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Analysis on Influencing Factors of ecological stability in Shendong Coal Mine Area

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Abstract

In this paper, descriptive statistical analysis, correlation analysis and principal component analysis were used to study the terrain factors such as slope position, slope, bulk density, total porosity and other soil factors, taking Bulianta coal mine (non-subsidence area, subsidence area of 1, 3, 8, 11 years) and Daliuta coal mine (non-subsidence area, subsidence area of 1, 2, 6, 13 years) The relationship between vegetation coverage and other indicators provides important theoretical basis for further discussion on vegetation restoration and site environmental factors of ecological vulnerability in Shendong mining area, as well as vegetation restoration and vegetation coverage expansion, so as to control the impact of soil erosion on vegetation growth and distribution and maintain ecological stability. The results show that the main factors affecting the effect of vegetation restoration are terrain height and slope position, followed by soil moisture status, and finally altitude. Therefore, in order to promote the growth of vegetation, improve the ecological environment of the mining area and make it stable, the slope and other topographic factors should be reasonably regulated. Reasonable land preparation measures can give full play to its terrain advantages, make the soil and vegetation symbiosis, so as to continuously improve the soil, maintain the healthy growth of vegetation, reduce the amount of water and soil loss, and promote the ecological stability of the mining area.

Keywords

Ecological restoration, Stability analysis, Ecological factors, Shendong Mining Area.

1. Introduction

In a sense, the degree of development and utilization of coal resources promotes and restricts the economic development and social progress of a country. The development and utilization of coal mineral resources should ensure the coexistence of ecological economy and ecological environment and be established on the basis of "sustainable" [1-3]. Shendong mining area has been developed and utilized for more than 30 years. It is known as the largest original coal mining base in China. Due to the large-scale development of coal mineral resources in Shendong mining area [4], the serious imbalance of water resources supply and demand in recent five years has had a very bad impact on the production and living of Shendong mining area and the ecological environment security problems [5,6], which has become a stumbling block for the rapid development of coal base. The evolution of coal mining environment promotes the instability of various eco-environmental factors and reduces the adaptability to interference [7-10]. If the environmental conditions change, it can cause a series of butterfly effects, and the security and stability of the overall ecosystem of the ecosystem gradually

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decline, which leads to the destruction and degradation of the ecosystem [11,12], and it is difficult to restore and reconstruct [13,14].

The necessary premise of rebuilding the whole ecosystem of Shendong mining area is to restore the necessary ecological industrial structure and ecological environment function in the process of development and utilization, so as to ensure its own stability [10,15,16]. Vegetation plays the most important role in the process of ecosystem restoration in Shendong mining area. Vegetation has good effects on Soil and water conservation, water conservation and ecological environment improvement. From the canopy to the root system [17,18], vegetation can slow down the soil erosion caused by runoff at different levels, improve soil infiltration [19], reduce the sediment transport on the slope surface [11,20,21], and reduce the amount of soil and water loss. Therefore, in recent years, people pay more and more attention to the development and protection of vegetation. To sort out and clarify the relationship of vegetation terrain soil system in Shendong mining area is an important step in the ecological restoration degree and ecological late management in this area [7]. However, it is still a serious problem how to find out the relationship network and determine the decisive factors of ecological vegetation restoration [22-24]. As we all know, there is a significant correlation between the degree of vegetation restoration and the environment. Only by defining the suitable site environment of plants can we achieve the purpose of vegetation restoration and sustainable development of ecological environment. Based on the above factors, the analysis of the correlation between soil, terrain factors and vegetation development after land reclamation in Shendong mining area has a far-reaching guiding role in improving land reclamation measures in the mining area.

The main research methods of this paper are principal component analysis and SPSS Software data processing [10,25], correlation analysis method, through three methods to find out the correlation between vegetation restoration and soil and terrain factors, study the main environmental factors affecting the process of vegetation restoration, find out the system relationship between vegetation soil terrain after reclamation in subsidence area, and give vegetation reconstruction of the mining area in accordance with the actual situation of coal mining in loess area and wind sand area And ecological restoration reasonable and scientific suggestions.

