longitudes (43°17'31.9″ - 43°20'13.3″ E) and latitudes (36°59'53.4″ - 37°01'02.4″N) at an elevation ranging from 1,402 to 1,745 meters above sea level. was chosen as a case study due to its environmental and economic importance. Various species of trees grow naturally there, including *Quercus Aegilops*, *Quercus infectoria*, *Acer monspessulanum*, *Prunus microcarpa*, *Pyrus syriaca*, *Juniperus oxycedrus*, *Crataegus azarolus*, *Prunus webbii*, *Pistacia eurycarpa*, and *Lonicera arborea*. Scientific tools were used to measure the area-specific diversity of each sample, based on the number of species present within a defined unit area. The Margalef index indicated clear variation between samples during the two periods (2014 and 2024), showing a decrease in diversity at sites with southern exposures and steep slopes. The Menhinick index showed variation in species richness, which was relatively high at an altitude of (1530) m, while the lowest value was recorded at (1745) m above sea level. The Shannon-Weaver diversity index (Shannon-Weaver) differed in biodiversity between samples, reflecting environmental effects on tree growth. This is consistent with the Simpson and Evenness indices, indicating high species equivalence. The chi-square test values showed low values across all indices (Margalef, Menhinick, and Shannon), suggesting no significant difference between the two time periods at a significance level of (0.05). Similarly, the insignificant chi-square results between 2014 and 2024 indicate no statistically significant differences in tree composition or species distribution within the plant community during this period.

***Keywords*:** Biodiversity indicators, Tree species, chi-square test, Environmental changes, Gara mount..

INTRODUCTION

Pure and mixed forests are vital natural resources that span diverse regions and environments worldwide. They play a crucial role in maintaining biodiversity while serving as dynamic ecosystems characterized by diversity and abundance, contributing to ecosystem vitality and resilience [1]. The distribution and diversity of tree species within these ecosystems are influenced by multiple environmental factors, including human activities, climate, soil composition, topography, and water availability. Climate is a primary determinant of forest composition and structure [2] Global warming-induced shifts in climate patterns significantly impact forest diversity by altering temperature and precipitation regimes, leading to changes in species distribution and potential biodiversity loss. Soil composition also plays a pivotal role in shaping forest ecosystems, as nutrient content, pH, and texture determine the types of plants that can establish and persist in a given area. Soil properties are essential for understanding ecosystem responses to natural and anthropogenic changes. Topographic features—such as elevation, slope, and aspect—further enhance forest diversity by creating microclimates. Additionally, water availability is a key factor influencing forest resilience and biodiversity. These environmental factors interact in complex ways [3]. Monitoring forest vitality and biodiversity is critically important, particularly under escalating pressures from human activities and climate change. Research underscores the need for sustainable forest management strategies that balance resource exploitation with ecosystem health. Understanding species' geographical distributions and their interactions enables policymakers to predict distribution, abundance, and dispersal patterns. According to [4], predicting plant species distribution—including forest trees—is vital for assessing future forest changes, which profoundly affect biodiversity through habitat loss and ecosystem degradation. Thus, sustainable resource management requires balancing environmental needs with the services and products these resources provide. Species distribution and density are determined by biotic and abiotic factors at a given site. Gains or losses of species often result from environmental pressures, leading to imbalances in distribution and abundance. Rapid climate change exacerbates these shifts, with temperature and precipitation altering species ranges and prompting geographical redistributions. Such changes may involve species migration or biological community restructuring, highlighting the need to understand environmental impacts on biodiversity [5,6]. These studies emphasize the use of environmental models to predict future tree distributions under climate change, providing essential guidance for forest management policies. In this study, we evaluated plant diversity using established metrics: Species richness (Margalef Index and Menhinick Index), Diversity indices (Shannon Diversity Index and Simpson's Index), and Evenness (Pielou's Evenness Index).

