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Study on Plant Diversity and Soil Properties of Different Forest Types in Pisha Sandstone Area and Their Correlation

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Abstract: Studying the variation characteristics of species diversity and soil properties across different forest types, as well as their interrelationships, enhances our understanding of the differences in forest growth and development within the Pisha sandstone area. In this study, we sampled and analyzed plant diversity along with physical and chemical soil factors from four distinct forest types in the Pisha sandstone region of Inner Mongolia. Our objective was to explore the characteristics of species diversity and soil properties associated with these forest types and to elucidate the relationship between them. The results showed that the order of soil moisture, nutrients, and species diversity in the four forest types was PT > AA > CK > PA.PT; this was significantly higher than other forest types. AA played an important role in the conservation of soil moisture and nutrients under the forest, and the soil nutrient level of PA was significantly lower. Using correlation analysis, we determined that soil properties were the key factors affecting the understory species diversity of different forest types, and SWC, SOM, and AN were the dominant factors in the relationship between the two. Using PCA, it was found that PT and AA had good ecological benefits of soil and water conservation. Our findings indicate that soil nutrient content and moisture levels are critical factors limiting plant species diversity in the Pisha sandstone area. Furthermore, PT and AA demonstrate a beneficial effect on ecological restoration efforts within this region. This study offers a theoretical foundation for managing the process of forest ecological restoration in the Pisha sandstone area.

Keywords: forest stand type; understory plant diversity; soil physicochemical properties; plantation forest; pisha sandstone area

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Academic Editor: Choonsig Kim

Received: 21 November 2024
Revised: 15 January 2025
Accepted: 20 January 2025
Published: 23 January 2025

Citation: Fan, D.; Yang, Z.; Guo, J.; Qin, F.; He, H.; Han, W. Study on Plant Diversity and Soil Properties of Different Forest Types in Pisha Sandstone Area and Their Correlation. *Forests* **2025**, *16*, 211. https://doi.org/10.3390/f16020211

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1. Introduction

Pisha sandstone is a loose interbed of sandstone characterized by thick layers of sandstone, sandy shale, and argillaceous sandstone found within Paleozoic Permian, Mesozoic Triassic, Jurassic, and Cretaceous formations. The distinctive diagenetic structure of the Pisha sandstone region contributes to significant soil erosion. In response, a substantial number of resilient trees and shrubs have been planted as part of ecological restoration efforts [1]. However, the fragile ecological environment has led to the proliferation of a single plant community in the area, and species diversity and aboveground biomass are at low levels. Soil serves as the essential substrate for plant survival [2]. The spatial distribution of soil nutrients significantly impacts not only the growth and biomass allocation of individual plants and plant populations but also influences the structure of plant communities. This

includes aspects such as species composition, as well as both aboveground and belowground biomass diversity and distribution [3]. The enrichment, spatial distribution, and redistribution of soil nutrients can directly affect the growth, development, and succession of vegetation. Therefore, environmental factors, such as plant species and distribution, are closely related to soil nutrients [4]. "Nevertheless, there is a paucity of studies investigating the relationship between soil properties and species diversity in sandstone regions".

Soil exerts both direct and indirect influences on the growth and development of plants by providing essential water and nutrients [5]. Furthermore, plants can enhance soil properties and improve fertility through their root activities. The regulation of soil characteristics in relation to nutrient availability positively impacts the diversity of forest plant species [6]. Xue, Y.C. et al. found that soil water content is positively correlated with understory species richness, whereas no significant correlation was observed between soil bulk density and biodiversity [7]. Additionally, soil nutrients and moisture significantly affect the diversity of understory species [8]. N and P are recognized as critical factors that influence plant diversity, growth, and development [9]. Odum, E.P. et al. demonstrated that increases in SOM and N levels have beneficial effects on improving species diversity and richness, thereby enriching the vertical gradient within a plant community [10]. It has been established that N is positively correlated with the plant dominance index [11], while P plays a crucial role in sustaining species diversity [12].

However, increases in N and P content usually cannot promote the diversity of plant species [13]. Jin, G.Z. et al. believed that the addition of N causes nutrient imbalance in herbaceous plants and considerably reduces the richness and diversity of understory plants in Pinus koraiensis Siebold plantations [14]. Zhang, C. et al. found that while the species diversity of a community decreased following various levels of N and P addition in the Hulunbeier grassland, this intervention nevertheless proved beneficial for both the diversity and stability of grassland species [15]. The mechanisms by which soil factors influence these dynamics are extremely complex. To date, most studies examining the relationship between soil properties and plant diversity have concentrated on homogeneous soil conditions, with relatively few investigations dedicated to ecological restoration efforts in sandstone areas. Moreover, our understanding of these topics has many gaps [16].

