

## Article

# Importance of Soil Organic Matter and the Species Pool for Local Species Richness in Montane Ecosystems

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**Abstract:** Understanding the response of plant species richness to environmental filters is critical for conservation management as there is an increasing emphasis on plant restoration in urban/rural planning. However, empirical studies on the effects that the regional species pool has on plant species richness often overlook small spatial scales, therefore requiring more comprehensive approaches. As mountains can act as barriers to plant dispersal, the impact on the species pool, particularly, should be a priority. This study aimed to investigate how the regional species pool affects the local plant species richness in a multivariate context. We sampled vascular plant communities along three transects located in three valleys across the Chongli District, China, where four common habitat types were selected for sampling: grassland, shrubbery, pure forest, and mixed forest. We compared the differences in the multi-scale species richness and species composition between habitats and regions and used piecewise structural equation modeling to analyze the relative importance of the regional species pool, habitat species pool, soil resource availability, and exposure for local plant richness. The  $\beta$ -diversity had the highest contribution to the total species richness between valleys and habitats. The species composition between regions and habitats showed a significant difference and the local species richness was most strongly affected by the soil characteristics, but effects from the regional species pool still played an important role. Conservation efforts and urban/rural planning should use a multi-level and multi-scale approach based on a detailed structural investigation.

**Keywords:** plant diversity; species composition; multivariate model; dispersal limitation



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## 1. Introduction

Mountain ecosystems are considered a unique system in terms of their ecological and biogeographical patterns and mechanisms [1]. Due to variations in altitude and topography, significantly different microclimates in the mountain environment easily form, which can have an impact on the biodiversity distribution pattern. Mountains can partially act as a natural barrier to the spread of species, such that a rich biodiversity pattern can form at a small spatial scale in mountain ecosystems [2]. Previous studies have explored species diversity patterns along elevational gradients, with the documentation of different patterns in many regions and taxa [3].

Plant diversity is a good indicator of the overall biodiversity in most ecosystems [4]. In general, in terrestrial ecosystems, if there is no strong human interference, the top-down impact between organisms is not strong (in marine ecosystems, the top-down impact is more important), the bottom-up impact mechanism plays a major role [5]. The impact is more important plants as producers play a key role in controlling ecological processes [6]. Exploring the pattern of plant diversity and its influencing factors can aid in biodiversity protection and planning. However, in mountain ecosystems, as plants cannot move, their spread, which is hindered by the mountains, depends on wind, insects, and animals. Therefore, plant diversity may increase due to increased environmental heterogeneity, but it can also decrease due to a shortage of arriving diaspores and a lack of particular species

compared to areas with no dispersal limitations [7,8], or also preserve endemic species with a limited areal distribution [9–11].

The “species pool hypothesis” was proposed by Taylor (1990), whose concept has been prototyped since the theory of island biogeography [12,13] (The use of the term “species pool” has had different meanings in the literature. “Species pool” here means all species available in a particular area without regard for a specific abiotic habitat filter. In this paper, it can be considered as unfiltered pool or simply flora). The species pool contains both observed and dark biodiversity, i.e., the absent portion of the species pool (the set of species that could potentially inhabit a study site) [14]. Throughout evolutionary history, climate and dispersal have remained the two main determinants of the species found in a region, where local environmental factors determine which species within the region form a site-specific species pool [15]. This species pool then constrains the observed local richness by determining the number of species that can colonize the site [16]. An increasing number of studies have agreed that understanding the mechanisms behind the impact of species pools on biodiversity is important for ecological restoration and protection [17,18]. Disentangling the effect of species pools on biodiversity requires more empirical research in systems where species pools are clearly defined and manipulated independently of the species present in the region [19,20].

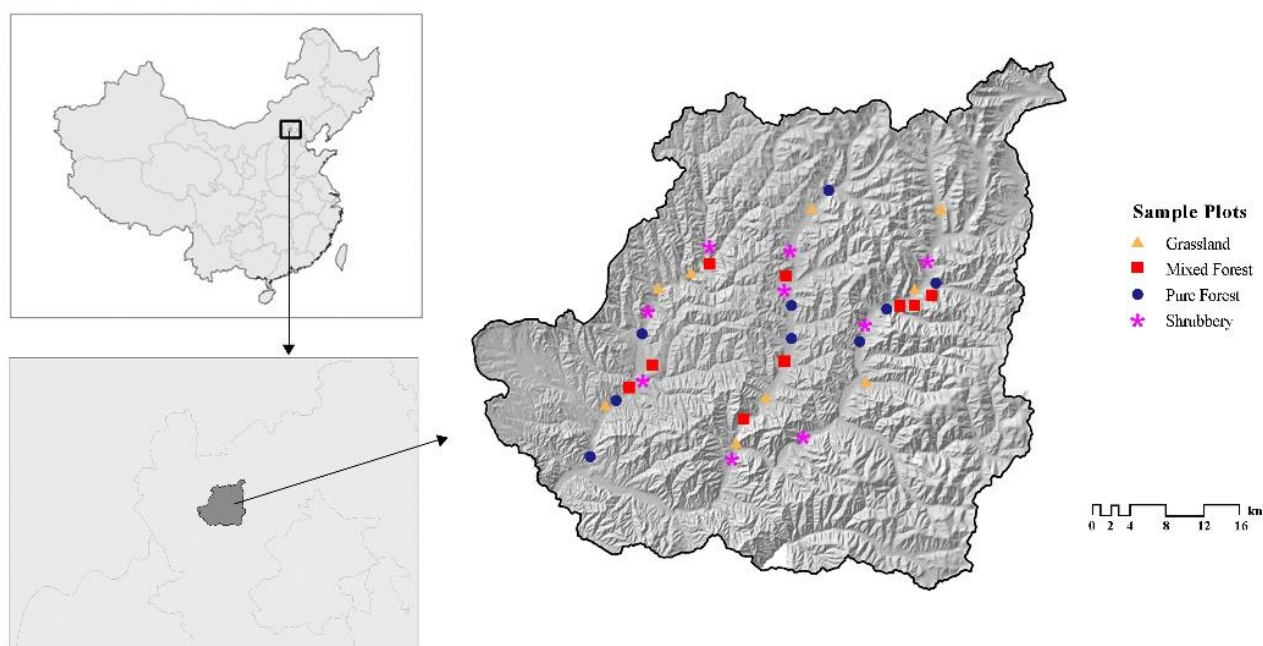
Observed species diversity is composed of  $\alpha$ -diversity at the local scale and  $\beta$ -diversity which occurs among samples at multiple sampling scales [21]. Some empirical tests use observational gradients in regional (gamma) species richness as a surrogate for the species pool, but these approaches cannot directly clarify the role of the species pool size [20]. Different species pools have differing environmental filtering, stochastic colonization, and extinction processes that create ecological drift [22]. This effect will eventually be reflected in differences in the  $\beta$ -diversity [20]. However, the patterns of  $\beta$ -diversity in different species pools are not yet generalized.

