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Applying Trait-Based Modeling to Achieve Functional Targets during the Ecological Restoration of an Arid Mine Area

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Abstract: (1) Background: Because ecosystem degradation has become a global phenomenon which seriously affects the health of natural ecosystems and human well-being, restoration of degraded ecosystems has attracted increasing attention. However, many of the methods used in current ecological restoration work have rarely combined ecological restoration practices with the quantitative goal of restoring ecosystem function. (2) Methods: In this study, based on the conceptual framework of response-effect traits and Community Assembly by Trait Selection model (CATS model), a restoration strategy for a degraded abandoned mine in Wuhai City, China has been provided. This restoration strategy connected the ecosystem function targets to the appropriate recovery species and their required abundances. (3) Results: The results showed that a relative abundance ratio of 8:2 for S. grandis to B. dasyphylla was best for a shady slope, while a 6:4 ratio of K. tragus to B. dasyphylla was best for repair on a sunny slope of the degraded mine area. (4) Conclusion: This study provides a typical example of applying ecological theory in practice that will be useful for current and future studies and applications. This approach will ensure that governance efforts to restore degraded ecosystems are effective and efficient.

Keywords: plant functional trait; degraded ecosystem; mine area; trait-based model; ecological restoration

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1. Introduction

Due to climate change and human disturbance, ecosystem degradation has become a global phenomenon which seriously affects the health of natural ecosystems and human well-being [1,2]. In this context, the restoration or reconstruction of degraded ecosystems has attracted increasing attention [3]. However, ecological restoration projects have rarely combined ecological restoration practices with the quantitative goal of restoring ecosystem function [4]. There is a considerable gap between the practitioners who carry out ecological restoration projects and the scientists who carry out theoretical research on ecological restoration [4]. Therefore, the practical application of ecological restoration theory and research is necessary to provide demonstrative examples that can inform and benefit the management and restoration of degraded ecosystems.

Abandoned mine areas are typical degraded ecosystems [5–7]. Because mineral resources are required for social and economic development, the demand for mines is increasing, which motivates mining efforts for these increasingly scarce materials. In arid areas, due to low rainfall, vegetation coverage is low and ecosystems are fragile [8]. Mines not only cause damage to the surface ecosystem, but also produce a large amount of sand and dust which represent a great environmental burden [6]. Atmospheric particulate matter as a source of air pollution not only harms the health of surrounding environments, but also aggravates climate change [9]. Furthermore, it can have a variety of adverse effects on humans and other living organisms, so it has attracted widespread attention from all countries of the world [9,10].

Due to the serious environmental degradation of abandoned mine areas, the natural recovery of damaged ecosystems is a slow and difficult process [6]. Therefore, ecological restoration measures should be adopted by management agencies to speed the recovery of abandoned mine areas. However, the improper selection of plant species for the restoration of arid mine areas, or the lack of systematic research on the environments of abandoned mine areas, will lead to differences in the ecosystem function of the restored ecosystem compared with the natural ecosystem. In practice, this would not only mean that the targets of ecological restoration were not achieved, but also that a lot of manpower and material resources had been wasted [11]. Recently, trait-based models have been developed and applied to translate ecosystem functional targets into required abundances of ecologically restorative species, providing targets for achieving the desired ecological restoration effect [12].

At present, theoretical studies on plant functional traits have begun to receive more and more attention among restoration ecologists [12–14]. Many studies have shown that the coupling of response and effect traits is an effective method for studying ecosystem function, but very few relevant experimental studies exist [4,15]. The concept of traits in reference to species functional traits was proposed in the 1990s [16] and is defined as the morphological, physiological, and phenological characteristics of individual plants [17]. Response traits refer to species functional traits that can respond to environmental change, and effect traits refer to traits that can influence ecosystem function [4]. Response and effect traits can be divided into different components according to the responses of different species to environmental change or their effects on ecosystem function. However, there is no clear defining boundary between them [18]. For example, Lavorel and Garnier [19] found that plant response traits were affected by soil nutrients, but these almost completely overlapped with the effect traits determining primary productivity (for example, specific leaf area appears in both components at the same time). However, there was almost no overlap between the response traits affected by fire (such as plant height) and the effect traits that determined the fire resistance of the community (such as plant water content). To date, studies have focused on plant roots [20], leaves [21,22], and various other organs and examined trait responses to the environment [23] as well as trait effects on ecosystem function [24,25]. However, few studies have combined the two aspects of response and effect traits. In order to obtain species compositions that meet specific restoration targets, Laughlin et al. [14] proposed the Community Assembly by Trait Selection model (CATS model) based on the concept framework of response-effect traits. Through this model, based on specific ecosystem function goals for specific restoration areas, suitable species and their required relative abundance ranges can be obtained.