Sandstone is widely distributed globally and is often mined as a building material, and the ecological restoration of mining areas is an inevitable key issue in the region [17]. Pisha sandstone easily erodes because of its unique diagenetic structure [18]. Therefore, this study selected Pisha sandstone area *Pinus tabuliformis* (PT) forests, mixed PT and *Armeniaca sibirica* (PA) forests, mixed PA and *Amygdalus davidiana* (AA) forests, and natural grassland (CK) as the research objects. By analyzing the plant and soil data from four distinct forest types, this study formulated the following objectives: (1) to investigate variations in species diversity and soil properties across different forest types, and to assess the ecological benefits of soil and water conservation practices within these ecosystems; (2) to elucidate the correlation between soil properties and plant diversity; and (3) to explore the mechanisms underlying soil–plant interactions in various forest types. The findings of this research can provide a scientific foundation for restoring and enhancing the ecological environment in regions characterized by sandstone globally.

2. Materials and Methods

2.1. Overview of the Study Area

The study area is situated in the West Heidaigou watershed of Xuejiawan Town, Jungar Banner, Ordos City, Inner Mongolia, where extensive bedrock exposure is prevalent (Figure 1). This exposed area constitutes over 70% of the total region and is covered by loess to a depth of 40–60 cm, resting on Pisha sandstone [19]. The predominant soil type

found in this region is chestnut soil. The geomorphology predominantly features granular hills interspersed with gullies and ravines, with altitudes varying between 1110 m and 1300 m. The climatic conditions are characterized as temperate continental, marked by long, dry winters and short, warm summers [20]. Rainfall is concentrated in the summer months of June to August, torrential rains are predominant, and the annual total rainfall is approximately 400 mm [21]. The natural vegetation in the study area is not well preserved, characterized by low species diversity and sparse cover [22]. The herbaceous vegetation is mainly composed of large needle fescue (*Stipa grandis*) and thyme (*Thymus mongolicus*). Shrubs are mainly sea buckthorn (*Hippophae rhamnoides*), lemon bar (*Caragana korshinskii*), and caraway (*Lespedeza bicolor*). The primary tree species is the creosote bush (PT) [23]. The flora of China contributes to the identification of species [24].

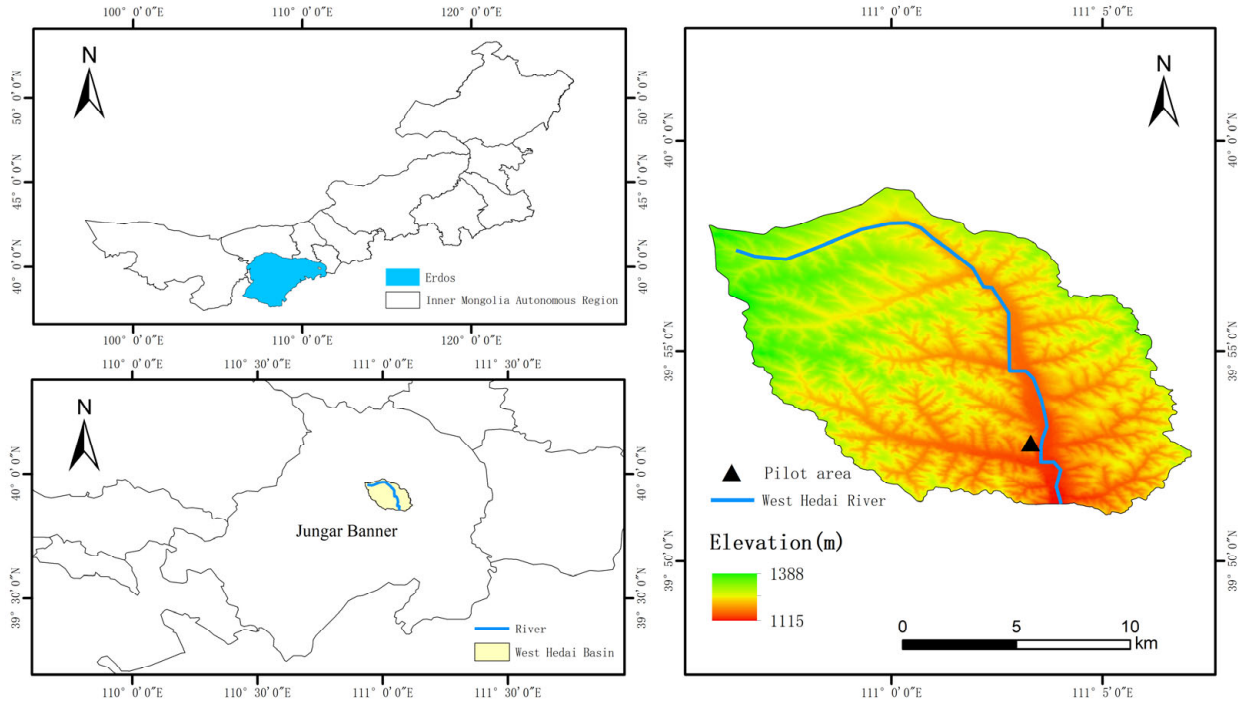

Figure 1. Map of the study area.