The results show that the regular land is related to vegetation restoration and environmental restoration to a great extent. European scientists compared the soil physical and chemical properties of cultivated farmland in the northwest of the United States and the collaborative change characteristics of soil vegetation roots. The results showed that the percentage of soil nutrients in this area had been greatly increased after land consolidation. Geologists used geostatistics to study the difference of soil organic matter content with soil depth the regional distribution map of the percentage of soil organic matter nutrient content was made [10,26], and a reasonable land control plan was formulated. The above two studies respectively elaborated the positive correlation between land consolidation, soil nutrients [27] and ecological vegetation restoration from two different perspectives.

Soil and water conservation measures refer to the technical measures and management measures taken for the prevention and control of soil and water loss, protection, improvement and rational utilization of water and soil resources [4,28], and improvement of ecological environment. The general idea of arrangement of soil and water conservation measures in China is as follows: suit measures to local conditions and fortify due to hazards [29,30]. In view of the mining area and waste dump area formed by mining, the principle of zoning prevention and ecological priority should be adhered to, and the relationship among ecological, economic and social benefits should be taken into account, and ecological benefits should be highlighted. In order to stabilize the slope, control soil erosion, improve the ecological environment and promote the sustainable development of local economy, three kinds of treatment measures, namely engineering measures [31,32], plant measures [9,33] and temporary measures, are adopted. The engineering measures mainly include slag retaining works for stabilizing slope and slag body, slope protection engineering, flood control and drainage engineering, etc. Plant protection measures should be taken to restore the natural landscape on the

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premise of safety and stability. Temporary measures are protective measures for the disturbed surface and occupied area formed by the construction of roads and construction sites during the construction preparation period and construction period. Soil and water conservation measures in the United States mainly use water to change runoff to control soil erosion, change agricultural practices [25] through land management [3,22,34], and improve land use by returning farmland to grazing prohibition [35].

2. Materials and Methods

2.1 Study area

Shenfu Dongsheng mining area is located in the southeast of Ordos Plateau, the northern edge of Loess Plateau in Northern Shaanxi, and the southeast edge of Maowusu Desert. It is 38° 52′ ~ 39° 41′ N and 109° 51′ ~ 110° 46′ E. It is about 38-90km long and 35-55km wide, with an area of 3539km2. In terms of zonal vegetation types, the surface vegetation in the mining area belongs to the typical warm temperate steppe area. The grassland community mainly develops on the chestnut soil or loessial soil in the Loess ridge and loess hilly land, with *thymus* or *cryptocaryopsis scabra* community as the main community. Vegetation is mostly crops and weeds in the field, as well as abandoned land vegetation.

2.2 Methods

2.2.1 Descriptive statistical analysis

Soil index is the index reflecting vegetation's effect on soil improvement. The bulk density and total porosity under different restoration modes can be used as soil evaluation index parameters. Bulk density is a sensitive index of soil compactness, and it is also one of the important parameters reflecting soil physical properties. It affects the permeability, permeability, water holding capacity and solute transport capacity of soil. Total porosity is closely related to soil water holding capacity, water movement and water supply. Vegetation index is the index reflecting the growth status of vegetation itself. Species diversity index, species richness and evenness under different vegetation restoration modes can be used as index parameters for vegetation stability evaluation. Vegetation coverage refers to the percentage of the ratio of the vertical projection area of the whole plant community or the aboveground part of each individual to the area of the quadrat. The greater the vegetation coverage is, the more significant the reduction of soil and water loss will be.

2.2.2 Correlation analysis

The correlation matrix can be used to analyze the correlation among terrain, soil and vegetation index in the process of vegetation restoration between loess area and aeolian sand area in Shendong mining area. In order to further judge the impact of terrain and soil conditions on vegetation, partial correlation analysis of topographic soil factors was conducted (Table 4). Partial correlation analysis refers to the process that when two variables are related to the third variable at the same time, the influence of the third variable is eliminated and only the correlation between the other two variables is analyzed.

2.2.3 Principal component analysis

2.3 Data sources

The data in this paper are from the continuous surface monitoring data of Shendong mining area by Inner Mongolia Agricultural University. The data set is a long-term fixed-point monitoring data set, which meets the requirements of statistics and ecology.

3. Results

3.1 Descriptive statistical analysis

According to the data (Table 1), the variation range of ecological indicators in Shendong area is not very large, and the standard deviation and variation range of dominance, evenness, bulk density and diversity of vegetation are very small, close to the average value. The relative height, vegetation

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coverage, slope position and other indicators of sand dune vary greatly, among which the dune landform factor and vegetation coverage factor change most.