In this study, we first investigated soil factors and plant functional traits, such as leaf area and root length, in Wuhai, a city in China's arid western region. Then, we investigated mine area environments in Wuhai and set appropriate ecosystem function targets for the ecological restoration of the mine area. Finally, the CATS model was used to connect the ecosystem function targets to the appropriate recovery species and their required abundances. Based on the concept framework of response-effect traits, this study has provided a useful example that advances the study of restoration ecology.

2. Materials and Methods

2.1. Study Area

The study area, including the abandoned mine and its surrounding areas, was located in Wuhai in the arid western region of China (Figure 1A,B). The study area has a typical continental climate with an average annual temperature of 9.8 °C. The annual precipitation in Wuhai ranges from 80 mm in the west to 250 mm in the east, and the average evaporation is about 3249 mm [26]. Brown calcic soil, gray desert soil, and chestnut soil are the main soil types in the area [26]. The study area biome changes from steppe in the east to desert in the west.

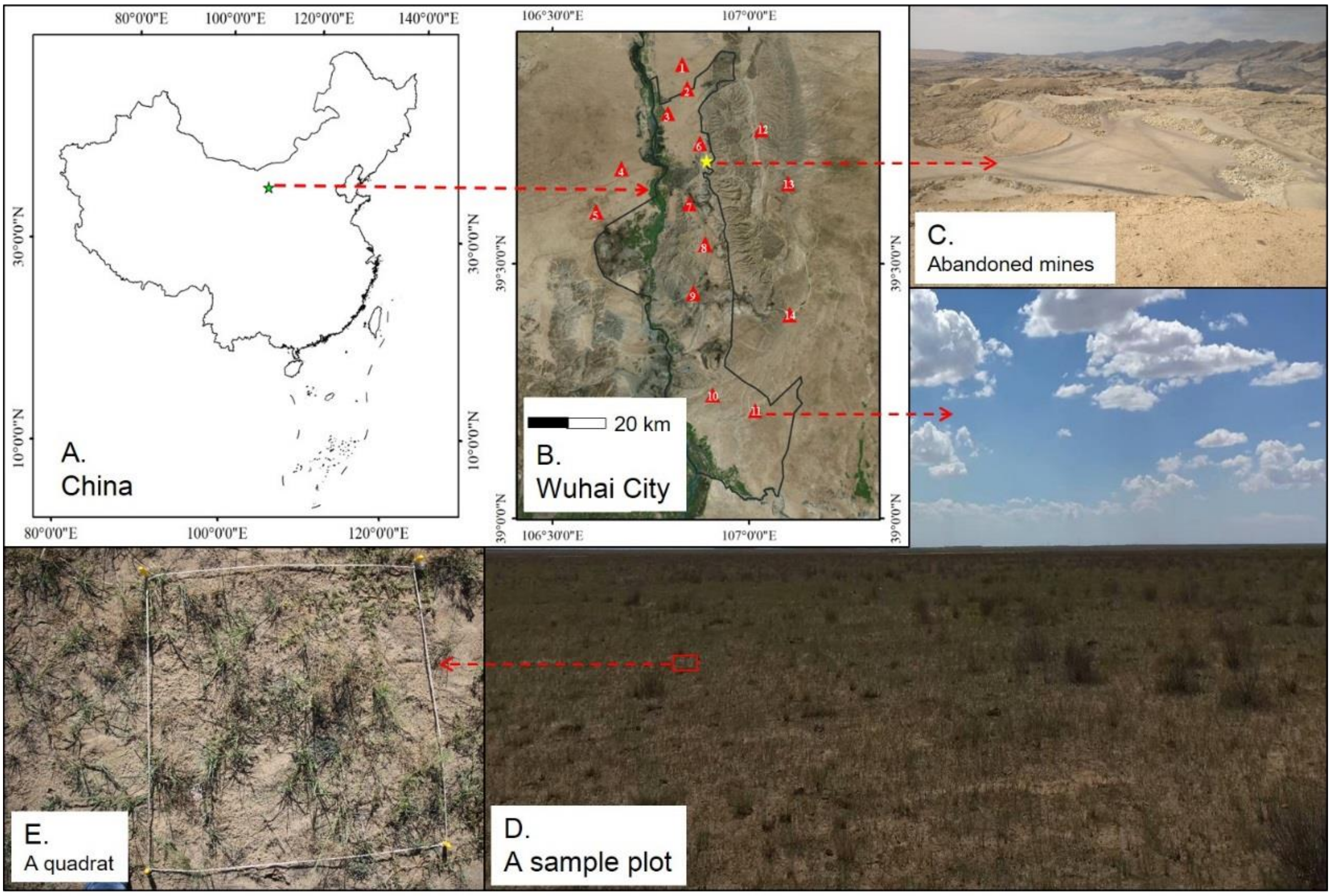

Figure 1. Research site and the plot locations of this study. (**A**): Location of Wuhai City in China; (**B**): Locations of abandoned mines and sample plots in Wuhai City; (**C**): Abandoned mines; (**D**): A sample plot in Wuhai City; (**E**): A quadrat in a sample plot.