2.2. Research Methodology

2.2.1. Field Sample Plot Layout and Vegetation Survey

In August 2023, well-grown PT, PA, and AA forests and CK with essentially the same stand structure in the upper reaches of Xihedaigou in Jungarqi county were investigated. PT, AA, and PA are the three main forest planting types in Pisha sandstone area. By studying these three forest types and CK, the differences in soil characteristics and plant growth status under the forest after 15 years of planting can be directly reflected. A number of tree sample plots with basically the same density, slope, slope direction, and elevation were selected for each forest stand, and three 20 m × 20 m tree sample plots were evenly distributed. The "checking feet per tree" method [25] was employed for the investigation, and the following parameters were recorded in the sample plots: diameter at breast height (DBH), tree height, number of plants, and crown width. Additionally, three herbaceous sample plots measuring 1 m × 1 m were established to record the names, numbers, heights, and coverage of both shrubs and herbaceous plants. Table 1 presents the basic information regarding the sample plot.

Table 1. Basic information of sample plots.

Sample Size	Forest Types	Elevation/m	Slope/°	Density /(tree·ha^{-1})	DBH/cm	Tree Height/m	Tree Age/year
1	PT	1208	15	3200	44.63	5.24	16
2		1223	15		38.55	4.83	
3		1216	14		42.08	4.52	
4	PA	1205	16	3250	41.84	3.75	15
5		1211	15		44.39	4.23	
6		1204	16		37.75	3.98	
7	AA	1203	15	3150	39.38	4.42	13
8		1209	15		36.15	5.10	
9		1213	16		34.38	4.52	
10	CK	1185	15	—	—	—	—
11		1187	15				
12		1193	16				

2.2.2. Measurement of Aboveground Biomass of Herbs

The aboveground parts of the plants in the herb sample plots were harvested using a mowing technique and subsequently placed into kraft paper bags. The fresh weight of each part was measured. Afterward, the samples were transported indoors and dried in an oven at 75 °C until a constant weight was achieved. The dry weight and aboveground biomass of the herbs were then calculated.

2.2.3. Species Diversity Calculations

The species composition, cover, height, and biomass of the vegetation in the herbaceous samples were analyzed. Subsequently, the relative cover (RC), relative height (RH), and relative biomass (RB) of the plants within these samples were calculated. Finally, the importance value (IV) for each species in the samples was determined. To assess the diversity of vegetation at this sampling site, four indices were employed: Shannon–Wiener diversity index (H), Simpson's dominance index (D), Margalef's richness index (R), and Pielou's evenness index (Jsw). The calculation formulas are as follows [26]:

(IV):

$$IV = \frac{RC + RH + RB}{3} \quad (1)$$

$$RC = \frac{\text{Coverage of species}}{\text{Sum of cover of all species}} \times 100\% \quad (2)$$

$$RH = \frac{\text{Height of the species}}{\text{Height of all species}} \times 100\% \quad (3)$$

$$RB = \frac{\text{Biomass of species}}{\text{Sum of biomass of all species}} \times 100\% \quad (4)$$

Shannon–Wiener:

$$H' = -\sum P_i \ln P_i \quad (5)$$

Simpson:

$$D = 1 - \sum P_i^2 \quad (6)$$

Pielou:

$$J_w = \frac{H'}{\ln S} \quad (7)$$

Margalef:

$$R = \frac{S - 1}{\ln N} \quad (8)$$

In this context, RC, RH, and RB denote relative cover, relative height, and relative biomass, respectively. S represents the total number of species present within the sample. Pi refers to the relative abundance of individuals belonging to the ith species (i.e., the ratio of individuals to total species: Ni/N). N signifies the overall count of individuals across all species in the sample; whereas Ni indicates the number of individuals specific to the ith species.

2.2.4. Determination of Soil Physical and Chemical Properties

The nutrients and water accessible to plants are primarily concentrated in the top 0–40 cm of the soil layer due to the shallow loess overburden and underlying Pisha sandstone within the study area. Consequently, an experiment was conducted in each tree sampling plot by randomly excavating three soil profiles to a depth of 40 cm. Soil samples were collected at four specific depths: 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm using a ring knife and soil shovel. The samples were subsequently transported to a laboratory for analysis. Soil bulk density (SBD) and soil water content (SWC) were assessed through cutting ring methods and drying measurement techniques. The determination of soil organic matter (SOM) was performed after heating and oxidation with potassium dichromate; available phosphorus (AP) was quantified via the molybdenum-antimony colorimetric method following immersion in sodium bicarbonate; available potassium (AK) was analyzed using flame photometry with ammonium acetate immersion; finally, available nitrogen (AN) was evaluated utilizing the alkaline dissolved diffusion method.