Materials And Methods

Forests are integrated and resilient ecosystems characterized by unique biodiversity that enables them to adapt to changing conditions. Despite increasing pressures, including climate change and human activities, their stability is threatened, and plant species distributions are shifting [7]. Their abundance depends on overlapping factors, including annual precipitation (400–800 mm), soil quality (sandy-clay soils rich in minerals), and human pressures such as overgrazing and illegal logging. Forests possess significant adaptive mechanisms, such as natural regeneration after disturbances and the ability to compensate for lost carbon through enhanced photosynthesis [8]. As renewable natural resources, forests can restore themselves and maintain ecological balance [9]. The study area is located on Mount Gara in the northwestern part of Dohuk Governorate, within the Zagros Mountain range that stretches across Iraq, Turkey, and Iran. This area is one of the region's most prominent topographical features, distinguished by unique geographical characteristics that underscore its environmental and economic importance. It lies between longitudes 43°17'31.9″–43°20'13.3″ E and latitudes 36°59'53.4″–37°01'02.4″ N, with elevations ranging from 1,402 to 1,745 meters above sea level. Rainfall plays a key role in determining tree growth, productivity, and vitality by supplying water essential for physiological processes like photosynthesis and nutrient transport. These processes, in turn, drive leaf area expansion and trunk diameter growth [10]. The temporal and spatial distribution of rainfall is closely tied to productivity: balanced rainfall (particularly during critical seasons such as spring) enhances fruit yield, while its absence reduces seed quality and can lead to production collapse [11]. Adequate rainfall mitigates drought stress, which otherwise weakens trees' resistance to pests and diseases. However, excessive rainfall or flooding can cause soil waterlogging and impair root respiration [12]. Climate change exacerbates these risks by altering precipitation patterns, necessitating tools like growth-ring analysis and climate modeling to understand tree responses to such fluctuations. Soil formation depends fundamentally on the complex interplay between climatic and geomorphological factors. Prevailing climatic conditions—such as temperature, precipitation, and relative humidity—determine the physical and chemical processes governing rock weathering and soil formation. This interaction produces diverse soil properties across climatic zones: chemical weathering dominates in humid regions due to acid rain, while mechanical weathering prevails in arid regions because of thermal expansion and contraction [13].

Identifying and preparing tree species

Understanding tree species composition is critically important for assessing biodiversity and ecosystem functions in a given area. This knowledge provides valuable insights into an ecosystem's capacity to support wildlife, regulate local climate, and determine conservation and regeneration requirements. This classification follows the methodology established by researcher [14].

The number of tree species at each site was determined through comprehensive field surveys designed to collect quantitative data on tree diversity. These surveys involved precise species identification, counting, and documentation, yielding essential information about species abundance, distribution, and prevalence. Such data are instrumental in analyzing ecosystem dynamics. Additionally, tree diameters and heights were measured, including diameter at breast height (DBH), crown height, and crown diameter for all study samples.

Biodiversity Index

Species diversity in Jabal Gara was quantified by measuring the number of distinct species within designated areas. Vegetation distribution and spread are influenced by key factors such as topographic variations (e.g., aspect, elevation, and slope). To evaluate biodiversity, standardized scientific tools were employed to measure species diversity per sample, offering insights into environmental patterns and organism distribution [15].

Plant Diversity Indices

-**Richness Index and Margalef's Index**

These indices are robust tools for assessing species richness. High values indicate elevated biodiversity, while low values suggest declining diversity. Introduced by [16], they are widely used in ecological studies for cross-site or temporal comparisons.

Equation:

$$D_{mar=}\frac{(S-1)}{LnN}$$

Where:

- S = number of species
- N = total number of individuals of all species
- $D_{mar=}$(Margalef's diversity index) richness (abundance) index

-**Menhinick Index**

A widely adopted quantitative measure of species richness in ecological communities, valued for its simplicity. It calculates the ratio of species count to the square root of total individuals [17].

Equation:

$$D_{mn} = \frac{S}{\sqrt{N}}$$

Where:

- S = number of species
- N = total number of individuals
- D_{mn}= (Menhinick diversity index)

-**Shannon-Weaver Index**

A prominent statistical metric for ecosystem diversity, combining species richness and evenness [18].

Equation:

$$H = -\sum_{t=1}^{n} pi\ Ln\ pi$$

Where:

- H = diversity index
- pi = proportion of individuals belonging to species

$$pi = \left(\frac{ni}{N}\right)$$

-**Simpson's Index**

A key tool for analyzing dominance and diversity. High values reflect equitable species distribution, while low values indicate dominance by few species [19].