The abandoned opencast mine is located in the center of the study area (Figure 1B,C). The terrain of the mining area has changed dramatically, and the wind erosion is serious. The mining work was started in 2011 and continues to this day. Before mining work, the local vegetation type was consistent with the surrounding areas. Now, due to intense human disturbance, there is almost no vegetation coverage in the abandoned mining area.

2.2. Plots Selection

From July to August of each year from 2018 to 2020, field surveys were conducted on the abandoned mine, which was selected as restoration area in this research, and its surrounding areas, which is the site outside of the restoration area, in Wuhai (Figure 1C). To consider the effect of topography on vegetation restoration in the abandoned mine, a shady slope sample plot and a sunny slope sample plot in the mine area were selected as environmental survey plots in restoration area. Furthermore, around the restoration area, 14 flat terrain plots were selected as native plant survey plots. In total, 16 survey plots were established. To reduce the effects of rainfall on the concentration of total suspended particulate matter in air, dust retention of plant leaves, and soil moisture, plot monitoring was conducted on the 8th day after rainfall.

2.3. Vegetation Investigation

Three 1 × 1 m quadrats were randomly selected within each plot, making a total of 48 quadrats (Figure 1D,E). Plant species names, community richness, number of plants per species, and coverage were recorded or estimated for each quadrat. Within the plot, 10 healthy plants with good growth and no disease were randomly selected as plant samples for each species. The whole plant was harvested with a shovel, and then soil was backfill. Leaves and intact roots of each plant sample were obtained. Root length, root diameter, root surface area, and root volume were analyzed with Winrhizo-Pro root analysis system. We soaked the collected leaves in distilled water and washed them. All the cleaning solution was then filtered through a filter membrane with a 0.15 μm pore size. The filter membrane with filtrate was then put into a 60 °C oven (Binder FED53) to dry to a constant volume, and then weighed with a 1/10,000 balance. The difference between the mass of filter membrane before and after filtration was taken as the dust retention of plant leaves. The fresh leaves were weighted and scanned (Epson 600), and the leaf area was calculated. We then put the leaves in the oven at 60 °C (Binder FED53) to dry to a constant weight, and weighed the dry leaves. The ratio of leaf area to dry weight was taken as the specific leaf area. The ratio of leaf dry weight to fresh weight was taken as leaf dry matter content. The ratio of leaf dust retention to leaf area was calculated as the dust retention per unit leaf area within 8 days.

2.4. Soil Sampling

In the center of each quadrat, a soil drill was used to obtain 30 g top soil samples (0–30 cm). Soil total nitrogen and phosphorus were determined using an automatic chemical analyzer (SmartCHM200). Soil water content was measured using the drying method.

2.5. Total Suspended Particulate Matter (TSP) Concentration Monitoring

A portable dust monitor (Dustmate) was used to monitor the concentration of TSP around the sample site from July to August 2020. Measurements were taken at each monitoring site once in the morning and once in the evening, and the average value was calculated as the background value of atmospheric dust concentration in the plot.

2.6. Data Analysis

2.6.1. Correction of Dust Retention by Plant Leaves

Since the background value of atmospheric dust concentration affects the dust retention process of plants, it is necessary to correct the dust retention amount per unit leaf area of different plots for their local atmospheric dust quantities so as to ensure that the dust retention amount per unit leaf area of all plants can be compared under similar environmental conditions. Since the mine area was selected as the restoration area in this study, we assessed the dust retention amount per unit leaf area in the mine area, based on the actual dust retention data per unit area in different plots, and the measured atmospheric TSP values in different regions. The correction formula is:

$$\mathrm{DR} = DR_{measure} \times \left(\frac{TSP_{restoration}}{TSP_{plot}} \right) \tag{1}$$

where DR is the corrected dust retention per unit leaf area of plant leaves; $DR_{measure}$ is plant dust retention per unit area measured in the quadrat; $TSP_{restoration}$ is the measured TSP in the mine area; and TSP_{plot} is the TSP measured in the plot.

2.6.2. Calculation of Community-Weighted Mean (CWM)

We calculated CWM to obtain the average values of species traits within plant communities.

$$\mathrm{CWM} = \sum_{i=1}^{n} p_i \times trait_i \tag{2}$$

where CWM is the average value of a trait within a plant community; p_i is the relative abundance of species i in the community, which can be calculated by the ratio of the abundance of species i to the abundance of all species in the community; and $trait_i$ is plant functional trait i.

2.6.3. Linear Model Fitting

We first calculated the value of CWMs and soil factors in each of the 14 herb plots outside of the abandoned mine. Then, a generalized linear model was used to analyze the relationship between soil factors and CWMs from the 14 herb plots, and the significant relationship, marked by the correlation curves with the high value of R^2, were selected to build the CATS model.