2.2.5. Data Processing

We used SPSS26.0 software for analysis of variance, and differences among the characteristic indices and correlation of each characteristic index in different forest types were tested using the least significant difference method and Pearson correlation coefficient (Pearson, $\alpha = 0.05$). Canoco 5.0 was employed to conduct redundancy analysis and quantify the extent of interpretation regarding the correlation between soil properties and community species diversity. The KMO and Bartlett's test were employed to assess the suitability of the indicators as well as the correlations among them (KMO > 0.6, Bartlett's $p < 0.001$), and the principal component factor score method was used in evaluating the ecological benefits of the nonforest types. Origin 2021 was used in drawing charts.

3. Results and Analysis

3.1. Characteristics of Understory Vegetation and Species Diversity in Different Forest Types

3.1.1. Characteristics of Plant Composition, Importance Value, and Growth

A total of 31 species of understory herbaceous plants, belonging to 22 genera across nine families, were identified within the four forest types: eight species of Gramineae (25.81%), nine species of Asteraceae (29.03%), five species of Leguminosae (16.13%), and three species of Rosaceae (9.68%). PT had the highest degree of variation in species number in the herb layer with stand type, followed by AA, PA, and CK (Table 2). Stand types exerted a significant influence on the growth characteristics of understory herbs ($p < 0.05$). The understory herbaceous plants in CK had the highest average height and aboveground biomass, followed by those in PT, and the total coverage was the opposite. The reason is that no tree in CK competed with *Stipa capillata* and *Stipa grandis* for soil nutrients and water, and thus the height and biomass of herbaceous plants in CK were significantly higher than

those in tree plots, and the dominant position of constructive species on resources limited the increase in CK diversity (Tables 3 and 4).

Table 2. Species composition of herbaceous plant communities in different forest types.

Stand Type	Family	Genus	Species
PT	7	14	18
PA	6	12	14
AA	7	13	15
CK	5	8	10

Table 3. Important values of understory herbaceous plants under in different forest types.

Stand Type	Main Species and Importance Values (%)
PT	*Stipa-grandis* (43) + *Artemisia-gmelinii* (24) + *Artemisia-dubia* (24) + *Leymus-chinensis* (22) + *Potentilla-tanacetifolia* (11)
PA	*Stipa-capillata* (44) + *Stipa-grandis* (29) + *Stipa-breviflora* (28) + *Leymus-chinensis* (16) + *Lespedeza-bicolor* (15)
AA	*Stipa-grandis* (73) + *Thymus-mongolicus* (63) + *Leymus-chinensis* (30) + *Aster-altaicus* (12) + *Lespedeza-bicolor* (11)
CK	*Stipa-capillata* (48) + *Stipa-grandis* (34) + *Leymus-chinensis* (25) + *Stipa-breviflora* (25) + *Lespedeza-bicolor* (17)

Table 4. Growth characteristics of understory herbaceous plants under in different forest types.

Stand Type	Total Cover/%	Total Biomass/g·m^{-2}	Average Height/cm
PT	38.61 ± 4.63 a	193.21 ± 61.21 a	25.05 ± 5.34 ab
PA	17.27 ± 5.32 b	149.33 ± 28.89 c	23.73 ± 5.21 b
AA	19.22 ± 7.75 b	180.41 ± 57.91 b	24.01 ± 2.29 b
CK	16.57 ± 4.08 b	194.31 ± 8.85 a	28.27 ± 9.14 a

Note: Distinct lowercase letters in the table signify statistically significant differences ($p < 0.05$).

3.1.2. Characterization of Plant Community Species Diversity

The species diversity index exhibited significant variation among the four forest types ($p < 0.05$). The descending order of the Simpson index was found to be CK, AA, PT, and PA, which aligns with findings from previous studies. This result suggests that in the CK herb community, dominant species are notably prominent while a limited number of species account for a substantial proportion. Conversely, the Shannon–Wiener, Pielou, and Margalef indices indicated an order of PT > AA > PA > CK. These findings imply that forest type is not a primary determinant of plant diversity; rather, certain soil factors are likely responsible for the differences observed in understory plant diversity (Figure 2).

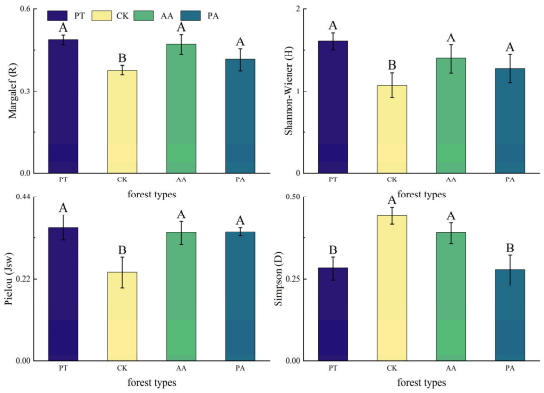

Figure 2. Characteristics of the species diversity index in the Understory Herb Layer of Plant Communities Across Different Forest Types. Note: Distinct capital letters in the figure denote statistically significant differences ($p < 0.05$).

