

Article

Applying Specific Habitat Indicators to Study *Asteraceae* Species Diversity Patterns in Mountainous Area of Beijing, China

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Abstract: The distribution pattern and influencing factors of specific species diversity play a crucial role in decision-making for biodiversity conservation. Identifying suitable regional habitat indicators to assess specific species diversity patterns is a global focus topic. A total of 112 sample plots were surveyed to investigate the relationship between *Asteraceae* species diversity and topography, soil nutrients, and stand factors, using a Structural Equation Model (SEM). Additionally, the Maxent model was utilized to predict the distribution pattern of *Asteraceae* species diversity in response to specific habitat factors. The findings revealed that soil nutrients, topography, and canopy closure had different impacts on *Asteraceae* species diversity, with soil nutrients showing the highest relative coefficient, followed by topography and canopy closure. The elevation and slope gradient were identified as direct and indirect influences on *Asteraceae* species diversity. The contribution rate of potential environmental variables on the *Asteraceae* species diversity was ranked as follows: STN (29.7%) > SOM (28.5%) > slope (8.5%) > Ele (8.1%). *Asteraceae* species diversity was found to be abundant in the locations with SOM (>27 g/kg), STN (>1.8 g/kg), Ele (165–333 m), and slopes (5–12 degrees). Soil nutrient content serves as a key indicator for assessing the abundance of *Asteraceae* species diversity and should be considered in biodiversity conservation.

Keywords: *Asteraceae* species; habitat indicators; biodiversity conservation; Maxent model



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1. Introduction

The *Asteraceae* family, holding great economic and medicinal importance, is the pre-dominant family of angiosperms [1]. These plants are known for their resilience and ability to thrive in harsh conditions, playing a vital role in maintaining ecosystem stability [2]. With the intensification of global climate change and the impact of human activities, *Asteraceae* community ecosystems have been sharply reduced and their protection is facing unprecedented difficulties [3]. Therefore, analyzing the effects of site and stand factors on *Asteraceae* plant diversity can provide an important theoretical basis for guiding biodiversity conservation [4,5].

The presence and distribution of *Asteraceae* species are primarily influenced by various factors such as climate, soil nutrients, topography, stand density, and canopy closure [6,7]. Temperature and precipitation play a fundamental role in determining the growth and distribution of understory species on a large scale [8–11]. From the aspect of stand scale, the site condition has a decisive bearing on the growth and distribution of plant diversity [12–14]. Factors like altitude and slope gradient affect the water and nutrient requirements of these plants [15,16]. Soil nutrients, particularly nitrogen, organic matter, and phosphorus, also significantly affect the growth of plants [17,18]. In the current research on understory species diversity, which mainly concerns the effects of environmental factors and stand structure on species composition and diversity [19–21], the studies have seldom considered *Asteraceae* plant diversity; however, existing studies have indicated that *Asteraceae* plants are strong indicators of site conditions [22].

The majority of the research utilized statistical analysis techniques to examine the correlation between understory plant diversity and environmental factors; however, these methods hardly determine the suitable distribution range of plant diversity accurately, despite a higher abundance diversity index [23–25]. Therefore, there is a crucial need for finding a suitable approach to quantify the range of plant diversity. Maximum entropy models offer significant advantages in forecasting species distribution and have become widely utilized in species prediction [26–28].

The main goals of our research are to (1) analyze the primary habitat factors that influence *Asteraceae* species diversity, (2) determine the direct and indirect effects of habitat factors on *Asteraceae* species diversity, and (3) predict the distribution range of abundant *Asteraceae* species diversity.

2. Materials and Methods

2.1. Study Sites

The Beijing–Tianjin Sandstorm Source Phase II Forestry Project in Beijing is mainly distributed in its mountainous areas ($39^{\circ}12'–41^{\circ}05' \text{ N}$, $115^{\circ}25'–117^{\circ}30' \text{ E}$) and covers about $10,400 \text{ km}^2$. The areas belong to a warm temperate semi-humid monsoon climate, with an average annual precipitation from 470 to 660 mm and an average yearly temperature from 11 to 13°C . Land use types consist of woodland and grassland. Zonal soils are mainly composed of meadow soil, mountainous brown forest soil, and mountainous cinnamon soil.

2.2. Field Investigation and Soil Sampling

Based on the *Asteraceae* species distribution data provided by existing studies [1], a total of 112 representative *Platycladus orientalis* plantations' sample sites ($20 \text{ m} \times 20 \text{ m}$) were selected for investigation (as shown in Figure 1). The following variables were measured at the sample plots: stand density, canopy closure, elevation, aspect, slope, and geographic coordinates [15]. Ten soil samples were randomly collected from the 0–10 cm soil layer using a standard soil sampler with a 100 cm^3 capacity, with the aim of measuring the basic physical and chemical properties of the soil [29].