2.6.4. CATS Model

Firstly, based on the linear relationship between the investigated plant functional traits and soil factors, and the value of soil factors in the restoration area, the response trait target values in the restoration community were chosen to keep the restoration species in the restoration area alive. Secondly, based on the distribution of dust retention amount per unit leaf area of different plants, the maximum value was set as the effect trait target for the restoration area. This was selected based on the goal of maximizing the restoration community's dust retention ecosystem function. Finally, the CATS model was used to predict the required relative abundances of restoration species under the environmental conditions of the restoration area and based on the response-effect trait target values of the restoration community. The mathematical formula of this model is as follows:

$$\sum_{i=1}^{S} t_{ik} p_i = \overline{T_k} \quad (3)$$

$$\sum_{i=1}^{S} p_i = 1 \quad (4)$$

$$p_i > 0 \quad (5)$$

where, t_{ik} is trait k of species i; p_i is the relative abundance of species i in the restoration area; T_k is the trait target value in the repair community; and S is the total number of selected plant species. The model was solved in R-4.1.1 with package "limSolve".

3. Results

3.1. Plant Distribution

Plants in this study area are dominated by herbs and include 52 herb species. Among the 14 plant survey plots, the most widely distributed species included: *Bassia dasyphylla*, *Artemisia frigida*, and *Stipa gradis*. The *S. gradis* community in plot 7 had the highest coverage (76.8%), while the *A. fridgida* community in plot 3 had the lowest coverage (25.2%). The highest richness occurred in plot 8, which contained 8 herbs, while the lowest richness occurred in plot 4, which contained only 1 herb (Table 1).

Table 1. Vegetation and soil conditions of the plots.

Sample Plot	Vegetation Coverage (%)	Species Richness	Soil Total Nitrogen (g/kg)	Soil Total Phosphorus (g/kg)	Soil Water Content (%)
Mine area (sunny)	—	—	0.40	0.17	3.03
Mine area (shady)	—	—	0.39	0.21	4.50
1	34.6	2	0.16	0.17	2.34
2	27.3	4	0.20	0.27	3.20
3	25.2	5	0.28	0.26	2.66
4	54.7	1	0.13	0.16	1.42
5	67.4	2	0.25	0.23	1.72
6	29.4	4	0.42	0.36	4.53
7	76.8	7	0.55	0.39	7.63
8	68.1	8	0.40	0.33	6.12
9	44.9	6	0.58	0.28	8.19
10	25.5	3	0.23	0.21	2.98
11	28.3	2	0.27	0.21	2.94
12	43.9	4	0.30	0.35	3.38
13	39.1	4	0.30	0.36	4.27
14	41.6	3	0.36	0.35	3.56

3.2. Plant Functional Traits

The results showed that *Oxytropis racemosa* had the largest specific leaf area. Correspondingly, its leaf dry matter content was the smallest. The specific leaf area of *Asparagus gobicus* was smallest and, correspondingly, its leaf dry matter content was the largest. In terms of dust retention per unit leaf area of plants, among the 22 plants investigated, the species with the strongest dust retention ability was *Salsola collina*. The species with weakest dust retention ability was *Psammochloa villosa* (Table 2). *Heteropappus altaicus* had the largest total root length of 279.81 cm, while the total root length of *Saposhnikovia divaricata* was only 9.00 cm, which was the smallest. *Artemisia desertorum* had the largest root surface area of 64.55 cm^2, while *Asparagus gobicus* had the smallest largest root surface area of 5.67 cm^2. In addition, *Saposhnikovia divaricata* had the largest average root diameter of 8.05 mm, and the largest root volume of 4.58 cm^3 (Table 2).

Table 2. Plant functional traits.

	DR (g/m^2)	SLA (cm^2/g)	LDMC (g/g)	RL (cm)	RSA (cm^2)	RD (mm)	RV (cm^3)
CWM aim in sunny area	14.80	37.07	0.34	59.91	22.07	0.40	0.11
CWM aim in shady area	15.90	43.15	0.29	89.88	22.82	0.40	0.22
Allium mongolicum	1.81	56.94	0.28	60.35	20.82	1.10	0.57
Artemisia desertorum	2.45	23.73	0.26	120.95	64.55	1.70	2.74
Artemisia frigida	6.94	35.81	0.28	200.14	34.14	0.54	0.46
Asparagus gobicus	1.29	18.36	0.47	47.59	5.67	0.38	0.05
Astragalus grubovii	1.74	42.53	0.34	59.33	12.75	0.68	0.22
Bassia dasyphylla	17.79	61.76	0.21	131.14	14.79	0.36	0.13
Cleistogenes serotina	7.34	44.74	0.34	186.30	12.46	0.21	0.07
Echinops latifolius	4.09	31.13	0.39	65.21	8.98	0.44	0.10
Hedysarum scoparium	3.07	29.87	0.38	102.69	16.97	0.53	0.22
Heteropappus altaicus	5.48	46.79	0.24	279.81	52.60	0.60	0.79
Kali tragus	9.54	72.01	0.22	60.03	14.11	0.75	0.26
Olgaea leucophylla	5.26	59.12	0.25	17.10	17.05	3.17	1.35
Oxytropis racemosa	6.39	76.28	0.25	88.80	17.36	0.62	0.27
Peganum harmala	3.84	21.69	0.41	59.33	22.24	1.19	0.66
Peganum nigellastrum	1.34	45.62	0.21	92.07	24.90	0.86	0.54
Psammochloa villosa	0.47	32.19	0.37	54.74	51.34	2.99	3.83
Ptilotrichum cancscens	3.84	55.86	0.29	61.37	40.60	2.11	2.14
Salsola collina	18.03	32.26	0.22	172.76	22.87	0.42	0.24
Saposhnikovia divaricata	6.17	57.49	0.23	9.00	22.77	8.05	4.58
Sophora alopecuroides	7.35	41.66	0.28	78.52	28.10	1.14	0.80
Stipa grandis	2.56	22.26	0.43	38.87	6.43	0.53	0.09
Zygophyllum mucronatum	7.13	45.58	0.27	50.79	11.70	0.73	0.22