Environmental filtering is generally accepted as an important process for shaping the species richness or composition, but the species pool size is an influential factor that cannot be ignored [23,24]. The primary aim of this study is to clarify the effect that the species pool has on species richness by choosing samples in different valleys between mountains in combination with the effect of different environmental filters. We compared the species richness and species composition in different valleys, where dispersal limitations exist, and habitats, with an absence of dispersal limitations, thus hypothesizing that the species richness and species composition should show significant differences between regions (valleys) as those between habitats. We specifically tested the  $\beta$ -diversity at different spatial scales, where the distribution pattern of species diversity between different regions was expected to be different to that of habitats.

## 2. Methods

### 2.1. Study Area

The study region is located in Chongli District (40°47′–41°17′ N, 114°17′–115°34′ E), Zhangjiakou City, Hebei Province, China, which is a transition zone between the Inner Mongolia Plateau and North China Plain (Figure 1). This region experiences an East Asian continental monsoon climate, with a mean annual temperature of ~4.5 °C and a mean annual precipitation exceeding 488 mm. This region is characterized by mountains, most of which are steep and at an elevation of 1500–2000 m. The average elevation of the total region gradually increases from the southwest to the northeast.



**Figure 1.** Sampling plots along three valleys in Chongli District, Zhangjiakou City, Hubei province, China.

## 2.2. Site Selection and Plant Sampling

We sampled plant communities along three transects located in three valleys (East, Middle, and West), where four common habitat types were selected for sampling: grassland (G), shrubbery (S), pure forest (P), and mixed forest (M). In each habitat type, three  $20 \times 20 \text{ m}^2$  plots were established as the basis for vegetation recording, resulting in a total of 15 study plots in each valley. The slope of all sample plots was less than  $15^\circ$  to avoid the effects of slope inclination. To avoid spatial autocorrelation, all plots were sampled at least 1 km from each other. Study plots were randomly located within the habitat but had to be more than 15 m from the edges and more than 20 m from roads to avoid habitat edge effects and agricultural disturbances. Each transect in the different valleys was treated as a region due to the high mountains that separated them. The slope angles of all sample plots were lower than  $15^\circ$ . Information on the elevation and slope direction of all the sample plots was recorded during plant investigation. The slope direction was recorded as 0/1 data (0: sunny slope; 1: shady slope).

The coverage and species richness of vascular plants were surveyed during the early (June) and late (September) blooming season of 2015 to maximize species detection. Each  $20 \times 20 \text{ m}^2$  plot was divided into four  $10 \times 10 \text{ m}^2$  sub-plots. All trees and shrubs were recorded in the sub-plots, and herbaceous species were recorded in four randomly placed  $1 \text{ m}^2$  plots, one within each sub-plot. The plants were identified according to the Flora of China (<http://www.floraofchina.org> (accessed on 1 September 2019)). Plants that could not be identified at the species level were analyzed at the generic level (<3% of all species).

## 2.3. Soil Sampling

Soil organic matter was measured from composite soil samples collected in September 2015 as an indicator of soil resource availability [25]. Five randomly selected soil samples were collected at depths of 0–20 cm using a 50 mm diameter sand auger at each plot. Samples were sieved (<2 mm) to remove roots and other large organic debris, homogenized, and air-dried prior to chemical analysis. We pooled the dried samples within each plot and ground each in a ball mill until the material had a talcum powder consistency. We then analyzed the soil organic matter using the potassium dichromate oxidation method (Walkley–Black method) [26].

## 2.4. Data Analysis

We used the one-way ANOVA for a comparison of the plant richness while a Tukey HSD test was used to perform comparisons between habitat types and regions. A comparison of species composition was evaluated with an analysis of similarities (ANOSIM) based on the Bray–Curtis distance [27].