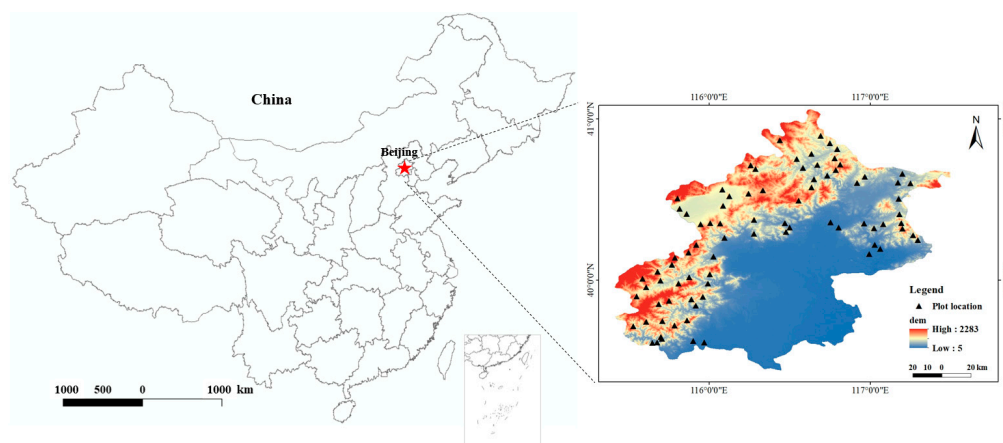


Figure 1. Location map of the study area.

We randomly laid out ten $1 \text{ m} \times 1 \text{ m}$ samples in each standard sample plot [22], and the names of the plants and the number of plants of each species in each sample were recorded for calculating the understory diversity; the environmental and stand factors are shown in Table 1.

Table 1. Environmental and stand factors data of standard plots.

Environmental and Stand Factors	Ranges	Mean	Standard Deviation
Elevation (m)	114–770	359.69	116.12
Slope (°)	3–39	18.81	10.02
Soil organic matter content (g/kg)	13.84–116.58	44.68	21.35
Soil total nitrogen content (g/kg)	0.98–6.58	2.97	1.25
Soil total phosphorus content (g/kg)	0.24–1.12	0.57	0.15
Soil total potassium content (g/kg)	9.25–40.72	20.25	6.06
Soil available nitrogen content (mg/kg)	91.57–415.24	135.39	80.62
Soil available phosphorus content (mg/kg)	0.09–4.005	6.91	1.59
Soil available potassium content (mg/kg)	37.533–444.82	1.01	0.34
Stand density (plant·hm ^{−2})	500–1975	1035.18	286.71
Canopy closure	0.5–0.95	0.76	0.11

2.3. Data Analysis and Modeling

2.3.1. Asteraceae Diversity Index Calculation

In this study, we calculated a total of four *Asteraceae* species diversity indices. The formula for calculating diversity is as follows:

$$\text{Shannon–Wiener index } H = \sum_{i=1}^S \ln P_i \times P_i \quad (1)$$

$$\text{Simpson index } SD = 1 - \sum_{i=1}^S p_i^2 \quad (2)$$

$$\text{Margalef index } H = (S - 1) / \ln N \quad (3)$$

$$\text{Gleason index } D = \frac{S}{\ln A} \quad (4)$$

where S is the total number of understory herbaceous species; p_i is the ratio of the number of individuals of the i_{th} species to the total number of individuals of all species; N is the total number of herbaceous individuals in the understory.

2.3.2. Maxent Model

The maximum entropy model is a spatial distribution model of the species at the geographical scale [30]. It is based on the maximum entropy theory, and is applied to measure the maximum likelihood of a sample [31]. The objective of the model is to infer the location information through incomplete information and to identify the conditions under which the probability reaches its maximum [32]. The accuracy of the model was verified by using the receiver operating characteristic curve (ROC), and the accuracy was judged by calculating the area (AUC) enclosed by the curve and the abscissa [33,34]. Two sets of data are required for the operation of the maximum entropy model: one is the geographical distribution data of *Asteraceae* species, which are expressed by the latitude and longitude of each species; the second is the raster data of environmental factors in the study area. The elevation of Beijing is derived from the 30 m × 30 m digital elevation model (DEM), the aspect and slope gradient are extracted from the DEM (<http://westdc.westgis.ac.cn>, accessed on 12 March 2024), and the soil nutrients data of the study sites are modified by the measured soil nutrients data by means of Kriging interpolation.

3. Results

3.1. The Relationship between the Asteraceae Species Diversity Indices

The correlation of these diversity indices is shown in Figure 2. The results demonstrate that the Shannon–Wiener index had the highest correlation with the other three indices, with an R^2 of 0.87, 0.74, and 0.70. After a comprehensive comparison of the correlations of these indices, we chose the Shannon–Wiener index to measure the overall level of *Asteraceae* species diversity.