DR, dust retention per unit leaf area; SLA, specific leaf area; LDMC, Leaf dry-matter content; RL, root length; RSA, root surface Area; RD, root diameter; RV, root Volume. CWM aim in sunny/shady area, the trait aim of community-weighted mean in repair area of sunny/shady slope.

3.3. Concentration Characteristics of Total Suspended Particulate Matter

The total suspended particulate matter concentration in the study plots ranged from 74.62 $\mu g/m^3$ to 336.78 $\mu g/m^3$. Previously, Kriging interpolation has shown that the overall distribution of total suspended particulate matter concentration in Wuhai has zonal and radioactive characteristics. The high values were mainly concentrated in the western and north-eastern areas of Wuhai, while concentrations were low in the central and southern areas (Figure 2).

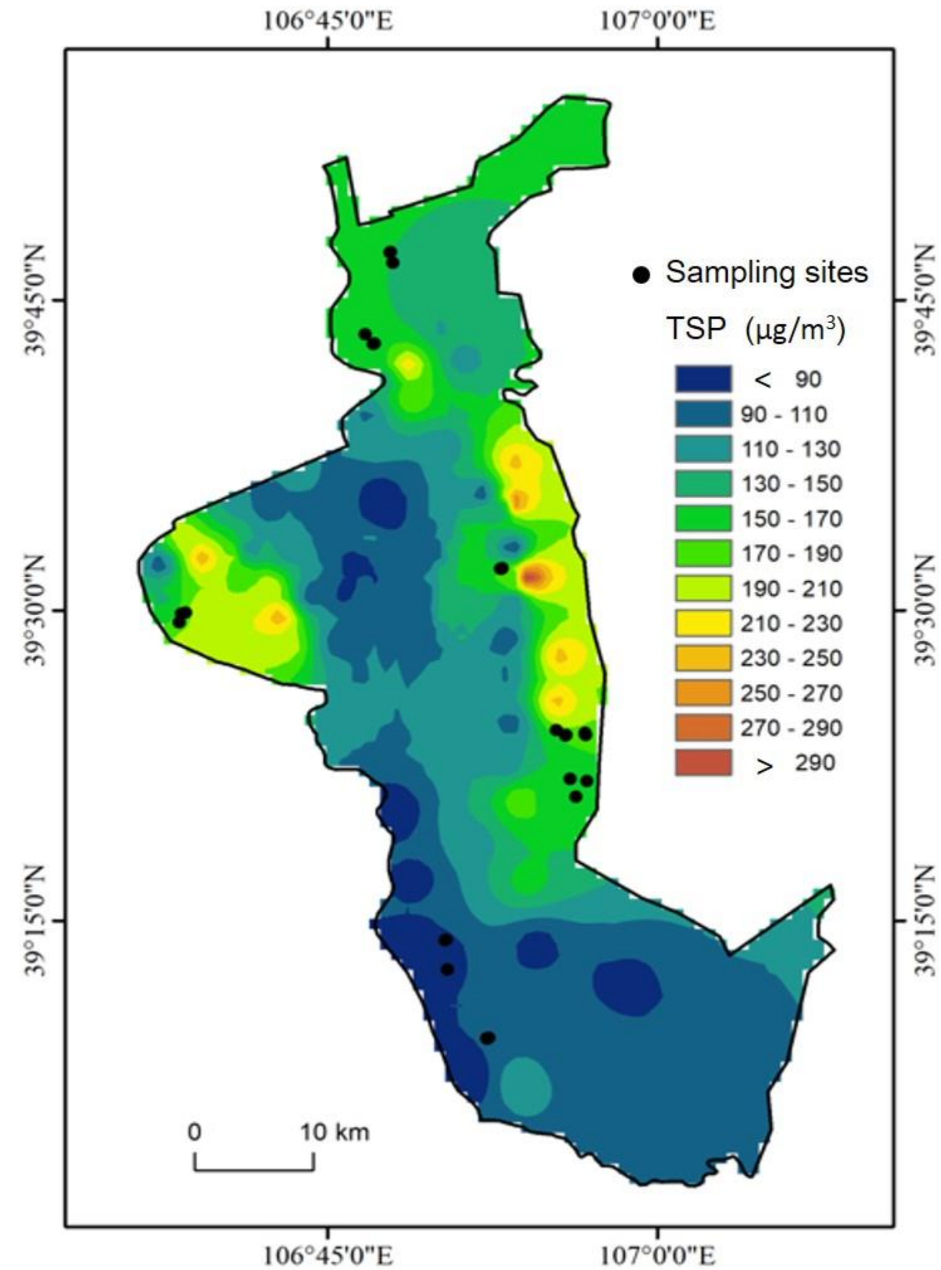

Figure 2. Distribution of total suspended particulate matter in city of Wuhai.

3.4. Soil Factors

Because the study area was located in an arid area, the soil nutrients and water contents were generally low. Soil total nitrogen content was between 0.13–0.58 g/kg. Soil total phosphorus content was between 0.17–0.39 g/kg, with slightly lower content in the restoration area (mine area) than in the other plots. Soil water content ranged from 1.42 to 8.19% (Table 1).

3.5. Linear Model Relating CWMs and Environmental Factors

After comparing different types of correlation curves, fitted by linear model, six curves with the highest value of R^2 were selected to build the CATS model. The results showed that the specific leaf area increased first and then decreased with increasing soil water content, and there was a significant correlation between them. The relationship between soil water content and leaf dry matter content also exhibited a significant correlation, but in a U-shaped curve. Root surface area had a significant negative correlation with increasing soil total nitrogen content. Root diameter increased initially and then decreased with increasing soil total nitrogen content and, overall, there was a significant positive correlation between them. The average root volume had a significant positive correlation with soil total phosphorus content. Root length had a significant positive correlation with soil total phosphorus content (Figure 3).