Equation:

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where:

- n= total individuals per species
- N= total individuals
- D= Relative concertation index

-**Evenness Index (Pielou's Index)**

The Evenness Index, also known as the Pielou Index after its creator [20], is one of the complementary indices to diversity measures, focusing on measuring the balance of distribution of individuals among different species in a given community. The index shows the extent to which relative abundance is evenly distributed among those species. The evenness index ranges from 0 to 1, with values close to 1 indicating an even distribution of individuals among species (high evenness), while low values indicate the dominance of one or a few species (low evenness). According to the following equation:

$$J = {}^{H}/_{Lns}$$

Where:

- H = Shannon diversity index
- S = total species count

Results And Discussion

Biodiversity is one of the fundamental pillars supporting ecosystem sustainability and providing vital environmental services to humans and other organisms. The study of biodiversity is particularly important in mountainous areas, where diverse climatic and topographical conditions create habitats for numerous species with unique adaptations [21]. Among these areas, Mount Karah in the Kurdistan Region of northern Iraq stands out for its exceptional biological richness, resulting from its varied terrain, elevation gradients, and environmental factors. These elevation gradients foster diverse habitats that sustain a wide variety of plant and animal species. However, this biodiversity faces growing threats from climate change, human activities, and environmental degradation, underscoring the need for comprehensive studies to assess its status and develop sustainable management and conservation strategies [22]. The biodiversity of Mount Kara was analyzed using established statistical indicators: Species Richness (calculated using both the Margalef and Menhinick indices), the Shannon Diversity Index (combining richness and evenness), Simpson's Index (measuring relative dominance concentration), and the Pielou's Evenness Index. These metrics are presented in Table 1.

Table 1: Diversity index values in Mount Gara for the years 2014-2024 in Duhok Governorate.

no. of sample	Margalef, Richness index		Menhinick, Richness index		Shannon Index (H)		Simpson index (D)		(Evenness index) pielou index	
	Year 2014	Year 2024	Year 2014	Year 2024	Year 2014	Year 2024	Year 2014	Year 2024	Year 2014	Year 2024
1	0.96	0.82	0.30	0.18	1.32	0.96	0.32	0.53	0.68	0.49
2	1.49	1.06	0.49	0.21	1.44	1.12	0.35	0.51	0.63	0.51
3	1.37	1.12	0.38	0.26	1.62	1.63	0.27	0.30	0.70	0.74
4	1.20	1.12	0.32	0.25	1.44	1.31	0.31	0.37	0.65	0.60
5	1.05	1.23	0.29	0.35	1.84	1.60	0.18	0.27	0.88	0.73
6	1.18	1.09	0.30	0.23	1.39	0.90	0.38	0.59	0.63	0.41
Min.	0.96	0.29	0.29	0.18	1.32	0.90	0.18	0.27	0.63	0.41
Max.	1.49	0.49	0.49	0.35	1.84	1.63	0.38	0.59	0.88	0.74
Mean	1.21	0.17	0.35	0.25	1.51	1.25	0.30	0.43	0.70	0.58
S.D	0.20	0.08	0.08	0.06	0.19	0.31	0.07	0.13	0.09	0.13
χ^2	1.47		1.47		2.54		5.58		5.58	

Table 1 highlights the importance of species richness and protection from extinction [23] to address diverse environmental pressures and ensure species' capacity for natural regeneration. The Margalef index values varied significantly between the study periods (2014 and 2024). In 2014, the highest value (1.49) was recorded in Sample 2, indicating relatively high species richness, while the lowest value (0.96) occurred in Sample 1. This reduction in Sample 1 resulted from its composition: 533 trees distributed across seven species per hectare, with *Quercus egilops* dominating (46.3% of individuals). This imbalance reflects the sample site's environmental conditions a south-facing slope with greater solar exposure and aridity, favoring drought-adapted species while excluding less tolerant ones. The steep slope (18%) further exacerbated surface runoff, soil erosion, and reduced moisture retention, negatively impacting species diversity. These findings align with [24], who demonstrated that Margalef index values decline in south-facing, steep, and arid sites, emphasizing how ecological and topographical balance determines species richness in regenerating mountain ecosystems. The standard deviation (0.20) corroborates [25] observation that Margalef index sensitivity depends on species count and sample size.