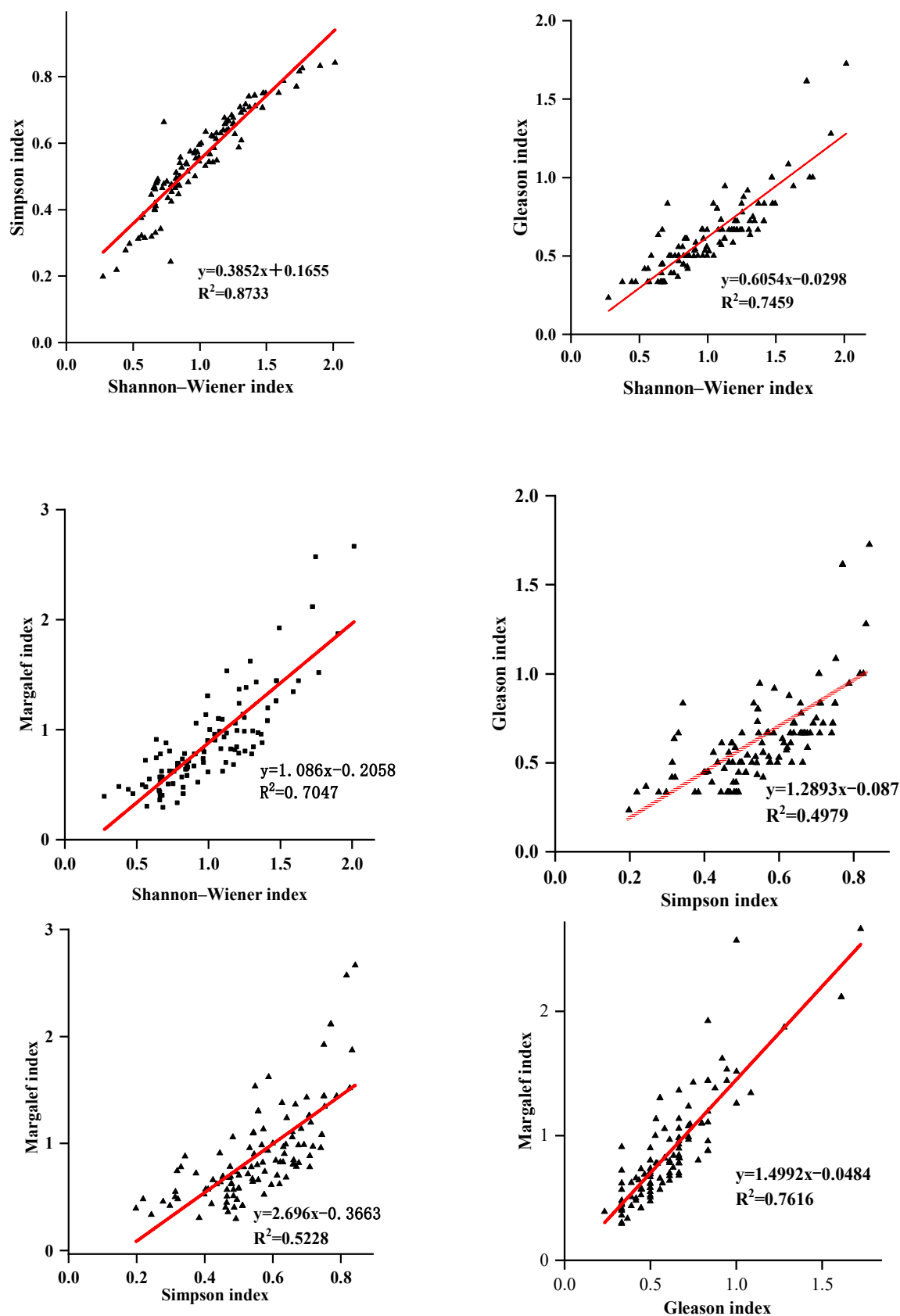


Figure 2. Correlation of the four *Asteraceae* diversity indices.

3.2. Effects of Environmental Factors on Asteraceae Species Diversity

The direct and indirect effects of elevation, slope, and soil nutrient factors on *Asteraceae* diversity are shown in Figure 3. The soil nutrients had a significant effect on the *Asteraceae* species diversity ($p < 0.01$), and the elevation and slope significantly affected the *Asteraceae* species diversity ($p < 0.05$). The standardized effects of these factors on the *Asteraceae* species diversity are shown in Table 2. The direct impact coefficients were soil nutrients (0.54), slope (−0.21), and elevation (−0.17); the indirect impact coefficients were the elevation (−0.06) and slope (−0.02). Overall, soil nutrients were the dominant factors affecting *Asteraceae* species diversity, with the direct effects being the primary mechanism that dictated diversity. The elevation and slope also had important impacts on *Asteraceae* species diversity.

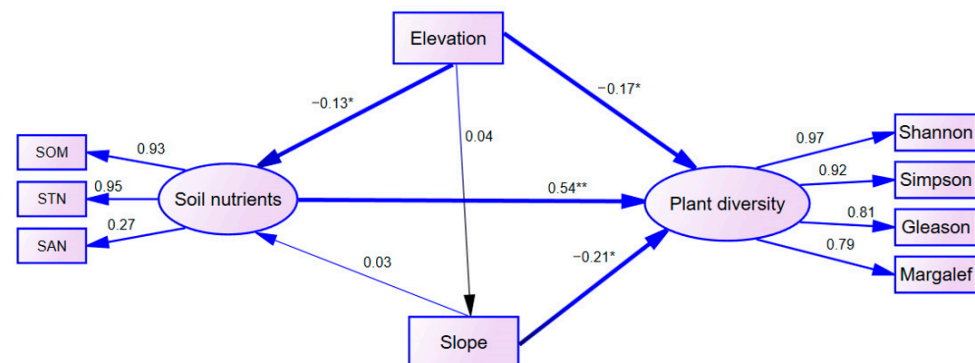


Figure 3. Effects of elevation, slope closure, and soil nutrient factors on *Asteraceae* species diversity (CMIN/DF = 1.1, CFI = 0.99, RSMEA = 0.03). Notes: * $p < 0.05$, ** $p < 0.01$.