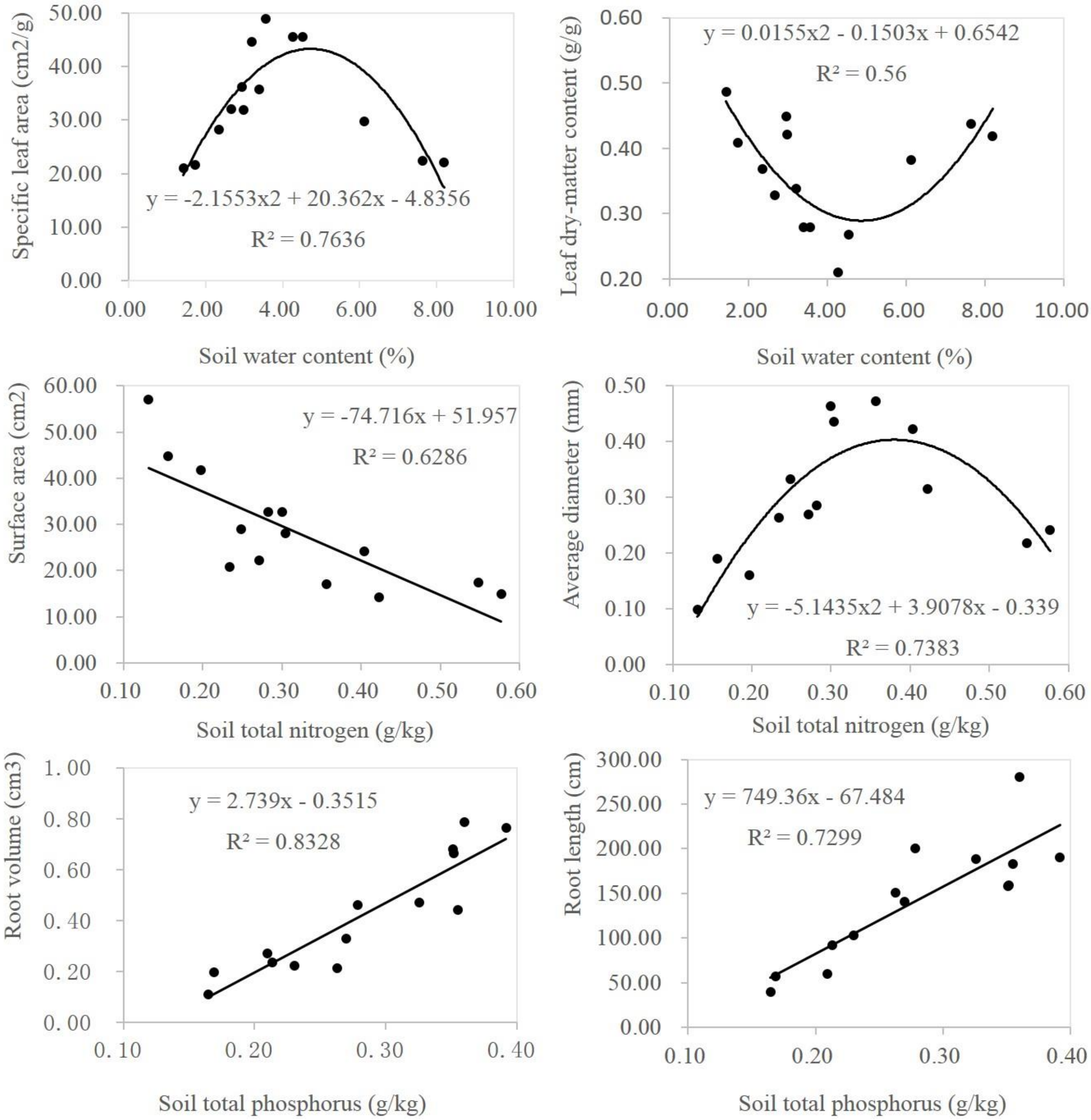

Figure 3. Fitting results of linear model for specific leaf area and soil water content, soil water content and leaf dry matter content, root surface area and soil total nitrogen, root diameter and soil total nitrogen content, average root volume and soil total phosphorus content, and root length and soil total phosphorus content.

3.6. Fitting Results of CATS Model

For the shady slope of the restoration area, the relative abundances of the species obtained by the CATS model were as follows: the average relative abundances of *Stipa grandis* and *Bassia dasyphylla* should be relatively high, with a median values of 0.46 and

0.13, respectively. This indicated that under these environmental conditions, *S. grandis* was suitable to be the dominant species in the future repair community, and *B. dasyphylla* was suitable to be the subdominant species in the future repair community. Therefore, an 8:2 ratio of *S. grandis* to *B. dasyphylla* would be the appropriate ratio in the future target community to achieve the target function in the shady slope ecosystem of the mine area (Figure 4). For the sunny slope of the restoration area, the relative abundances of the species obtained by the CATS model were as follows: the average relative abundances of *Kali tragus* and *B. dasyphylla* should be higher than all others. This indicated that the typical xerophytic herbs *K. tragus* and *B. dasyphylla* in a ratio of 6:4 are suitable for the repair community (Figure 4).