3.2. Characteristics of Soil Physicochemical Properties in the Understory of Different Forest Types

The soil properties of the 0–40 cm layer exhibited significant variability among the four forest types ($p < 0.05$). SBD increased gradually with depth; however, no significant differences were observed among the four forest types. The vegetation types ranked in decreasing SWC were as follows: PT > PA > AA > CK in the 0–20 cm soil layer, and AA > PT > CK > PA in the 20–40 cm soil layer. Soil nutrients and SWC exhibited a decline with increasing soil depth, being predominantly concentrated within the top 0–20 cm of soil. Overall, PT demonstrated the highest levels of soil nutrients, followed by AA, while PA displayed the lowest nutrient concentrations. The contents of SOM, AN, AP, and AK within the 0–20 cm layer adhered to the ranking order of PT > AA > CK > PA; this pattern is consistent with observed trends in understory species diversity. These results suggest a significant correlation between soil nutrient availability and understory plant diversity across the four forest types. Furthermore, SWC, SOM, AN, and AP values for AA presented an initial increase followed by a subsequent decrease as soil depth increased, peaking at 30 cm depth. This finding indicates that AA positively influences both nutrient enrichment and water retention in soils (Figures 3 and 4).

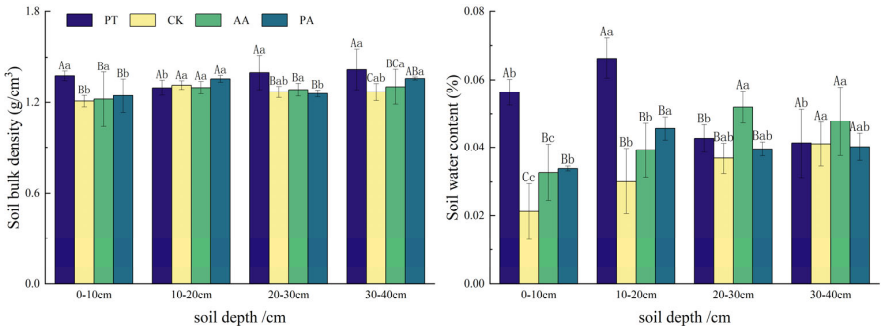

Figure 3. Characteristics of the 0–40 cm SWC and SBD in different forest types.Note: Capital letters denote significant differences among soil layers within the same forest type ($p < 0.05$), while lowercase letters indicate significant differences between different forest types within the same soil layer ($p < 0.05$).

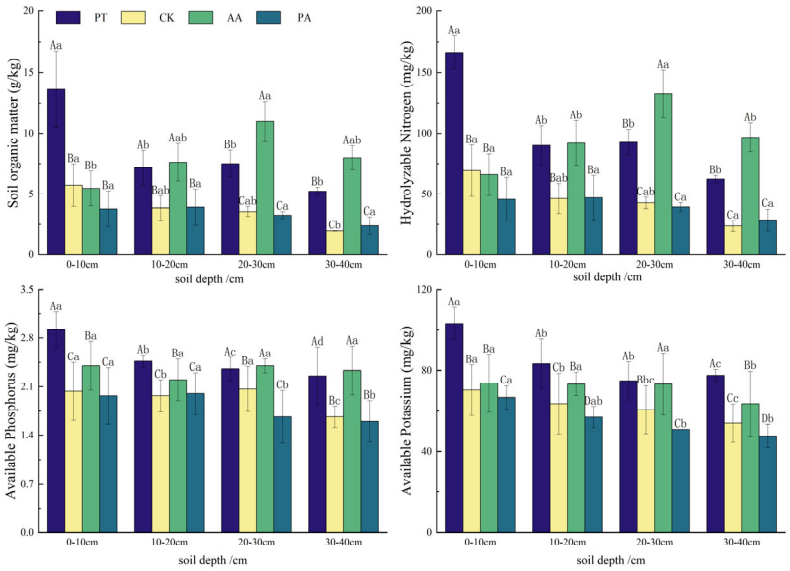

Figure 4. Characteristics of soil available N, P, K, and SOM in different forest types. Note: Capital letters denote significant differences among soil layers within the same forest type ($p < 0.05$), while lowercase letters indicate significant differences between different forest types within the same soil layer ($p < 0.05$).

3.3. Relationship Analysis Between Understory Plant Diversity and Soil Factors

The results of the correlation analysis indicated that the species diversity of understory plants in this region was predominantly influenced by the physical and chemical properties of the surface soil ($p < 0.05$). In the 0–40 cm soil layer, SOM, AN, and SWC had strong correlation with the Shannon-Wiener index and the Margalef index. SBD, AP, and AK were significantly positively correlated with species diversity only in the 0–10 cm soil layer, while the correlation was not obvious in the 20–40 cm soil layer. SWC is the key factor affecting the Pielou index and Simpson index. SOM and AN may positively influence the levels of AP and AK in the understory soil. It is evident that SWC, SOM, and AN are the principal factors influencing species diversity in this region (Figure 5).