Table 2. Standardized effects of these factors on the understory *Asteraceae* diversity.

Impact Factors	Direct Effect	Indirect Effect	Total Effect
Elevation	−0.17 *	−0.06	−0.24 *
Slope	−0.21 *	−0.02	−0.23 *
Soil nutrients	0.54 **		0.54 **

Notes: * $p < 0.05$, ** $p < 0.01$.

3.3. Maximum Entropy Model Results

In this study, the Shannon–Wiener diversity index ranged from 0.27 to 2.01, the average value was 1.01, a screening value equal to the average *Asteraceae* species diversity at the sample sites was determined, and those values beyond this screening value were considered in the sample plots with abundant *Asteraceae* species diversity. The ROC curves as shown in Figure 4.

The contribution rate of potential environmental variables on the *Asteraceae* species diversity was ranked as follows: soil total nitrogen (29.7%) > soil organic matter (28.5%) > slope (8.5%) > elevation (8.1%), and the cumulative contribution rate was 74.8% (Table 3). The contribution rate of other environmental variables was between 3.5% and 4.9%, which had little impact on *Asteraceae* species diversity. The above analysis shows that the main environmental variables affecting the *Asteraceae* species diversity were soil nutrient factors (soil organic matter and soil total nitrogen), of which the cumulative contribution rate was 58.2%. Taking the probability of existence greater than 0.7 as the threshold value, the contribution rate of STN was the highest among the soil factors, reaching 29.7%; when the STN was greater than 1.8 g/kg, the probability of existence was greater than 0.7. The contribution rate of SOM in the soil variables ranked second, which was 28.5%. It can be seen from Figure 5 that when the SOM was greater than 27 g/kg, the probability of existence was greater than 0.7. Obviously, this was suitable for the distribution of the abundant *Asteraceae* species diversity level when the total nitrogen content of soil was more than 1.8 g/kg. Moreover, the probability distribution remains the largest when it reaches 2 g/kg. When the elevation ranges from 165 to 333 m, the probability of existence was

greater than 0.7 (Figure 5). The probability of existence reaches the peak at about 230 m, indicating that low mountain areas were the most suitable for the *Asteraceae* species growth; when the elevation was less than 100 m or more than 500 m, the probability of existence decreases, indicating that these two elevations were not conducive to their distribution. The contribution rate of the slope degree to *Asteraceae* diversity was 8.1%; when the slope range was 5 to 12°, the probability of existence was greater than 0.7 (Figure 5). The probability of existence reached the peak value when the slope degree was about 8 degrees, indicating that the gentle slope area was most suitable for their distribution; when the slope degree was less than 2 degrees or more than 22 degrees, there was a rapid decline in the probability, indicating that the two slopes were not conducive to their distribution.

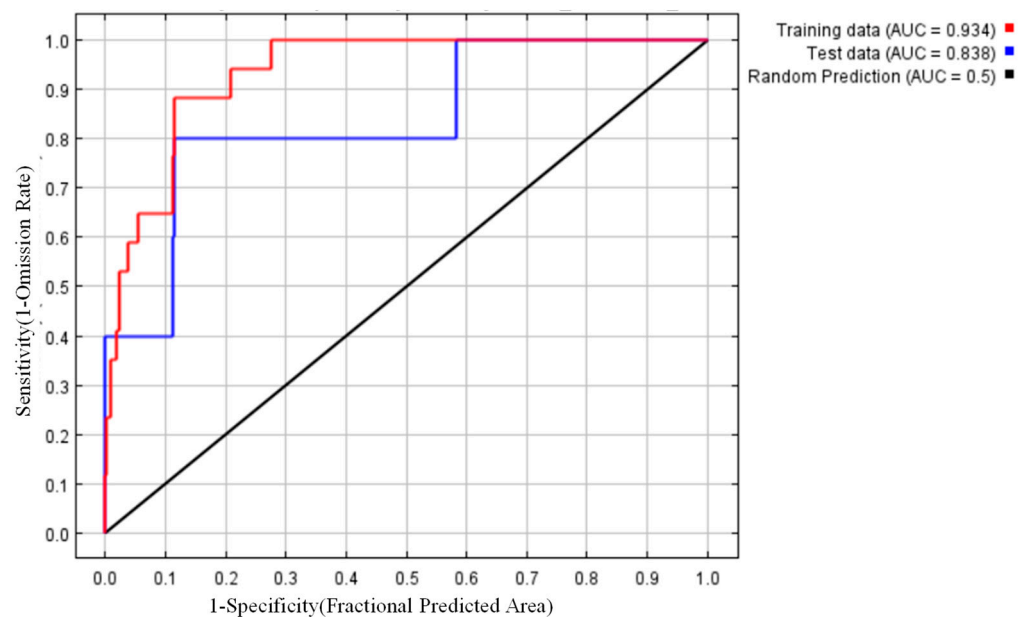


Figure 4. ROC curves.

Table 3. Contribution and cumulative contributions of environmental factors to the *Asteraceae* diversity.