The “true” regional richness of plants (species pool) was calculated based on a non-parametric species richness estimator (second-order Jackknife). We used a second-order Jackknife estimator because previous studies have shown that this method can determine the actual richness value more rapidly than other estimators [28,29]. The second-order Jackknife estimator was calculated as follows:

$$S_{\text{Jack2}} = S_{\text{obs}} + a_1 \times (2 \times N - 3)/N - a_2 \times (N - 2)^2/N \times (N - 1)$$

where  $S_{\text{Jack2}}$  is the extrapolated richness,  $S_{\text{obs}}$  is the observed richness,  $a_1$  represents the number of species found in only one sample,  $a_2$  is the number of species found in precisely two samples, and  $N$  is the number of samples.

The nonparametric richness estimation, ANOVA, and ANOSIM were performed using the “vegan” packages in R [30]. We used additive diversity partitioning of the total diversity observed ( $\gamma_{\text{total}}$ ) [31] for the total species. The total diversity observed ( $\gamma_{\text{total}}$ ) was partitioned as follows:

$$\gamma_{\text{total}} = \alpha + \beta_1 + \beta_2$$

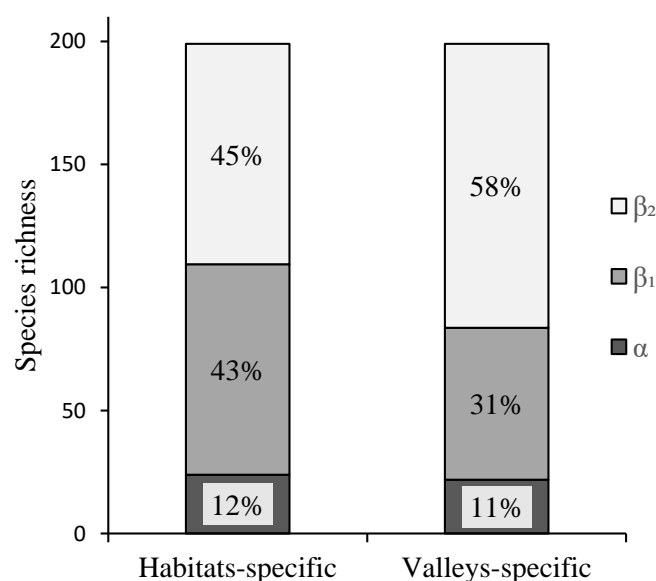
where  $\alpha$  is the mean richness within the plots,  $\beta_1$  is the mean within the habitat types or valleys, and  $\beta_2$  is the mean between the habitat types or regions.

We performed piecewise structural equation modeling (SEM), which was fitted using the “piecewise SEM” package [32] in R 3.1.2 [33] to test the different causal hypotheses involving local soil resource factors, species pools, and local plant richness. A standard SEM approach based on comparisons between the observed and predicted covariance matrices was not used because SEM has historically relied on covariances among variables, rather than the values of the data points themselves. While this approach permits a wide variety of model forms, it limits the incorporation of detailed specifications [32]. The model fit the data adequately based on output from a  $\chi^2$  goodness-of-fit test.

Detrended Correspondence Analysis (DCA) was performed to illustrate the variation in plant species composition in different valleys. The presence/absence data were used, and the species that occurred in less than 1% of the sample plots (rare species) were excluded from the ordination analysis.

## 3. Results

A total of 199 plant species were found at the study sites (Table A1). For the diversity components (Figure 2), the lowest contribution to the overall species richness was made by the  $\alpha$  diversity (12% and 11%). The highest contribution to the overall species richness ( $\gamma$ ) was made by the  $\beta_2$  diversity irrespective of the different habitat types (45%) or different valleys (58%). This indicates that the species turnover rate between different valleys is significantly greater than that between different habitats. In contrast, the contribution of the  $\beta_1$  diversity showed a different pattern (43% and 31%).



**Figure 2.** Components of the plant diversity (mean species richness) in different habitat types and different valleys, categorizing the  $\gamma$  diversity into the  $\alpha$  diversity within the plots, the  $\beta_1$  diversity within the habitat types/valleys, and the  $\beta_2$  diversity between the habitat types/valleys. G: grassland, M: mixed forest, P: pure forest, S: shrubbery, E: eastern valley, M: valley in the middle, W: western valley.

The ANOSIM analysis reflects the difference in plant species composition (Table 1). It showed that the plant species compositions were significantly different both between the valleys ( $R = 0.124$ ,  $p = 0.001$ ) and habitats ( $R = 0.073$ ,  $p = 0.024$ ). The one-way ANOVA analysis reflects the difference in plant species richness (Table 2). It showed that there is no significant difference in species richness between the four different habitat types ( $p = 0.175$ ). However, there are significant differences in species richness among the three different valleys ( $p = 0.023$ ). The analysis of species pool (boxplot, Figure 3) also showed the same trend.