Table 1 Descriptive statistical analysis of terrain soil vegetation data

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
N	10	10	10	10	10	10	10	10	10	10	10	10
Mini	24	4.6	3.6	4	4.6	1.4	37.93	21	1.74	1.76	0.73	0.62
Maxi	31	25.9	9.5	10.7	11.1	1.62	46.36	45	10.86	3.17	0.95	0.86
Mean	26.7	14.55	6.8	7.7	7.72	1.52	41.69	32.2	6.69	2.57	0.86	0.77
Std.D	2.06	10.15	2.49	3.01	2.95	0.08	2.9	8.04	2.93	0.48	0.07	0.08
Variance	4.23	103.09	6.18	9.09	8.71	0.01	8.41	64.62	8.57	0.23	0.01	0.01

Note: S1、S2……S12in the table S12 represents leeward slope, relative height of sand dune, top, middle and bottom of slope, bulk density, total porosity, vegetation coverage, richness, diversity, dominance and evenness.

In order to further analyze the relationship between the ecological factors in the wind-blown sand area and the subsidence area, the Z-score standard was used to deal with the differences of the quantitative dimensions among different indexes (Table 2)

Table 2 Standardized treatment of Z scores of each index

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
A	0.63	-0.96	-0.8	-0.8	-0.9	1.3	-1.3	-0.9	-1.69	-1.67	-0.94	0.41
A1	-0.83	-0.93	-1.29	-1.23	-1.06	-1.61	1.61	-1.39	-1.4	-0.74	0.2	1.19
A2	0.15	-0.98	-1.19	-1.13	-0.95	-0.95	0.95	-0.9	-0.28	-1.04	-1.78	-2.02
A3	2.09	-0.91	-0.72	-0.83	-0.95	1.3	-1.3	-0.27	0.02	-0.15	-0.2	-0.61
A4	0.15	-0.94	-0.64	-0.71	-0.85	0.9	-0.9	-0.65	-0.31	-0.67	-1.2	-1.09
B	0.15	1.05	0.97	1	1.15	-0.29	0.29	0.85	0.61	1.24	1.2	1.14
B1	-0.83	0.9	0.73	0.93	0.81	-0.42	0.42	-0.03	1.2	1.04	0.95	0.28
B2	0.63	0.77	0.97	0.86	0.98	-0.82	0.82	1.22	1.42	0.98	0.68	0.01
B3	-1.31	1.12	0.89	0.9	0.84	-0.03	0.03	1.59	0.01	0.57	0.68	0.63
B4	-0.83	0.88	1.09	1	0.94	0.63	-0.63	0.47	0.42	0.44	0.42	0.07

Note: A, A1, A2, A3 and A4 in the table represent the wind sand control area, 1-year wind sand subsidence area, 8-year wind sand subsidence area, 11-year wind sand subsidence area, B, B1, B2, B3, B4 loess control area, 1-year loess subsidence area, 6-year loess subsidence area and 13-year loess subsidence area.

3.2 Correlation analysis among variables

Pearson correlation coefficient correlation coefficient matrix (Table 3) shows that terrain factors are significantly correlated with soil factors. Sand dune height has a strong positive correlation with vegetation coverage, richness, diversity, dominance, top, middle and bottom of slope, and has passed the test of 1% significance level. Vegetation coverage has strong positive correlation with diversity, top, middle and bottom of slope, and has passed the test of 1% significance level, and has strong positive correlation with richness and dominance, and this correlation has passed the test of 5% significance level; there is a strong positive correlation between richness and diversity, top, middle and bottom of slope, with correlation coefficients of both The results showed that the correlation coefficient was above 0.7, and the correlation coefficient passed the 1% significance level test, and had a strong positive correlation with the dominance degree, and passed the 5% significance level test; the diversity had a strong positive correlation with the dominance, the top, the middle and the bottom of the slope, the correlation coefficients were above 0.8, and passed the 1% significance level test; the dominance and evenness, the top of the slope, the top of the slope, the top of the slope and

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the bottom of the slope had a strong positive correlation There is a strong positive correlation between the middle and the bottom of the slope, the correlation is above 0.7, and this positive correlation has passed the test of 1% significance level; there is a complete negative correlation between bulk density and total porosity, and this complete negative correlation has passed the test of 1% significant level; there is a strong positive correlation between the top of slope and the middle and bottom of slope, and the correlation coefficient is very strong All of them were above 0.9 and passed the test of 1% significance level; there was a strong positive correlation between the middle slope and the lower slope, the correlation coefficient was 0.991, and passed the test of 1% significance level. It was found that each index had significant correlation in different degrees and passed the single tail test of $P < 0.01$ or $P < 0.05$. The results show that the influence of terrain factors on vegetation community is greater than that of other soil factors.