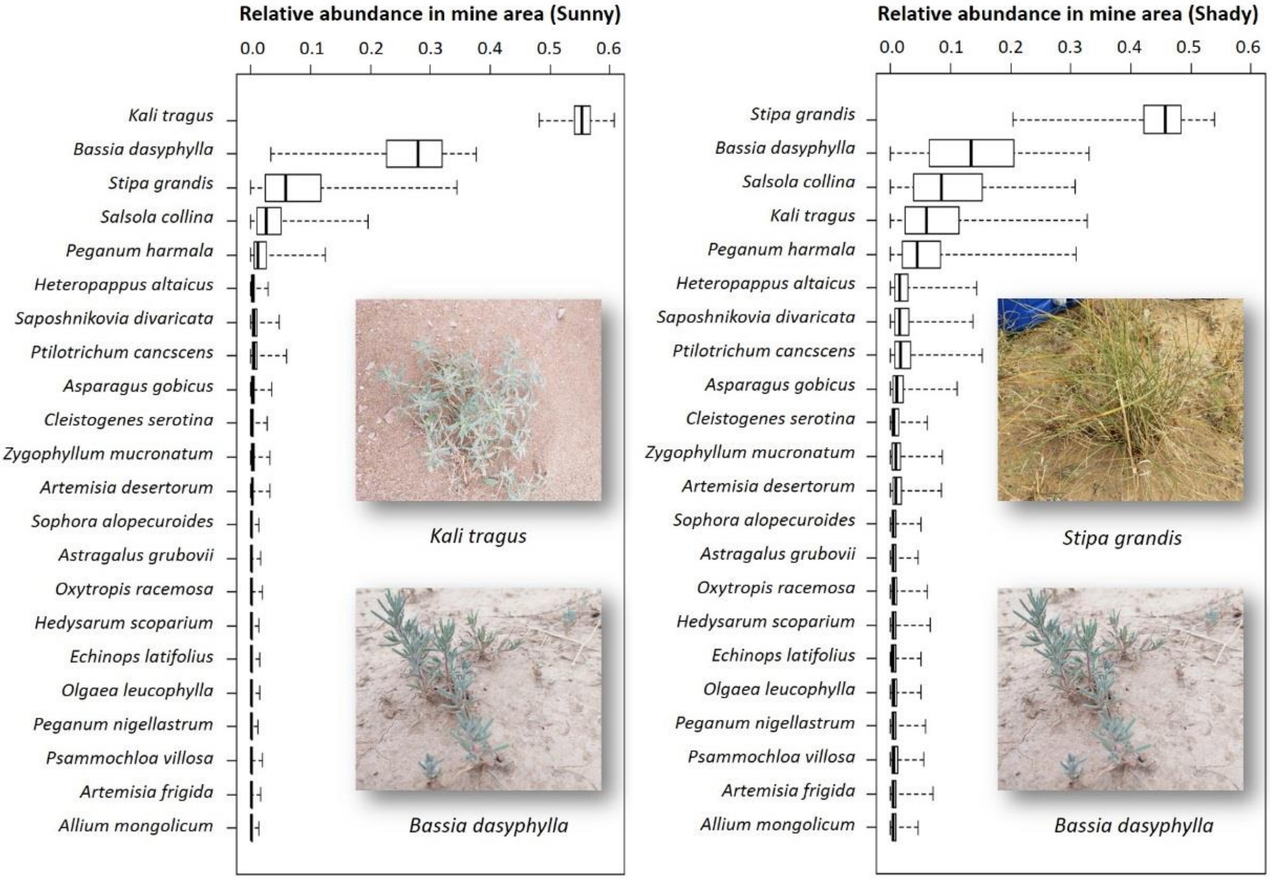

Figure 4. The relative abundances of the species in sunny or shady slope of mine area obtained by the CATS model.

4. Discussion

4.1. Relationships between Plants and Environmental Factors

Due to the low soil moisture and nutrient content in arid regions, the success of vegetation reconstruction in arid desert mine areas will depend largely on the selection of drought-tolerant plants [8]. Through natural selection, native species in arid areas have adapted to local conditions, and these adaptations have manifested as response traits. Xerophytes were the main plant type in the study area. They adopt various strategies to cope with environmental drought. For example, when the soil water content is low, plants can reduce their specific leaf area and increase leaf dry-matter content in response (Figure 3). In contrast, when soil water content is high, plants may use strategies opposite to those for drought stress (Figure 3). Soil nitrogen in the study area was low because it is mainly derived from decomposition of soil organic from litter [27,28], and there is relatively little litter in arid areas. In these conditions, it has been suggested that plants can increase the contact area between roots and soil by increasing root surface area and decreasing the average root diameter, both of which increase their nitrogen absorption ability (Figure 3). Compared with soil nitrogen, soil phosphorus content is most strongly affected by the soil matrix [27]. This indicated that soil phosphorus was less affected by the decomposition of litter than nitrogen in the arid study area. It could also be seen that the volume and length of plant roots developed well in areas rich in soil phosphorus (Figure 3). In addition, the dust retention per unit leaf area of herbaceous plants was significantly different among plots, which may have been due to differences in the leaf surface microstructures of different plants. Plant leaf surface morphology plays an important role in the retention of atmospheric particles. Future study is necessary to better understand the relationship between plant foliar microstructure characteristics and dust retention ability, and such a study would be conducive to the scientific and reasonable selection of dominant dust retaining plant species.

4.2. Prediction of Relative Abundance of Species Based on CATS Model