**Table 1.** Similarity of vegetation composition between habitat types and valleys tested by ANOSIM.

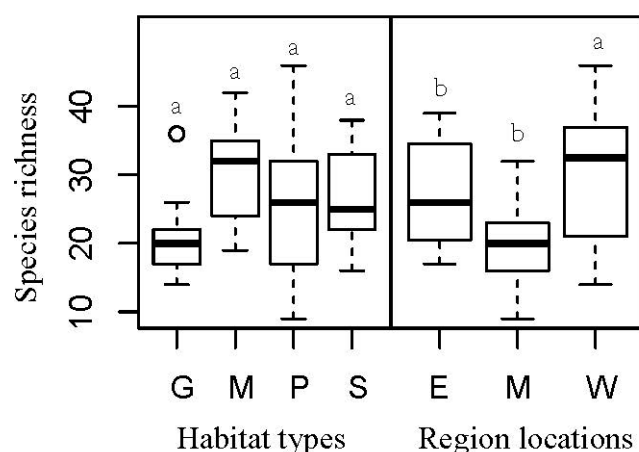
	ANOSIM Statistic R	p
Different valleys	0.073	0.024 *
Different habitat types	0.124	0.001 **

Note: \* indicates the statistical significance (\*  $p < 0.01$ , \*\*  $p < 0.01$ ) of estimated parameters.

**Table 2.** Different plant species richness between habitat types and valleys tested by one-way ANOVA.

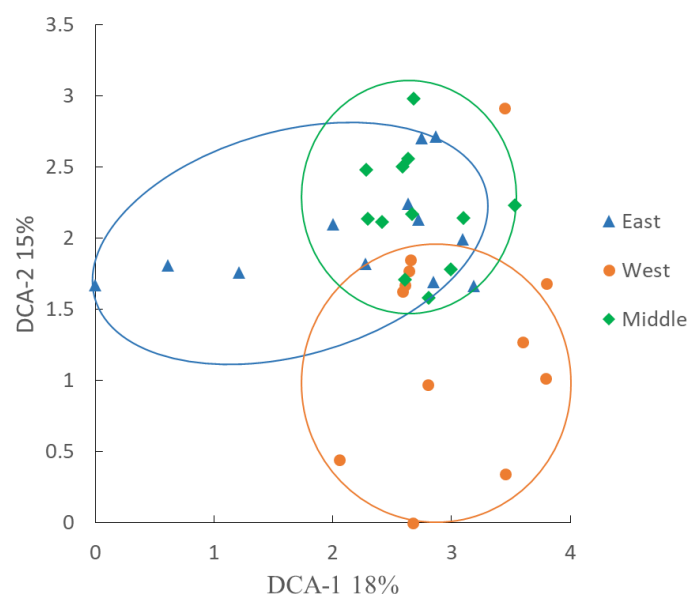
	Df	Mean	F-Value	p-Value
Different habitat types	3	141.11	1.855	0.157
Different valleys	2	292.58	4.248	0.023 *

Note: \* indicates the statistical significance (\*  $p < 0.01$ ) of estimated parameters.



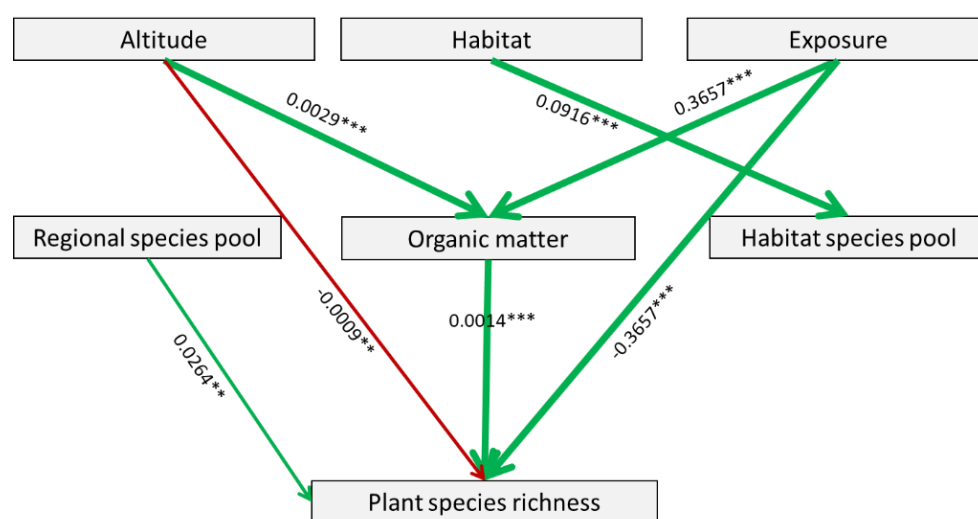
**Figure 3.** Box plots of the plant species pool at different habitat types (**left**) and different valleys (**right**). Center lines represent medians while the outer lines represent the interquartile range. Whisker lines represent the range of data that lie within one and a half times the interquartile range (1.53 IQR). Outlier detection is based on Tukey's method. G: grassland, M: mixed forest, P: pure forest, S: shrubbery, E: eastern valley, M: middle valley, W: western valley. a and b indicates significant differences, the same letter indicates no significant difference, and different letters indicate significant difference.

An additional DCA analysis (Figure 4) using the presence/absence transformed data suggested that the taxon identity (in addition to abundance) contributed significantly to the differences in the species richness between valleys. The general structure of the ordination diagram indicates a compositional overlap of the plots between the three valleys, which also excludes the possibility of a nested distribution pattern. The first two DCA axes explained 33.4% of the total variation in species composition, 18.1% by the first and 15.3% by the second axis (Figure 4). The results of DCA revealed that between different valleys, the distribution of plant species tends to be relatively clustered, especially in the middle valley, where there is an obvious clustering. For the species pool size (Figure 5), the box plot (Figure 3) shows that plant species richness varies significantly between valleys (ANOVA,  $F = 4.248$ ,  $p = 0.023$ ), yet we found no difference between habitats (ANOVA,  $F = 1.855$ ,  $p = 0.157$ ) (Table 2).