Table 3 Correlation coefficient matrix of each index in wind sand area and loess area

	S2	S8	S9	S10	S11	S12	S6	S7	S1	S3	S4	S5
S2	1											
S8	0.877**	1										
S9	0.742**	0.705*	1									
S10	0.901**	0.808**	0.883**	1								
S11	0.837**	0.676*	0.577*	0.869**	1							
S12	0.476	0.296	-0.04	0.385	0.774**	1						
S6	-0.181	0.003	-0.17	-0.235	-0.249	-0.186	1					
S7	0.181	-0.003	0.167	0.235	0.25	0.186	-1**	1				
S1	-0.48	-0.198	-0.04	-0.244	-0.337	-0.378	0.461	-0.461	1			
S3	0.973**	0.899**	0.775**	0.884**	0.787**	0.403	-0.07	0.008	-0.348	1		
S4	0.985**	0.877**	0.773**	0.891**	0.801**	0.423	-0.053	0.053	-0.396	0.995**	1	
S5	0.991**	0.875**	0.776**	0.902**	0.813**	0.439	-0.162	0.163	-0.414	0.985**	0.991**	1

Note: * * means significant at the level of $P < 0.01$, * indicates that it is significant at the level of $P < 0.05$

From the partial correlation coefficient table, it can be seen that there is a weak positive partial correlation between vegetation coverage and relative height of sand dunes, which has passed the test of 10% significance level; there is a strong negative partial correlation between vegetation coverage and slope, and this negative partial correlation has passed The results showed that there was a weak negative partial correlation between vegetation coverage and slope, and passed the test of 5% significance level.

Table 4 Partial correlation coefficient of topographic and soil factors

variable	Beta	t	sig	Partial Correlation	Collinearity Tolerancee
S1	0.131(a)	0.772	0.466	0.28	0.879
S2	0.057(a)	0.079	0.939	0.03	0.054
S4	-1.907(a)	-1.230	0.258	-0.422	0.009
S5	-0.326(a)	-0.347	0.739	-0.13	0.03
S6	0.010(a)	0.057	0.956	0.022	1
S7	-0.010(a)	-0.058	0.955	-0.022	1

Note: A. predictors in the model: (constant), slope top; B. dependent variable: vegetation coverage

3.3 Crop yield

Compared with the experimental data in the above table and the yield change trend in the Fig below, the final harvest yield of maize is also different under different irrigation frequency and irrigation amount. In a certain range, with the increase of irrigation frequency, crop yield is also increased. When the irrigation frequency and irrigation amount were more, the output value of maize reached

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the maximum, reaching 29300kg / ha. When the irrigation frequency and irrigation amount were less, the output value of maize decreased significantly, and the final output value was only 17575kg / ha. When the irrigation frequency and irrigation amount were too much, the maize yield also showed an increasing trend, which was close to the yield under moderate irrigation frequency and irrigation amount, But compared with the final yield, it can be clearly found that high frequency irrigation and excessive irrigation caused the inhibition of crop yield.