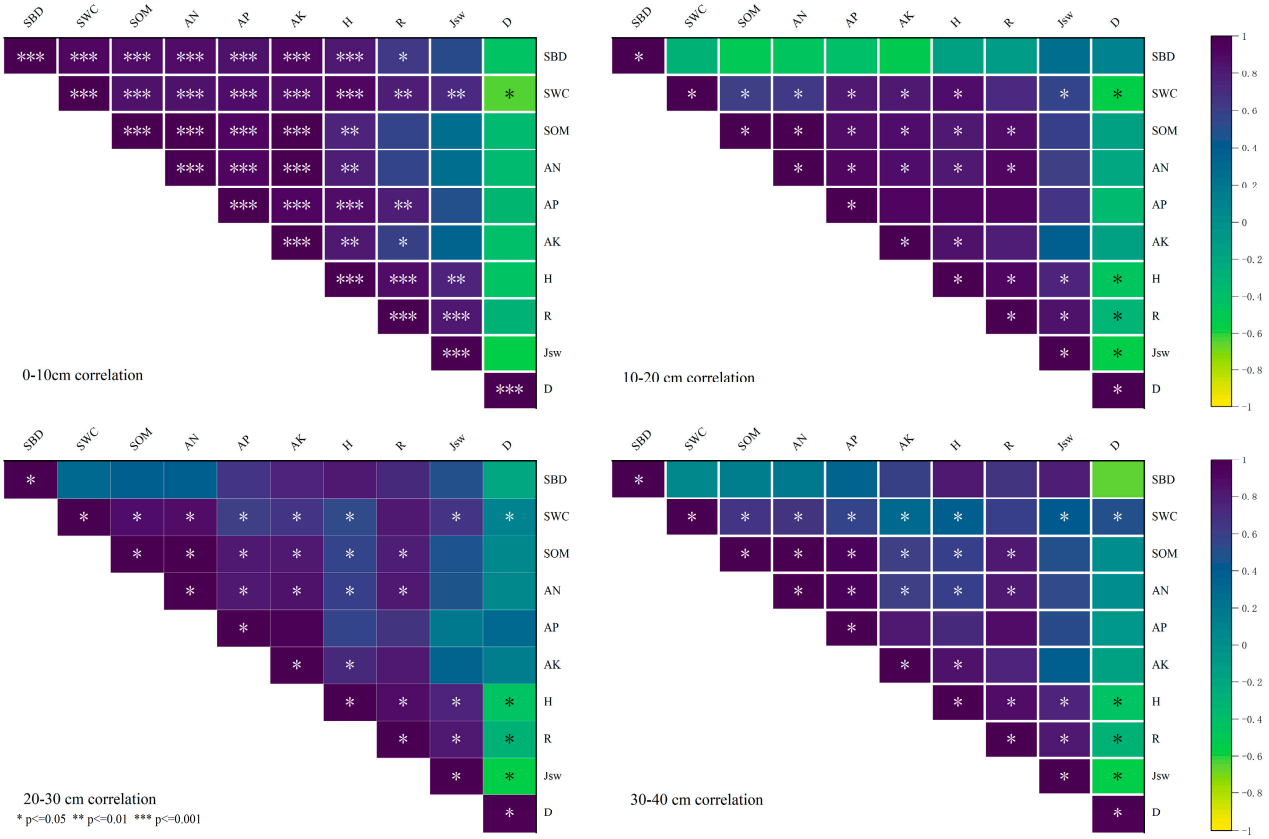

Figure 5. The relationship between soil properties and species diversity within the 0–40 cm soil layer.

3.4. Principal Component Analysis of Understory Plant Diversity and Soil Factors

Prior to the principal component analysis (PCA), KMO and Bartlett sphericity tests were required for assessing the correlation among indicators. As shown in Table 5, a KMO value greater than 0.6 indicates high correlations among indicators and is considered acceptable. A *p*-value of less than 0.00 in Bartlet's test of sphericity indicates that correlations among indicators exist and the indicators are suitable for factor analysis.

Table 5. KMO and Bartlett's test.

KMO Sampling appropriateness quantity		0.64
Bartlett's Test of Sphericity	Chi-square approximations	1046.848
	Degree of freedom	78
	Significance	0.00

The PCA of the evaluated indicators of plant diversity and the physical and chemical properties of soil in each forest stand revealed a contribution rate of 50.13%. The

contribution rates of principal components 2 and 3 were 21.57% and 9.54%, respectively. Furthermore, the cumulative contribution rates of these principal components were 81.24%, which basically reflected the vast majority of the information of the 13 selected indicators (Table 6).

Table 6. Correlation between the understory plant diversity index and soil physical and chemical properties across various forest types.