In 2024, Sample (5) recorded the highest Margalef Index (1.23), indicating a slight increase in species richness since 2014, while Sample (1) showed the lowest (0.82), reflecting a modest decline. These results suggest minor ecological changes affecting biodiversity, though not significantly. The standard deviation decreased from (0.20 - 0.14), indicating reduced variability and greater homogeneity in species richness. As [26] noted, such slight shifts may result from local environmental factors or biodiversity management efforts, suggesting relative ecological stability across samples. The Menhinick index, which reflects qualitative richness and biodiversity, showed variation among samples in 2014. Sample 2, at 1530 m elevation, recorded the highest value (0.25), indicating relatively high richness, while Sample 5, at 1745 m, had the lowest value (0.29), reflecting reduced richness due to its higher altitude. This aligns with [27], who found that the Menhinick index decreases with increasing altitude and slope in Himalayan humid forests, attributed to harsh conditions like cold and drought. By 2024, Sample 5 improved to 0.35, while Sample 1 dropped to 0.18. [28] attribute such variations to human activities like overgrazing. The standard deviation (0.06) confirmed moderate inter-sample variability. Collectively, Margalef and Menhinick indices revealed slight richness declines in Samples 1, 4 and 6 between 2014–2024, except for Sample 5. These patterns reflect localized impacts of climate change and habitat loss, though some areas show stabilization through management efforts [29]. Table 1 also presents Shannon-Weaver, Pielou's evenness, and Simpson indices. In 2014, Sample 5 had the highest Shannon value (1.84; highest diversity), while Sample 1 scored lowest (1.32). By 2024, Sample 3 peaked (1.63), and Sample 6 plummeted to 0.90, indicating biodiversity loss from environmental pressures (30). Simpsons diversity index values in 2014 ranged from 0.18 (Sample 5, high diversity) to 0.38 (Sample 6, dominance by few species), aligning with [31].

In (2024), the value of the index in sample (6) increased to (0.59), reflecting an increase in dominance and a greater decline in biodiversity compared to (2014). This may be a result of environmental or ecological changes that have unevenly affected the different species. As for sample (5), the index value increased from (0.18) to (0.27), indicating a slight decrease in biodiversity compared to (2014). The standard deviation (0.13) recorded an increase; however, this sample still retains the highest level of biodiversity among the samples [32]. The Pielou equivalence index is used to measure the degree of equivalence between species in a given ecological community. The index is based on the ratio of Observed Diversity to Maximum Possible Diversity, based on the total number of species in the community. Values close to (1) indicate high species parity, meaning that all species are relatively evenly distributed. Values close to 0 indicate inequality, with certain species dominating the community [33]. In 2014, Sample 5 recorded the highest Pielou index value (0.88), indicating high species evenness and a stable ecosystem. This aligns with [34], who noted that undisturbed natural habitats typically exhibit greater biodiversity and species uniformity. The low standard deviation (0.09) further reflects consistent species distribution within this sample. while, Sample 6 had a Pielou index value of 0.63, lower than Sample 5 but still indicating moderate species evenness, with some dominance by certain species reducing equivalence slightly.

By 2024, Sample 3 led (0.74), while Sample 6 declined sharply to 0.41, suggesting dominance by fewer species [35]. Chi-square tests (χ^2) for all indices showed no significant differences between 2014 and 2024 ($p > 0.05$). Low index values suggest species reduction and dominance by few taxa, likely from climate change and anthropogenic effects [36]. Simpson's index stability implies no major shifts in species dominance, indicating short-term biodiversity equilibrium [37]. The diversity of biological indicators used to measure biodiversity reflects the complexity of measuring diversity in natural systems and highlights the importance of selecting appropriate indicators for each type of data when assessing environmental and temporal changes. The Pielou's Evenness Index, which measures the evenness of the distribution of individuals between species, confirms the stability of this balance within the plant community, with no significant change in the distribution of individuals such that no species clearly dominates the others. Maintaining a close level of homogeneity indicates a balanced distribution of environmental resources, and reflects the low impact of environmental pressures or negative human activities during the period between (2014 and 2024), which supports the hypothesis of relative stability in the structural composition of the community. [38] stated that homogeneity affects the relationship between biodiversity and forest productivity, maintains the balance of resources and reflects the ability of plant communities to adapt to environmental pressures. These statistical results are consistent with field data, which showed variation in species distribution between sites, with some sites characterized by a relatively homogeneous distribution, while a slight dominance of some species was observed in other sites. However, this variation was not sufficient to cause significant differences in plant composition as a whole, reflecting the resilience of plant communities and their ability to adapt to different environmental conditions during the studied period, while maintaining a relative stability in biodiversity and homogeneity.