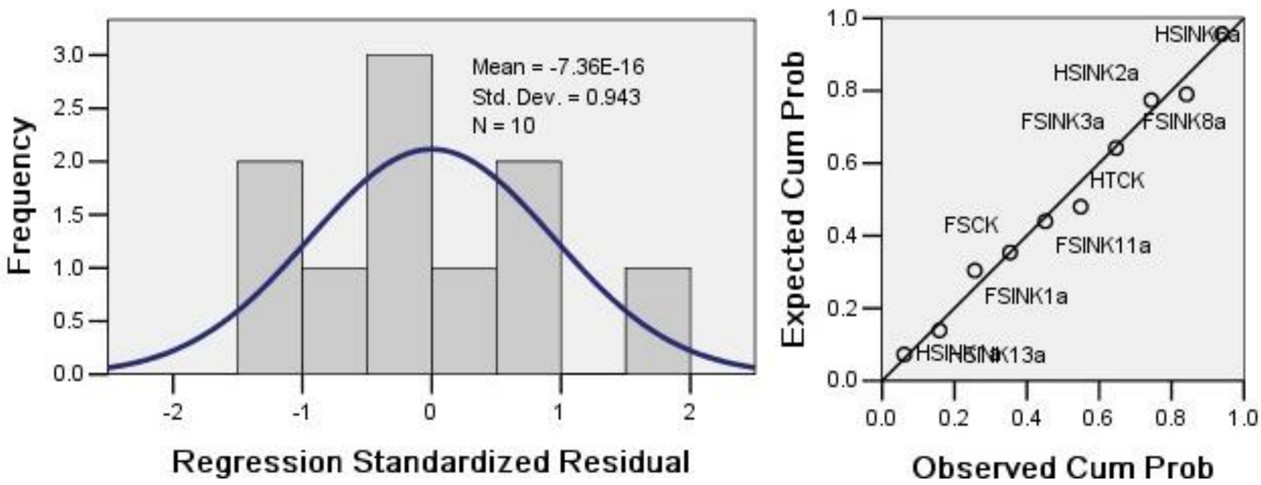

Figure 1 Residual histogram and cumulative probability diagram

The residual histogram and cumulative probability map show that the vegetation coverage is basically normal distribution, and the loess area, wind sand area, subsidence area and control area are in line with the trend, the impact of topography and soil on vegetation coverage is always.

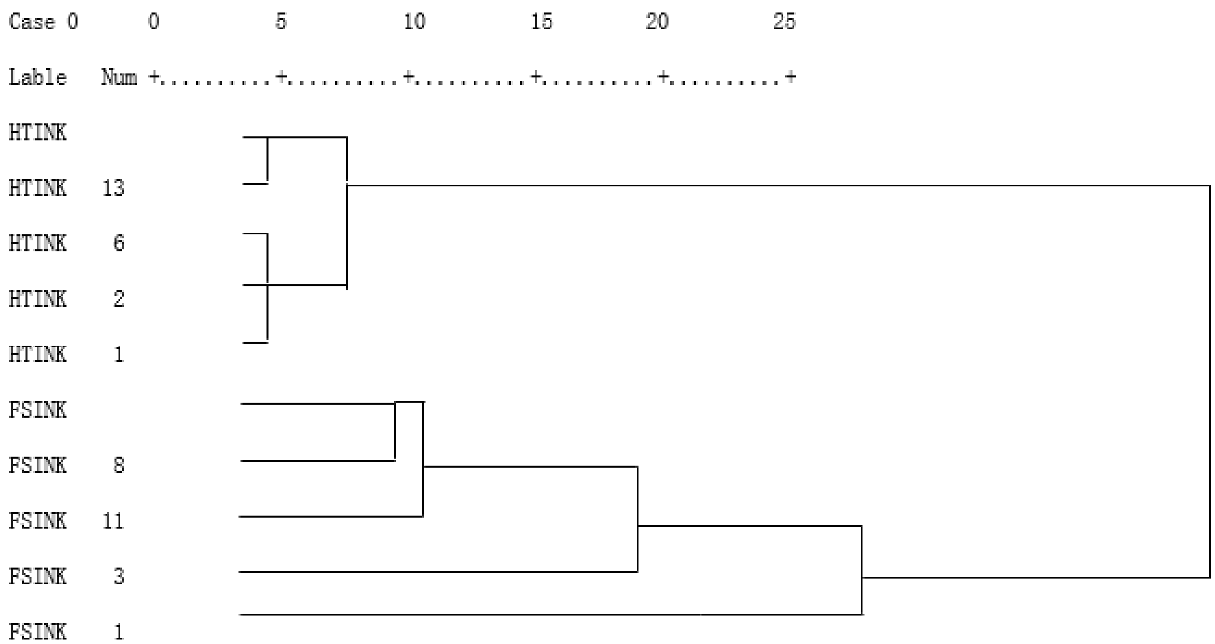

Figure 2. Hierarchical cluster analysis of indicators

Note: FEINK, $FEINK_1$, $FEINK_3$, $FEINK_8$ and $FEINK_{11}$ in the figure respectively represent the wind sand control area, 1-year wind sand subsidence area, 3-year wind sand subsidence area, 8-year wind sand subsidence area, 11-year wind sand subsidence area, HTINK, $HTINK_1$, $HTINK_2$, $HTINK_6$ and

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$HTINK_{13}$ represent loess control area, 1-year loess subsidence area, 2-year loess subsidence area, 6-year loess subsidence area and 13-year loess subsidence area.