Indicator Name	Principal Component		
	1	2	3
SOM	0.829	0.224	−0.414
AN	0.835	0.223	−0.408
AP	0.88	0.261	−0.255
AK	0.86	0.322	−0.135
SBD	0.474	−0.036	0.592
SWC	0.624	−0.106	0.297
Margalef	0.882	−0.172	−0.024
Simpson	−0.361	0.794	−0.117
Pielou	0.667	−0.618	0.03
Shannon–Wiener	0.917	−0.153	0.215
coverage	0.8	0.045	0.393
Biomass	0.368	0.859	0.196
Plant height	−0.186	0.845	0.356
Eigenvalue (math.)	6.517	2.804	1.24
Contribution rate	50.132	21.567	9.536
Cumulative contribution	50.132	71.699	81.235

The weights of the three main components were calculated using the factor loading values and criterion variables. Then, the composite scores of each stand type were calculated using the eigenvalues. The scores were normalized to derive composite scores for the various stand types, based on understory plant diversity and soil physicochemical properties (Table 7).

Table 7. Composite scores and ranking of different forest types.

Stand Type	F_1	F_2	F_3	Aggregate Score	Comprehensive Ranking
PT	3.37	0.05	0.75	1.77	1
PA	0.89	0.09	−1.13	0.36	2
AA	−1.66	−2.31	0.07	−1.33	4
CK	−2.60	2.17	0.31	−0.81	3

The comprehensive ranking of various stand types is PT > AA > CK > PA, suggesting that the species diversity and soil physicochemical properties in PT and AA are superior to those in other stand densities. Furthermore, PT more effectively promotes soil and water conservation within plantation woodlands situated in the Pisha sandstone region compared to other forest types (Table 7).

4. Discussion

4.1. Changes in Species Number and Growth Characteristics of Different Forest Types

In forest ecosystems, understory vegetation plays a crucial role in sustaining biodiversity and enhancing ecosystem functions [27]. Research has shown that the diversity, growth characteristics, and biomass of understory vegetation significantly influence soil and water conservation efforts [28]. In this study, 31 species of 9 families and 22 genera were found in the understory herbaceous layer of different forest types. The number of herbaceous community species in the four forest types was PT > AA > PA > CK [29]. The study found

that PT had the highest plant coverage, while CK had the lowest. The average plant height reached the highest in CK and the lowest in the PA group. Aboveground biomass analysis indicated that the CK was higher than that observed in the arboreal plots, which aligns with the findings of Wang, L. et al. [30]. The reason is that the herbaceous constructive species in CK are dominant in resource competition. Although they are dominant in biomass and plant height, they limit the improvement of community species diversity [31]. In the three arbor plots, although tree species are dominant in resource competition, the increase in canopy density and the diversity of litter have diversified the growth environment of understory herbs [32]. This has resulted in a marked enhancement of both species diversity and the coverage of understory plants [33]. The changes in the number of understory plant species and growth characteristics showed that the growth environment and soil nutrient water content of PT and AA were better than those of PA and CK.

4.2. Changes in Plant Diversity and Soil Properties in Different Forest Types

The species diversity index (SDI) is an indicator of species diversity within plant communities and an indicator of ecosystem stability [34]. In this study, forest types had a significant effect on the species diversity of the lower herb community ($p < 0.05$). Under various forest types, the Shannon–Wiener index, Pielou index, and Margalef index indicated that PT had the highest value, followed by AA, while CK exhibited the lowest value. Most studies, such as Zhu, S.W. et al., have concluded that mixed forests have higher species diversity than pure forests [35], contrary to the findings of this study. This phenomenon may be attributed to the fact that it is a native tree species within the Pisha sandstone region; *Pinus tabuliformis* is better adapted to the harsh local environment than other forest types, resulting in higher plant diversity of PT than PA and AA. It remains to be seen whether the results of this study will change over time. However, PA is quite different from PT and AA in species diversity, which may be due to the large interspecific competition between *Pinus tabuliformis* and *Armeniaca sibirica* [36]. Their exploitation of resources results in a decline in soil nutrients and water retention capacity, which significantly impacts the enhancement of understory species diversity.

The physical properties of soil have a direct or indirect impact on the growth and development of forest trees by regulating water supply, gas exchange, and root absorption within the plant's underground structures. In this study, we found that forest types had significant effects on SBD and SWC ($p < 0.05$). The SBD of PT and AA exhibited a slight increase with increasing soil depth, whereas the SBD of PA and CK did not show any significant changes with deepening soil layers. Additionally, the SWC in the surface layer of PT and AA was greater than that observed in deeper soil layers; conversely, PA and CK displayed an opposite trend [37]. The SBD and SWC of PT and AA were better than those of other stands. This finding indicates that PT and AA are more conducive to improving soil structure and maintaining soil moisture in sandstone areas, and can better play the role of soil and water conservation [38]. Different forest types contribute to variations in light and heat conditions, plant community structure, and litter composition in the lower layers [39]. These differences subsequently affect the chemical properties of the subsoil [40]. Forest types have a significant impact on AN, AP, AK, and SOM ($p < 0.05$) [41]. Generally, soil nutrients diminish with increasing soil depth, being predominantly concentrated within the 0–20 cm layer. This finding aligns with the conclusions drawn by Dong et al. [42]. This may be closely related to the soil microbial community [43]. Microorganisms and fungi residing in deep soil are unable to directly interact with the litter, which facilitates the accumulation of soil nutrients at the surface layer [44]. In this study, SOM, AN, AP, and AK showed PT > AA > CK > PA with forest types. The soil nutrient content of AA was about 8.3% lower than that of PT, and the soil nutrient content of PA was about 39.3% lower than