Variable Factors	Contribution Rate (%)	Cumulative Contribution Rate (%)
Soil total nitrogen	29.7	29.7
Soil organic matter	28.5	58.2
Slope	8.5	66.7
Elevation	8.1	74.8
Soil available nitrogen	4.9	79.7
Aspect	4.7	84.4

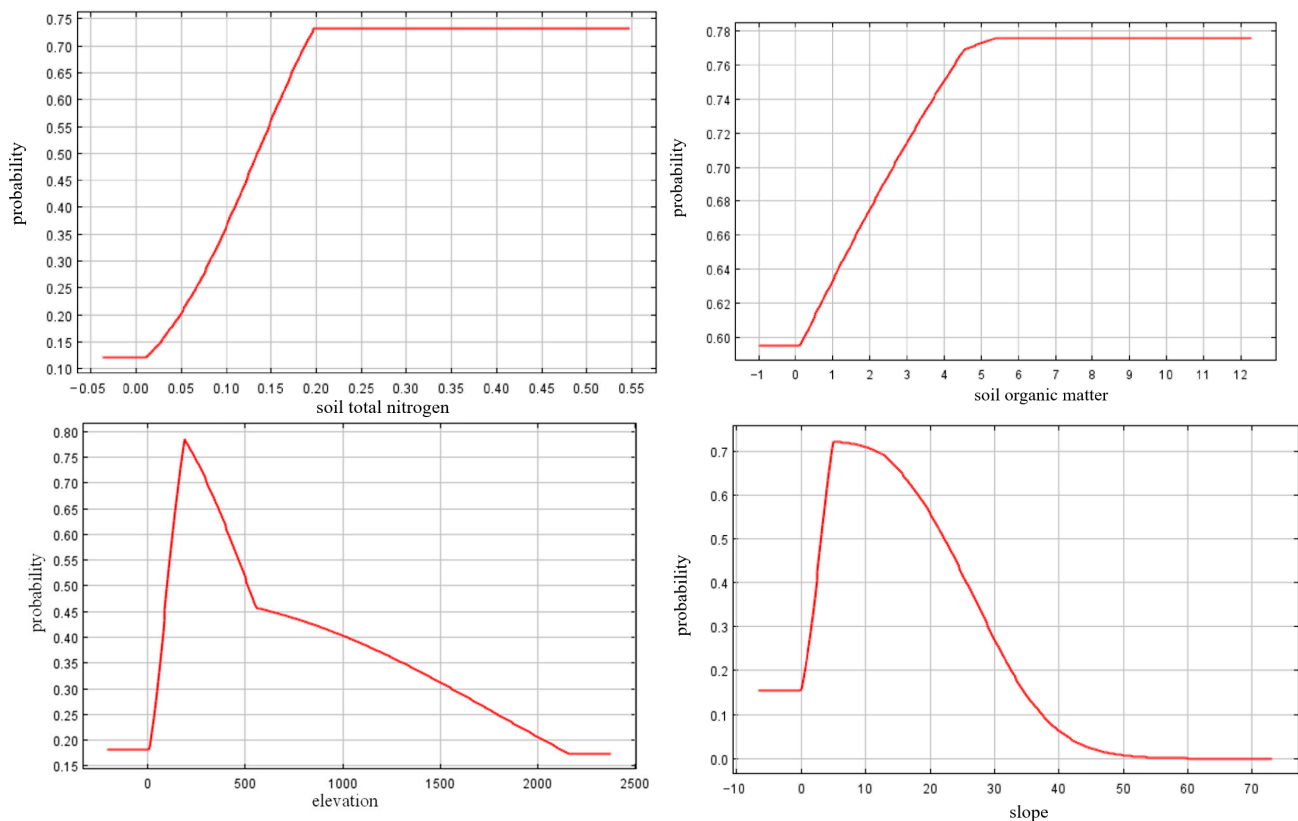


Figure 5. Response curve of the existence probability of abundant *Asteraceae* species diversity areas in relation to environmental factors.

4. Discussion

This study found that the soil organic matter and soil total nitrogen content were the dominant soil factors affecting the *Asteraceae* species diversity, with a cumulative contribution rate of 58.4%. The main reason was that soil organic matter contains various nutrients required for plant growth, which are some of the main sources of vegetation nutrition and can promote the growth and development of plants [35,36]. A large amount of nitrogen is necessary for plant growth; its abundance, shortage, and supply directly affect the growth level of plants [37,38]. When the soil organic matter content was less than 27 g/kg and the total nitrogen content was less than 1.8 g/kg, the probability of the existence of abundant *Asteraceae* species diversity decreased rapidly. An increase in soil nutrients such as soil organic matter and nitrogen will increase the competition to occupy ecological niches, which promotes the growth of *Asteraceae* plants [39–41]. Therefore, for the land with a soil organic matter content less than 27 g/kg and a soil total nitrogen content less than 1.8 g/kg in the Beijing Mountain area, a reasonable application of organic fertilizer and nitrogen fertilizer is conducive to increasing the *Asteraceae* species diversity.

Topographic factors such as the altitude and slope have a vital influence on species distribution, mainly because they are the fundamental factors affecting energy and material variation at the site scale [42,43]. The present study reveals that topographic factors, specifically elevation and slope, exert an impact on the diversity of *Asteraceae* species, accounting for a cumulative contribution rate of 16.6%. Soil nutrient conditions are better at medium altitudes and on gentle slopes, which provide favorable conditions for the growth and reproduction of *Asteraceae* plants [44,45]. Within the forest, canopy closure determines the effective light intensity, being able to redistribute light, heat, water, fertilizer, and other resources, thus directly affecting understory herbaceous diversity [46]. However, the canopy close variable has no significant effect on the *Asteraceae* species diversity in this study.