**Figure 4.** DCA ordination diagram of the plant species that occurred in at least 1% of the sample plots in the different valleys.





**Figure 5.** A diagram of the generalized structural equation model (SEM) for plant species richness. The arrows represent the flow of causality. The bold green lines represent very significant relationships (\*\* $p < 0.001$ ), the thin green line represents a significant relationship (\*\* $p < 0.01$ ), and the red line represents a negatively significant relationship. All lines are labeled with standardized path coefficients. The absence of a line indicates a hypothesized relationship that was nonsignificant ( $p > 0.05$ ) or had no ecological significance. The model was well supported by our data ( $\chi^2 = 44.5$ ,  $p = 0.905$ ).

The resulting SEM (Figure 5) was well supported by the data ( $\chi^2 = 44.5$ ,  $p = 0.905$ ), and none of the independence claims implied by the model were statistically significant ( $p > 0.05$ ), suggesting that all of the important relationships were specified in the model. As expected, the altitude, slope direction, soil organic matter, and regional species pool factors all influenced the plant species richness, either directly or indirectly. We use lines of different thicknesses to indicate the strength of the correlation. The thicker the line in the figure, the greater the correlation between the two. Environmental factors that have a direct impact on species richness include altitude, soil organic matter, exposure, and regional species pool. The plant species richness decreased, but the organic matter increased with an increasing altitude. The organic matter and species richness on shady slopes were higher than those on sunny slopes. Moreover, the species richness was positively correlated with the soil organic matter, and the regional species pool showed a significant effect on the local species richness. Nonetheless, the habitat or habitat species pool had no significant effects on the local plant species richness.

#### 4. Discussion

A comparison of the species richness in different habitats and valleys showed similar patterns for the relevance of the additive diversity components. The highest contribution to the total species richness was made by the differences in the species found ( $\beta$ -diversity) between habitats or valleys, followed by those between sample plots within habitats or valleys. However, the species turnover rate between the different valleys ( $\beta_2$  diversity) was substantially higher than that within the valleys, which is different than the habitats (almost equal). Previous studies have confirmed this finding of the  $\beta_{\text{region}}$  as the most relevant contributor to the total species richness phenomenon [34–36]. This implies that the dispersal limitation has led to differences in the species richness between valleys, an effect that may be greater than the differences caused by habitats. Another explanation is that the local species pool could be a consequence of the increase in environmental heterogeneity between regions.

The  $\beta$ -diversity or dissimilarity between communities was originally considered a consequence of niche differences and spatial (or resource) gradients in the environment.

However, previous research has suggested that the roles of chance and dispersal limitation between localities are also important [37]. By analyzing the entire abundance matrix (Table 1), our ANOSIM results showed significant differences in the species composition, both between habitat types and valleys. According to the ANOVA test (Table 2) and box plot result (Figure 3), there was no significant difference in the species richness between habitat types. Nonetheless, the species pool between different valleys (regions) was significantly different, as we hypothesized. These results also support the theory that the local species composition is partly determined by chance arrival from the regional pool, but diversity (or species richness) is still limited by niche space and fitness trade-offs [38].

Although previous studies have highlighted the importance of environmental filtering and large regional species pools in explaining local plant diversity patterns [29,39], our study revealed that regional species pools can still play an important role at small spatial scales (Figure 4). In our study area, the distance between the valleys varies from 5 to 15 km, which is short in terms of regional scales. Nevertheless, the habitat species pool had no significant effect on local species richness and our findings indicated that certain environmental factors are the dominant drivers of local plant richness. A negative effect of high elevation on local species richness was found in our study region, which is common in temperate mountain ecosystems. Altitude drives drastic changes in abiotic factors, such as water, temperature, and soil properties; the common pattern in subtropic mountainous regions is a monotonically decreasing curve with an increasing elevation [3]. Species richness showed a positive correlation with the soil organic matter, and, in many cases, the organic matter content was the factor that most strongly correlated with the plant species richness [40]. Soil organic matter levels can not only limit nutrient cycling and plant growth, but also stimulate microbial communities, which can affect the soil structure [41]. The shady slope had a higher species richness than the sunny slope, which may be related to the fact that excessive sunlight leads to soil moisture retention. Therefore, soil moisture on sunny slopes may have been too low to support more plants and microbes, resulting in higher levels of soil organic matter along the shady slope.

Owing to a lack of comprehensive research and administrative division, current planning and construction for vegetation ecological engineering is often based on counties or cities. Afforestation projects often apply the same tree species in all mountainous regions across the entire country. Our research indicates that the species composition or richness can vary significantly between regions. Therefore, future planning for ecological restoration projects should be normalized and elaborated, especially in mountain ecosystems. In addition to mountains, areas with high levels of human disturbance [42], rivers [43], and highways [44] can also cause dispersal limitations and create different microclimates, which eventually lead to a different species pool and diversity variation. As our results suggest that soil organic matter had the strongest effect on the local species richness, conservation efforts aimed at increasing plant richness could benefit from a higher soil resource availability for restoration and management. However, species richness at the local level should not be the only priority, i.e., richness at different spatial scales should not be ignored. Measuring the total species richness along various environmental or geographical gradients is crucial, and larger scale monitoring and replication across habitats or regions would improve assessments of species distribution patterns, which provide a reference for further management strategies. More detailed studies on different functional species groups could aid in our understanding of their niche breadth (trait variance) and potential sensitivity to different dispersal barriers and environment gradients.