Conclusion

This study revealed temporal changes in species richness and diversity between 2014 and 2024 across different ecological plots on Mount Gara. While some improvement occurred in Sample 5, other sites—especially Samples 1 and 6—experienced declines linked to harsh topographic and climatic conditions. The Margalef and Menhinick indices indicated reduced richness in arid, south-facing, and high-slope areas. Diversity indices (Shannon, Simpson) showed rising dominance by a few species, particularly in degraded habitats. Evenness values confirmed growing imbalance in species distribution, especially in Sample 6. Although statistical tests showed no significant differences between the two years, the ecological trends suggest localized biodiversity erosion, driven by environmental stress and human disturbance. These patterns underscore the need for ongoing biodiversity monitoring and the implementation of conservation measures to support ecosystem regeneration and long-term stability.

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أثر التغيرات البيئية على التنوع النباتي لجبل كاره للأعوام (2014 -2024) م في محافظة دهوك شمال العراق

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الخلاصة

تُعد العوامل المناخية والطبوغرافية والتربة من المحددات الرئيسية لتوزيع وانتشار الأشجار الطبيعية. لذا تم اختيار جبل كاره أحد أبرز معالم جبال زاكروس الممتدة بين العراق وتركيا وإيران، والمحصورة بين دائرتي عرض ***(43°20'13.3″-43°17'31.9″)*** شرقًا ودائرتي طول ***(36°59'53.4″ - 37°01'02.4″)*** شمالا، وعلى ارتفاع عن مستوى سطح البحر من (1402 – 1745).كنموذج للدراسة لما له من أهمية بيئية واقتصادية ، ففيه تنتشر انوع مختلفة من الاشجار طبيعيا (***Quercus aegilops***) ، (***Quercus infectoria***)، (***Acer monspessulanu***)، (***Prunus microcarpa***)، (***Pyrus Syriaca***) ، (***Juniperus oxycedrus***) ، (***Crataegus azarolus***) ، (***Prunus webbii***) ، (***Pistacia eurycarpa***) ، (***Lonicera arborea***). وتم استخدام أدوات علمية تقوم بقياس تنوع المساحة لكل عينة بالاعتماد على عدد الأنواع الموجودة ضمن وحدة مساحة محددة فلقد اشار مؤشر ***Margalef*** الى تباين واضح بين عينات خلال الفترتين (2014 و2024)، و أظهر انخفاضا في المواقع ذات الواجهات الجنوبية والانحدارات الحادة ، اما مؤشر ***Menhinick***، فقد أظهرت النتائج تبايناً في الثراء النوعي المرتفع نسبياً في ارتفاع (1530) م ، بينما سُجلت أقل قيمة في ارتفاع(***1745***) م فوق مستوى سطح البحر، بينما مؤشر دليل التنوع (***Shannon and weaver***).اختلف في التنوع الحيوي بين العينات وهذا يعكس تأثيرات بيئيا على نمو الاشجار ،وهذا يتطابق مع المؤشرات ***Simpson index***، ***Envenness index*** ، مما يشير إلى تكافؤ عالٍ بين الأنواع . وتبين من قيم اختبار (***χ^2***) (***Chi-Square***)، ولقد ظهرت بقيم متدنية في كل مؤشرات (***Margalef Index***) و (***Menhinck Index***) و(***Shannon Index***) ، وهذا يبين عدم وجود فرق معنوي بين الفترتين الزمنتين والتي تم تقدير هذه المؤشرات وعند مستوى معنوي (0.05)، وكذلك فنتائج اختبار كاي-تربيع (***χ^2***)غير المعنوية بين الفترتين الزمنيتين (2014،2024) تشير لغياب فروق إحصائية ذات دلالة بين التركيب الشجري للمجتمع النباتي وتوزيع الأنواع فيه خلال هذه الفترة.

الكلمات المفتاحية: مؤشرات التنوع الحيوي، انواع الاشجار، اختبار كاي سكوير، التغيرات البيئية.