5. Conclusions

Asteraceae plants have a rich species diversity and strong environmental adaptability; they play a key role in maintaining ecological balance in the mountainous areas of Beijing. However, the response of *Asteraceae* species diversity to specific habitat factors has been rarely explored. In this study, we utilized a structural equation model and a maximum entropy model to assess the effects of habitat factors on *Asteraceae* diversity. The results show that soil organic matter and total nitrogen dominated the *Asteraceae* species diversity, while slope and elevation factors had a significant effect on *Asteraceae* plants diversity. The effects of canopy closure and stand density on the diversity of *Asteraceae* were not significant. *Asteraceae* species diversity was abundant at the location with SOM (>27 g/kg), STN (>1.8 g/kg), Ele (165–333 m), and slopes (5–12 degrees). Soil organic matter and total nitrogen content serve as key indicators for assessing the abundance of *Asteraceae* species diversity. Our study demonstrated that it is advisable to apply organic fertilizer and nitrogen fertilizer to improve the *Asteraceae* species diversity in the sites where soil organic matter content and total nitrogen content are less than 27 g/kg and 1.5 g/kg respectively.

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Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Luo, C.J. Studies on Plant Diversity in Mountain Areas in Beijing. Master's Thesis, Beijing Forestry University, Beijing, China, June 2005.
2. Pan, Y.Z.; Chen, L.; Chen, J.Y.; Zhao, D.; Ye, D.L.; Wang, Z.H.; Wang, H.Y. Effects of Nitrogen and Phosphorus Addition on Medicinal Plant Community Characteristics in the Hulunbuir Meadow Steppe. *Chin. J. Grassl.* **2024**, *6*, 117–125. (In Chinese)
3. Ali, F.; Khan, N.; Rahmonov, O. Ecosystem Services and Linkages of Naturally Managed *Monothea buxifolia* (Falc.) A. DC. Forests with Local Communities across Contiguous Mountainous Ranges in Pakistan. *Biology* **2022**, *11*, 1469. [[CrossRef](#)] [[PubMed](#)]
4. Bilal, A.; Wang, Y.; Jia, H.; Liu, Y.; Eve, B.; Zhang, K. Optimizing stand structure for trade-offs between overstory timber production and understory plant diversity: A case-study of a larch plantation in northwest China. *Land Degrad. Dev.* **2018**, *29*, 2998–3008.
5. Makse, H.A.; Lucini, F.A.; Morone, F.; Tomassone, M.S. Diversity increases the stability of ecosystems. *PLoS ONE* **2020**, *15*, e0228692.
6. Du, Z.Z.; Yan, P.; Huang, G.; Ren, S.S. Biodiversity of *Asteraceae* from Oasis and Desert of Shihezi. *J. Northwest Bot.* **2013**, *33*, 1034–1040. (In Chinese)
7. Wu, B.C.; Zhou, L.J.; Qi, S.; Jin, M.L.; Hu, J.; Lu, J.S. Effect of habitat factors on the understory plant diversity of *Platycladus orientalis* plantations in Beijing mountainous areas based on maxent model. *Ecol. Indic.* **2021**, *129*, 107917. [[CrossRef](#)]
8. Wu, D.H.; Zhao, X.; Liang, S.L.; Zhou, T.; Huang, K.C.; Tang, B.J.; Zhao, W.Q. Time-lag effects of global vegetation responses to climate change. *Glob. Chang. Biol.* **2015**, *21*, 3520–3531. [[CrossRef](#)] [[PubMed](#)]
9. Li, T.F.; Kamran, M.; Chang, S.H.; Peng, Z.H.; Wang, Z.F.; Ran, L.J.; Hou, F.J. Climate-soil interactions improve the stability of grassland ecosystem by driving alpine plant diversity. *Ecol. Indic.* **2022**, *141*, 109002. [[CrossRef](#)]
10. Mi, J.; Ou, J.; Liu, H.; Shi, J.; Chen, D.M.; Bai, Y.F. The loss of plant species diversity dominated by temperature promotes local productivity in the steppe of eastern Inner Mongolia. *Ecol. Indic.* **2022**, *139*, 108953. [[CrossRef](#)]
11. Sabatini, F.; Jiménez-Alfaro, B.; Burrascano, S.; Blasi, C. Drivers of herb-layer species diversity in two unmanaged temperate forests in northern Spain. *Community Ecol.* **2014**, *15*, 147–157. [[CrossRef](#)]
12. Yang, Y.F.; Xu, B.; Yu, Q.Q.; Fan, L.K.; Guo, T.T.; Fu, D.S.; Chen, H.; Yan, H.; Shao, F.; Li, X.P. Distribution Pattern and Factors Influencing Spontaneous Plant Diversity in Different Wetland Habitats. *Forests* **2022**, *13*, 1678. [[CrossRef](#)]