## 5. Conclusions

Our study showed that soil organic matter is the most important abiotic factor for local plant assemblages. However, the species pool (in different valley) can still play an important role in effecting species richness. Our results showed that the highest species turnover rate appeared between different valleys. The species composition between both regions and habitats showed a significant difference, and the species richness between



valleys was significantly different, but not between habitats. The local species richness was most strongly affected by the soil characteristics and use. Wild habitat conservation efforts should begin with soil and vegetation monitoring studies for the purpose of adequate area management. Our study illustrated the significant effect the regional species pool has on the local species richness when exposed to the impacts of various environmental filters, even at small spatial scales. However, the production of biodiversity is a very complex phenomenon, and the changes in species richness are affected by many unknown factors. The research area in this article is relatively specific, and future research needs more verification. However, understanding this phenomenon should be understood from a broader perspective and its complexity should be fully understood. In conclusion, we suggest that urban and rural planning use a multi-level and multi-scale approach based on a detailed structural investigation.

**Author Contributions:** Conceptualization, X.L.; methodology, X.L.; software, X.L.; validation, Z.Y.; investigation, W.H.; data curation, W.H.; writing—review and editing, X.L.; visualization, X.L.; supervision, Z.Y. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** List of plant species found in the study areas.

Latin Name	Family Name	Generic Name
<i>Artemisia argyi</i>	Compositae	Artemisia
<i>Rumex patientia</i>	Polygonaceae	Rumex
<i>Cyperus nipponicus</i>	Cyperaceae	Cyperus
<i>Imperata cylindrica</i>	Gramineae	Imperata
<i>Thymus mongolicus</i>	Labiatae	Thymus
<i>Patrinia scabiosaeifolia</i>	Valerianaceae	Patrinia
<i>Echinochloa crusgalli</i>	Gramineae	Echinochloa
<i>Viola variegata</i>	Violaceae	Viola
<i>Ixeris sonchifolia</i>	Compositae	Ixeris
<i>Bupleurum chinense</i>	Umbellifera	Bupleurum
<i>Agropyron cristatum</i>	Gramineae	Agropyron
<i>Vicia faba</i>	Leguminosae	Vicia
<i>Xanthium sibiricum</i>	Compositae	Xanthium
<i>Melilotus suaveolens</i>	Leguminosae	Melilotus
<i>Stellaria dichotoma</i>	Caryophyllaceae	Stellaria
<i>Potentilla supina</i>	Rosaceae	Potentilla
<i>Plantago asiatica</i>	Plantaginaceae	Plantago

Table A1. Cont.

Latin Name	Family Name	Generic Name
<i>Arabis pendula</i>	Brassicaceae	Arabis
<i>Salix babylonica</i>	Salicaceae	Salix
<i>Cirsium selosum</i>	Compositae	Cirsium
<i>Allium fistulosum</i>	Liliaceae	Allium
<i>Cleistogenes caespitosa</i>	Gramineae	Cleistogenes
<i>Geranium dahuricum</i>	Geraniaceae	Geranium
<i>Saussurea davurica</i>	Compositae	Saussurea
<i>Astragalus dahuricus</i>	Leguminosae	Astragalus
<i>Calystegia hederacea</i>	Convolvulaceae	Calystegia
<i>Cirsium japonicum</i>	Compositae	Cirsium
<i>Artemisia sieversiana</i>	Compositae	Artemisia
<i>Euphorbia humifusa</i>	Euphorbiaceae	Euphorbia
<i>Cynanchum thesioides</i>	Asclepiadaceae	Cynanchum
<i>Sanguisorba officinalis</i>	Rosaceae	Sanguisorba
<i>Androsace umbellata</i>	Primulaceae	Androsace
<i>Malva crispa</i>	Malvaceae	Malva
<i>Lepidium apetalum</i>	Brassicaceae	Lepidium
<i>Heracleum hemsleyanum</i>	Umbellifera	Heracleum
<i>Clematis brevicaudata</i>	Ranunculaceae	Clematis
<i>Potentilla multicaulis</i>	Rosaceae	Potentilla
<i>Schizonepeta multifida</i>	Labiatae	Schizonepeta
<i>Roegneria kamoji</i>	Gramineae	Roegneria
<i>Cynanchum chinense</i>	Asclepiadaceae	Cynanchum
<i>Potentilla anserina</i>	Rosaceae	Potentilla
<i>Potentilla bifurca</i>	Rosaceae	Potentilla
<i>Potentilla discolor</i>	Rosaceae	Potentilla
<i>Amaranthus retroflexus</i>	Amaranthaceae	Amaranthus
<i>Saposhnikovia divaricata</i>	Umbellifera	Pastinaca
<i>Clinopodium chinense</i>	Labiatae	Clinopodium
<i>Saussurea runcinata</i>	Compositae	Saussurea
<i>Chrysanthemum lavandulaefolium</i>	Compositae	Chrysanthemum
<i>Brassica oleracea</i>	Brassicaceae	Brassica
<i>Polygonum alpinum</i>	Polygonaceae	Polygonum
<i>Setaria viridis</i>	Gramineae	Setaria
<i>Cynodon dactylon</i>	Gramineae	Cynodon
<i>Lycium chinense</i>	Solanaceae	Lycium
<i>Vicia cracca</i>	Leguminosae	Vicia
<i>Bidens pilosa</i>	Compositae	Bidens
<i>Rorippa indica</i>	Brassicaceae	Rorippa
<i>Campylotropis macrocarpa</i>	Leguminosae	Campylotropis
<i>Salix chaenomeloides</i>	Salicaceae	Salix
<i>Pinus thunbergii</i>	Pinaceae	Pinus
<i>Caragana rosea</i>	Leguminosae	Caragana
<i>Ostryopsis davidiana</i>	Betulaceae	Ostryopsis
<i>Halenia corniculata</i>	Halenia	Gentianaceae
<i>Medicago ruthenica</i>	Leguminosae	Medicago
<i>Scabiosa tschiliensis</i>	Dipsacaceae	Scabiosa
<i>Larix principis-rupprechtii</i>	Pinaceae	Larix
<i>Cucumis sativus</i>	Cucurbitaceae	Cucumis
<i>Artemisia annua</i>	Compositae	Artemisia
<i>Polygonatum sibiricum</i>	Liliaceae	Polygonatum
<i>Chenopodium glaucum</i>	Chenopodiaceae	Chenopodium
<i>Leontopodium leontopodioides</i>	Compositae	Leontopodium
<i>Agastache rugosa</i>	Agastache	Labiatae
<i>Kummerowia striata</i>	Leguminosae	Kummerowia
<i>Panicum miliaceum</i>	Gramineae	Panicum
<i>X canadensis</i>	Salicaceae	Populus