that of PT. There may be two reasons for this finding. First, there is a fierce interspecific competition between *Pinus tabuliformis* and *Armeniaca sibirica*, competing for water or some types of nutrients in the lower layer [45]. Consuming a large amount of soil moisture or nutrients leads to a shortage of resources in the lower layer. This situation seriously affected the growth and development of other species in the lower layer. Secondly, the planting density of this mixed forest is extremely high, which exacerbates the competition for soil moisture and nutrients in the lower layer [46], resulting in a decrease in soil fertility in the forest types.

4.3. Relationship Between Soil Properties and Plant Diversity

The results of the correlation analysis indicated that soil properties significantly influenced forest species diversity in the Pisha sandstone area [47]. This study revealed a clear correlation between the plant diversity index of each forest type and soil factors at varying depths [48]. It was found that there exists a significant positive correlation between soil physical and chemical indicators and the plant diversity index, specifically within the 0–10 cm soil layer ($p < 0.01$). The main reason is that litter decomposition and plant root activity are mainly concentrated in the soil surface, and their improvement of soil physical and chemical properties has no significant effect on deep soil [49]. In terms of soil factors, SWC exhibited a significant positive correlation with both the Shannon–Wiener index and the Pielou index, while demonstrating a significant negative correlation with the Simpson index within the 0–20 cm soil layers. These findings are consistent with those reported by Teng, Y.F. et al. [50]. Soil moisture directly affects plant growth, photosynthesis, and root development. The higher the water content, the richer the species composition, the higher the plant height, coverage, and biomass, and the lower the Simpson index. SOM and AN showed a significant positive correlation with species diversity in the 0–40 cm soil layer, aligning with findings from previous studies [51]. The elevated concentrations of SOM and AN play a crucial role in mitigating soil nitrogen loss, thereby enhancing species diversity and increasing the richness of dominant species [52]. It is evident that soil properties are fundamental factors influencing plant diversity in this region, with SWC, SOM, and AN predominantly shaping their interrelationship.

5. Conclusions

The results of PCA showed that the comprehensive scores of plant growth characteristics, vegetation diversity, and soil properties of the four forest types were PT > AA > CK > PA. This is consistent with the variation in soil nutrients under different forest types, which further shows that soil nutrients in this area play an important role in plant growth and species diversity improvement. This study conveys the important message that soil nutrient content and moisture content are critical factors that limit plant species diversity in the Pisha sandstone region. Furthermore, SWC, SOM, and AN emerge as the predominant variables influencing the relationship between these two key factors. Through this study, it is recommended that PT or AA be selected for subsequent plantation establishment. This approach aims to enhance the ecological restoration capacity of the Pisha sandstone area while maintaining elevated levels of soil nutrients and moisture. In view of the low nutrient and species diversity of PA soil, measures such as increasing organic fertilizer and compound soil should be taken to improve the nutrient level of PA soil. In the next few years, the interaction between forest planting types and planting densities as well as soil nutrients and plant diversity should be studied. It is expected to provide a basis for plantation planting and management in this area.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f16020211/s1, Table S1: Plant species and individual number of different forest types.

Author Contributions: D.F.: Conceptualization, formal analysis, investigation, methodology, supervision, visualization, writing—original draft, and writing—review and editing. Z.Y.: Investigation, writing—original draft. J.G.: Data curation, formal analysis, investigation, methodology, visualization, and writing—original draft. F.Q.: Formal analysis, investigation, methodology, visualization, and writing—original draft. H.H.: Writing—review and editing. W.H.: Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Open project of Key Laboratory of Soil and Water Conservation on Loess Plateau, Ministry of Water Resources (WSCLP202302), Ordos City Water Science and Technology Plan Project "The evaluation of the integrated benefits of soil and water conservation technology in key areas prone to soil and water loss in Xihedai Basin for ecosystem improvement", Inner Mongolia Autonomous Region "Science and Technology to Prosper Mongolia" Action Key Project (2022EEDSKJXM003), National Key Research and Development Program of China (No. 2023YFF1305104), National Natural Science Foundation project (42307463).

Data Availability Statement: The original contributions presented in this study are included in the Supplementary Materials; further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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