13. Zilliox, C.; Gosselin, F. Tree species diversity and abundance as indicators of understory diversity in French mountain forests: Variations of the relationship in geographical and ecological space. *For. Ecol. Manag.* **2014**, *321*, 105–116. [\[CrossRef\]](#)
14. Zhang, Q.P.; Fang, R.Y.; Deng, C.Y.; Zhao, H.J.; Shen, M.H.; Wang, Q. Slope aspect effects on plant community characteristics and soil properties of alpine meadows on Eastern Qinghai-Tibetan plateau. *Ecol. Indic.* **2022**, *143*, 109400. [\[CrossRef\]](#)
15. Zhang, L.; Qi, S.; Zhou, P.; Wu, B.C.; Zhang, D.; Cui, R.R.; Huang, X.; Ma, N. Influencing factors on herb diversity of *Platycladus platycladus* understory in Beijing Mountain area. *J. Grassl. Sci.* **2022**, *30*, 1794–1801. (In Chinese)
16. Zhang, L.; Qi, S.; Li, P.; Zhou, P. Influence of stand and environmental factors on forest productivity of *Platycladus orientalis* plantations in Beijing's mountainous areas. *Ecol. Indic.* **2024**, *158*, 111385. [\[CrossRef\]](#)
17. He, K.J.; Huang, Y.M.; Qi, Y.; Sheng, Z.L.; Chen, H.Y. Effects of nitrogen addition on vegetation and soil and its linkages to plant diversity and productivity in a semi-arid steppe. *Sci. Total Environ.* **2021**, *778*, 146299. [\[CrossRef\]](#)
18. Dong, D.; Ashfaq, A.; Huang, X.; Teng, M.J.; Wu, C.G.; Zhou, Z.X.; Liu, Y. Soil Available Phosphorus Loss Caused by Periodical Understory Management Reduce Understory Plant Diversity in a Northern Subtropical *Pinus massoniana* Plantation Chronosequence. *Forests* **2020**, *11*, 231. [\[CrossRef\]](#)
19. Cui, R.R.; Qi, S.; Wu, B.C.; Zhang, D.; Zhang, L.; Zhou, P.; Ma, N.; Huang, X. The Influence of Stand Structure on Understory Herbaceous Plants Species Diversity of *Platycladus orientalis* Plantations in Beijing, China. *Forests* **2022**, *13*, 1921. [\[CrossRef\]](#)
20. Wei, L.; Archaux, F.; Hu, F.L.; Bilger, I.; Gosselin, F. Stand attributes or soil micro-environment exert greater influence than management type on understory plant diversity in even-aged oak high forests. *For. Ecol. Manag.* **2020**, *460*, 117897. [\[CrossRef\]](#)
21. Reza, E.; Moslem, Y.; Mosleh, A.A. Effect of different shrub species on their sub-canopy soil and vegetation properties in semiarid regions. *Land Degrad. Dev.* **2021**, *32*, 3236–3247.
22. Zhang, L.; Ning, C.D.; Qi, S.; Hu, Y.S.; Li, P.; Wei, X.Y.; Wang, X.Y. Understory specific species appearances indicate the soil improvement of low-function *Platycladus orientalis* forest in Beijing's mountainous areas. *Ecol. Indic.* **2024**, *162*, 111996. [\[CrossRef\]](#)
23. Vanhellemont, M.; Baeten, L.; Verheyen, K. Relating changes in understory diversity to environmental drivers in an ancient forest in northern Belgium. *Plant Ecol. Evol.* **2014**, *147*, 22–32. [\[CrossRef\]](#)
24. Chen, H.; Du, S.; Huang, H.; Tian, L.Y.; Zhou, H.; Wu, J.Q.; Yu, X.B. Plant diversity in the understory of Eucalyptus plantations on Hainan Island and its response to environmental factors. *Front. Ecol. Evol.* **2024**, *12*, 1366094. [\[CrossRef\]](#)
25. Cheng, Y.L.; Peng, J.; Gu, Y.J.; Guo, H.Y.; Jiang, T.Y.; Yang, H.B. The Early Effect of Plant Density on Soil Physicochemical Attributes and Bacterial and Understory Plant Diversity in Phoebe zhennan Plantations. *Forests* **2023**, *14*, 1612. [\[CrossRef\]](#)
26. Zhao, X.N.; Zheng, Y.T.; Wei, W. Habitat Suitability Evaluation of Different Forest Species in Lvliang Mountain by Combining Prior Knowledge and maxent Model. *Forests* **2023**, *14*, 438. [\[CrossRef\]](#)
27. Shi, X.D.; Wang, J.W.; Zhang, L.; Chen, S.X.; Zhao, A.L.; Ning, X.D.; Fan, G.R.; Wu, N.S.; Zhang, L.; Wang, Z.D. Prediction of the potentially suitable areas of *Litsea cubeba* in China based on future climate change using the optimized Maxent model. *Ecol. Indic.* **2023**, *148*, 110093. [\[CrossRef\]](#)
28. Liu, J.M.; Xu, Y.Y.; Sun, C.W.; Wang, X.; Zheng, Y.L.; Shi, S.L.; Jia, L.M. Distinct ecological habits and habitat responses to future climate change in three east and southeast Asian Sapindus species. *For. Ecol. Manag.* **2022**, *507*, 119982. [\[CrossRef\]](#)
29. LY/T 2250-2014; China National Forestry and Grassland Administration. Technical Regulations for Forest Soil Survey; Standards Press of China: Beijing, China, 2014.
30. Hebbar, K.B.; Abhin, P.S.; Sanjo, J.V.; Neethu, P.; Santhosh, A.; Shil, S.; Prasad, P.V.V. Predicting the potential suitable climate for coconut (*Cocos nucifera* L.) cultivation in India under climate change scenarios using the maxent model. *Plants* **2022**, *11*, 731. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Zhao, G.H.; Cui, X.Y.; Sun, J.T.; Li, T.T.; Wang, Q.; Ye, X.Z.; Fan, B.G. Analysis of the distribution pattern of Chinese ziziphus jujuba under climate change based on optimized biomed and maxent models. *Ecol. Indic.* **2021**, *132*, 108256. [\[CrossRef\]](#)
32. Zhou, H.T.; Na, X.D.; Li, L.; Ning, X.L.; Bai, Y.R.; Wu, X.D.; Zang, S.Y. Suitability evaluation of the rural settlements in a farming-pastoral ecotone area based on machine learning maximum entropy. *Ecol. Indic.* **2023**, *154*, 110794. [\[CrossRef\]](#)
33. Zhang, Y.F.; Chen, S.T.; Gao, Y.; Yang, L.; Yu, H. Prediction of global potential suitable habitats of *nicotiana glauca* link et otto based on Maxent model. *Sci. Rep.* **2023**, *13*, 4851. [\[CrossRef\]](#) [\[PubMed\]](#)
34. Yang, S.L.; Wang, H.M.; Tong, J.P.; Bai, Y.; Alatalo, J.M.; Liu, G.; Fang, Z.; Zhang, F. Impacts of environment and human activity on grid-scale land cropping suitability and optimization of planting structure, measured based on the Maxent model. *Sci. Total Environ.* **2022**, *836*, 155356. [\[CrossRef\]](#)
35. Homeier, J.; Leuschner, C. Factors controlling the productivity of tropical and an forests: Climate and soil are more important than tree diversity. *Biogeosciences* **2021**, *18*, 1525–1541. [\[CrossRef\]](#)
36. Lin, S.; Li, Y.; Li, Y.H.; Chen, Q.; Wang, Q.L.; He, K.N. Influence of tree size, local forest structure, topography, and soil Resource availability on plantation growth in Qinghai Province, China. *Ecol. Indic.* **2021**, *120*, 106957. [\[CrossRef\]](#)
37. Zhang, X.; Li, X.; Ji, X.D.; Zhang, Z.Q.; Zhang, H.S.; Zha, T.G.; Li, J. Elevation and total nitrogen are the critical factors that control the spatial distribution of soil organic carbon content in the shrubland on the Bashang Plateau, China. *Catena* **2021**, *204*, 105415. [\[CrossRef\]](#)
38. Wang, Y.T.; Zhang, Y.M.; Wang, L.J.; Jing, X.; Yu, L.; Liu, P. Response of leaf biomass, leaf and soil C: N:P stoichiometry characteristics to different site conditions and forest ages: A case of *Pinus Tabuliformis* Plantations in the temperate mountainous area of China. *Front. Plant Sci.* **2022**, *13*, 1060406. [\[CrossRef\]](#) [\[PubMed\]](#)
39. Xu, H.G.; Qiang, S. *Inventory Invasive Alien Species in China*; China Environmental Science Press: Beijing, China, 2004. (In Chinese)