Table A1. Cont.

Latin Name	Family Name	Generic Name
<i>Chenopodium acuminatum</i>	Chenopodiaceae	Chenopodium
<i>Equisetum ramosissimum</i>	Equisetaceae	Equisetum
<i>Arthraxon hispidus</i>	Gramineae	Arthraxon
<i>Vicia sativa</i>	Leguminosae	Vicia
<i>Sonchus arvensis</i>	Compositae	Sonchus
<i>Diospyros lotus</i>	Ebenaceae	Diospyros
<i>Mulgedium tataricum</i>	Compositae	Mulgedium
<i>Sonchus oleraceus</i>	Compositae	Sonchus
<i>Ixeris polycephala</i>	Compositae	Ixeris
<i>latifolius Tausch</i>	Compositae	Echinops
<i>Oxytropis caerulea</i>	Leguminosae	Oxytropis
<i>Stellera chamaejasme</i>	Euphorbiaceae	Stellera
<i>Geranium wilfordii</i>	Geraniaceae	Geranium
<i>Lomatogonium carinthiacum</i>	Gentianaceae	Lomatogonium
<i>Salix chaenomeloides</i>	Salicaceae	Salix
<i>Asparagus schoberioides</i>	Asparagus	Asparagus
<i>Agrimonia pilosa</i>	Rosaceae	Agrimonia
<i>Phragmites australis</i>	Gramineae	Phragmites
<i>Rhamnus bungeana</i>	Rhamnaceae	Rhamnus
<i>Vigna radiata</i>	Leguminosae	Vigna
<i>Ampelopsis humulifolia</i>	Vitaceae	Ampelopsis
<i>Portulaca oleracea</i>	Portulacaceae	Portulaca
<i>Iris lectea</i>	Iridaceae	Iris
<i>Solanum tuberosum</i>	Solanaceae	Solanum
<i>Digitaria sanguinalis</i>	Gramineae	Digitaria
<i>Datura stramonium</i>	Solanaceae	Datura
<i>Erodium stephanianum</i>	Geraniaceae	Erodium
<i>Rosa bella</i>	Rosaceae	Rosa
<i>Gueldenstaedtia verna</i>	Leguminosae	Gueldenstaedtia
<i>Clematis hexapetala</i>	Ranunculaceae	Clematis
Unknown1	Leguminosae	Astragalus
Unknown2	Polygonaceae	Polygonum
<i>Medicago sativa</i>	Leguminosae	Medicago
<i>Hemistepta lyrata</i>	Compositae	Hemistepta
<i>Caragana korshinskii</i>	Leguminosae	Caragana
<i>Caragana korshinskii</i>	Leguminosae	Caragana
<i>Aconitum barbatum</i>	Ranunculaceae	Aconitum
<i>Myosoton aquaticum</i>	Caryophyllaceae	Malachium
<i>Eleusine indica</i>	Gramineae	Eleusine
<i>Galium verum</i>	Rubiaceae	Galium
<i>Elymus dahuricus</i>	Gramineae	Elymus
<i>Thermopsis lanceolata</i>	Betulaceae	Thermopsis
<i>Plantago depressa</i>	Plantaginaceae	Plantago
<i>Potentilla flagellaris</i>	Rosaceae	Potentilla
<i>Taraxacum mongolium</i>	Compositae	Taraxacum
<i>Stemmacantha uniflora</i>	Compositae	Stemmacantha
<i>Capsella bursa-pastoris</i>	Brassicaceae	Category
<i>Rubia cordifolia</i>	Rubiaceae	Rubia
<i>Clematis aethusifolia</i>	Ranunculaceae	Clematis
<i>Gentiana macrophylla</i>	Gentianaceae	Gentiana
<i>Corydalis repens</i>	Papaveraceae	Corydalis
<i>Euphorbia esula</i>	Euphorbiaceae	Euphorbia
<i>Hippophae rhamnoides</i>	Elaeagnaceae	Hippophae
<i>Oxytropis psamocharis</i>	Leguminosae	Oxytropis
<i>Allium senescens</i>	Liliaceae	Allium
<i>Kalimeris lautureana</i>	Compositae	Kalimeris
<i>Armeniaca sibirica</i>	Rosaceae	Armeniaca
<i>Potentilla kleiniana</i>	Rosaceae	Potentilla

Table A1. Cont.