The vegetation restoration effect of Shendong mining area was evaluated and classified by using inter group regression and Euclidean distance. The cluster diagram of Fig. 2 shows that the indexes can be divided into two categories according to 15 points of clustering: HTINK, HTINK 13a, HTCK 6a, HTINK2a and HTINK1a, and FSINK 8, FSINK 11a, FSCK3a, FSINK and FSINK1a.

3.4 Principal component analysis

The principal component analysis was carried out on the soil topographical indexes affecting vegetation restoration in Shendong mine subsidence area (Table 5). The cumulative contribution rate of principal component 3 has reached 91.12%, more than 85%, indicating that the first three principal components can be used to explain the impact of topography and soil on vegetation.

Table 5 Total variance explained

Component	Initial Eigenvalues	Variance contribution rate%	Extraction Sums of Squared Loadings		
			Total	% of Variance	Cumulative %
1	7.41	61.78	7.41	61.78	61.78
2	2.29	19.09	2.29	19.09	80.87
3	1.23	10.25	1.23	10.25	91.12
4	0.71	5.95	0.71	5.95	97.07
5	0.23	1.94			
6	0.09	0.76			
7	0.00	0.04			

The factor load matrix (Table 6) shows that slope position, terrain height and diversity have great influence on the first principal component F1, bulk density and total porosity have a greater impact on the second principal component F2, uniformity has a greater impact on the third principal component F3, and leeward slope has a greater impact on the fourth principal component F4.

Table 6 Factor load matrix

Factor	Component			
	F1	F2	F3	F4
Leeward slope	-0.427	0.563	0.288	0.626
Relative height of dunes	0.988	0.033	-0.034	-0.120
slope crest	0.963	0.223	-0.011	-0.111
Mid slope	0.972	0.169	-0.019	-0.125
Downhill	0.984	0.073	0.017	-0.092
Bulk density	-0.232	0.923	-0.278	-0.103
Total porosity	0.233	-0.923	0.278	0.103
vegetation coverage	0.872	0.267	0.078	-0.050
richness	0.784	0.179	0.553	0.101
Diversity	0.946	0.041	0.172	0.185
Dominance	0.885	-0.106	-0.275	0.324
Uniformity	0.503	-0.265	-0.757	0.315

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4. Conclusions

This paper analyzes the relationship between the topography and soil and vegetation restoration in different subsidence years of Shendong mining area

In the process of vegetation restoration in Shendong mining area, the main factor affecting the effect of vegetation restoration is terrain height and slope position, followed by soil moisture conditions, and finally altitude. Topography is very important to the growth and development of vegetation restoration after reclamation. Therefore, in order to promote the growth of vegetation, improve the ecological environment of the mining area and make it stable, we should reasonably renovate the slope and other terrain factors, and give play to its terrain advantages through reasonable land preparation and soil conservation measures, so as to make the soil and vegetation evolve together, so as to continuously improve the soil, maintain the healthy growth of vegetation, increase the vegetation coverage, and reduce the amount of soil and water loss to promote the ecological stability of the mining area.

In this paper, through descriptive statistical analysis, sum and other methods, taking Bulianta coal mine (non-subsidence area, subsidence area of 1, 3, 8, 11 years) and Daliuta coal mine (non-subsidence area, subsidence area of 1, 2, 6 and 13 years) in Loess Hilly Area as research objects, terrain factors such as slope position and slope, soil factors such as bulk density and total porosity, species diversity and species The relationship among richness, evenness and vegetation coverage was analyzed.

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Author Contributions

Y. Guo wrote the manuscript; B.L., Q. L., and J. Chang designed the experiments and analyzed the data; Chen Jing did the water and soil test and analysis, and revised the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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