40. Tang, S.C.; Wei, C.Q.; Pan, Y.M.; Pu, G.Z. Reproductive adaptability of the invasive weed *Parthenium hysterophorus* L. under different nitrogen and phosphorus levels. *J. Wuhan Bot. Res.* **2010**, *28*, 213–217. (In Chinese)
41. Jia, Y.Y.; Zhang, X.Y.; Yan, J.; Yin, J.L.; Zhang, F.J. Effects of three *Asteraceae* invasive plants on soil fertility of invaded domain. *J. Hebei Univ.* **2015**, *35*, 494–502. (In Chinese)
42. Souza, C.R.; Mariano, R.F.; Pompeu, P.V.; Santos, R.M.; Fontes, M.A. Carbon stock and uptake in the high-elevation tropical montane forests of the threatened Atlantic Forest hotspot: Ecosystem function and effects of elevation variation. *Sci. Total Environ.* **2023**, *882*, 163503. [[CrossRef](#)]
43. Zu, K.L.; Zhang, C.C.; Chen, F.S.; Shahid, A.; Ghulam, N. Latitudinal gradients of angiosperm plant diversity and phylogenetic structure in China's nature reserves. *Glob. Ecol. Conserv.* **2023**, *42*, e02403. [[CrossRef](#)]
44. Chen, S.; Ma, M.H.; Wu, S.J.; Tang, Q.Q.; Wen, Z.F. Topography intensifies variations in the effect of human activities on forest NPP across altitude and slope gradients. *Environ. Dev.* **2023**, *45*, 100826. [[CrossRef](#)]
45. Zhang, Y.; Wang, J.Z.; Wang, L. The resource distribution and growth status for *Platycladus orientalis* Plantations in lower mountains of Beijing. *For. Resour. Manag.* **2011**, *6*, 73–78. (In Chinese)
46. Wagner, S.; Fischer, H.; Huth, F. Canopy effects on vegetation caused by harvesting and regeneration treatments. *Eur. J. For. Res.* **2011**, *130*, 17–40. [[CrossRef](#)]

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