Latin Name	Family Name	Generic Name
<i>Duchesnea indica</i>	Rosaceae	Duchesnea
<i>Adenophora polyantha</i>	Campanulaceae	Adenophora
<i>Geranium sibiricum</i>	Geraniaceae	Geranium
<i>Amethystea caerulea</i>	Labiatae	Amethystea
<i>Ammannia baccifera</i>	Lythraceae	Ammannia
<i>Polygonum lapathifolium</i>	Polygonaceae	Polygonum
<i>Medicago lupulina</i>	Leguminosae	Medicago
<i>Asparagus cochinchinensis</i>	Liliaceae	Asparagus
<i>Hyoscyamus niger</i>	Solanaceae	Hyoscyamus
<i>Convolvulus arvensis</i>	Convolvulaceae	Convolvulus
<i>Beta vulgaris</i>	Chenopodiaceae	Beta
<i>Acalypha australis</i>	Euphorbiaceae	Acalypha
<i>Mazus japonicus</i>	Ranunculaceae	Mazus
<i>Spiraea pubescens</i>	Rosaceae	Spiraea
<i>Orostachys fimbriatus</i>	Crassulaceae	Orostachys
<i>Vicia unijuga</i>	Leguminosae	Vicia
<i>Potentilla chinensis</i>	Rosaceae	Potentilla
<i>Equisetum arvense</i>	Equisetaceae	Equisetum
<i>Saussurea ussuriensis</i>	Compositae	Saussurea
<i>Myosotis silvatica</i>	Boraginaceae	Myosotis
<i>Carex rigescens</i>	Cyperaceae	Carex
<i>Berberis poiretii</i>	Berberidaceae	Berberis
<i>Leonurus sibiricus</i>	Labiatae	Leonurus
<i>Polygala tenuifolia</i>	Polygalaceae	Polygala
Unknown3	Crassulaceae	Sedum
<i>Dracocephalum moldavica</i>	Labiatae	Dracocephalum
<i>Elsholtzia ciliata</i>	Labiatae	Elsholtzia
<i>Chrysanthemum chanetii</i>	Compositae	Chrysanthemum
<i>Bidens parviflora</i>	Compositae	Bidens
<i>Oxytropis glabra</i>	Leguminosae	Oxytropis
<i>Rhamnus parvifolia</i>	Rhamnaceae	Rhamnus
<i>Populus simonii</i>	Salicaceae	Populus
<i>Inula japonica</i>	Compositae	Inula
<i>Scorzonera austriaca</i>	Compositae	Scorzonera
<i>Linum usitatissimum</i>	Linaceae	Linum
<i>Corydalis yanhushuo</i>	Papaveraceae	Corydalis
<i>Leymus chinense</i>	Gramineae	Leymus
<i>Glycine soja</i>	Leguminosae	Glycine
<i>Arundinella hirta</i>	Gramineae	Arundinella
<i>Deyeuxia arundinacea</i>	Gramineae	Deyeuxia
<i>Avena fatua</i>	Gramineae	Avena
<i>Papaver nudicaule</i>	Papaveraceae	Papaver
<i>Iris dichotoma</i>	Iridaceae	Iris
<i>Leonurus artemisia</i>	Labiatae	Leonurus
<i>Artemisia capillaris</i>	Compositae	Artemisia
<i>Poa sphondylodes</i>	Gramineae	Poa
<i>Pinus tabulaeformis</i>	Pinaceae	Pinus
<i>Ulmus pumila</i>	Ulmaceae	Ulmus
<i>Ulmus pumila</i>	Ulmaceae	Ulmus
<i>Achnatherum sibiricum</i>	Gramineae	Achnatherum
<i>Zea mays</i>	Gramineae	Zea
<i>polygonatum odratum</i>	Liliaceae	Polygonatum
<i>Pharbitis purpurea</i>	Convolvulaceae	Pharbitis
<i>Polygala tenuifolia</i>	Polygalaceae	Polygala
<i>Viola prioantha</i>	Violaceae	Viola
<i>Poa annua</i>	Gramineae	Poa
<i>Thalictrum squarrosum</i>	Ranunculaceae	Thalictrum
<i>Potentilla bifurca</i>	Rosaceae	Potentilla

Table A1. Cont.

Latin Name	Family Name	Generic Name
<i>Halerpestes ruthenica</i>	Ranunculaceae	Halerpestes
<i>Stipa capillata</i>	Gramineae	Stipa
<i>Astragalus adsurgens</i>	Leguminosae	Astragalus
<i>Axyris amaranthoides</i>	Chenopodiaceae	Axyris
<i>Salsola collina</i>	Chenopodiaceae	Salsola
<i>Artemisia scoparia</i>	Compositae	Artemisia
<i>Oplismenus compositus</i>	Gramineae	Oplismenus
<i>Aster ageratoides</i>	Compositae	Aster
<i>Oxalis corniculata</i>	Oxalidaceae	Oxalis

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