Two methods are commonly used in vegetation restoration work. One method is based on history. This method references past ecosystem conditions to determine the optimal plant community structure configuration [29]. However, this method may be disadvantageous because the past and future environmental conditions may be different. Therefore, vegetation restoration strategies based on the past cannot be guaranteed to apply to environmental conditions in the future. The other repair community determination method uses comparative tests conducted on different plant species [30]. When a species is shown to be suitable for the current environment, it can be included in the vegetation restoration community. In contrast to traditional methods, the CATS model goes one step further and predicts the required community assemblages for future environmental conditions based on their response and effect traits.

In the restoration area, the main species in the restoration community were *S. grandis*, *B. dasyphylla*, and *K. tragus*, which are suitable species for restoration in this area. The adaptation strategy when using *S. grandis*, which is a typical grassland plant species, is to expand the range of phosphorus absorption and improve phosphorus acquisition ability by increasing the underground biomass in low nutrient environments [31]. On the other hand, when the habitat conditions are poor, *S. grandis* can also cope with an environment with a smaller specific leaf area [31]. *S. grandis* is a pioneer plant in arid areas, which indicates that *S. grandis* has a high stress tolerance [31]. In the face of harsh habitats, *S. grandis* has unique adaptation strategies: it can quickly complete germination, excavation, and growth in areas with extremely rare rainfall. The root system of *S. grandis* occupies a wide space and can make full use of underground nutrients and water [32]. In addition, *S. grandis* has a small seed size so its seeds can be spread easily by the action of the wind. This can help speed the development of plant communities. *K. tragus* can reduce the pH of the soil near its rhizosphere, and change strong alkali environments [33]. This helps facilitate the absorption of soil nutrients and water by the plant community. These physiological characteristics are effective adaptations that help *K. tragus* survive in arid areas. The most typical morphological feature of *B. dasyphylla* is its pubescence covering [34]. This helps protect the internal tissues of the plant from harsh environmental effects [35]. In an arid environment, plant surface hairs can also help to adsorb condensed water [36]. Dense growth of *B. dasyphylla* increases the surface coverage of bare ground and plays a positive role in the fixation of aeolian soil [36].

In the process of vegetation restoration in the mine area, the selected plant species should be suitable for growth in the local environment. The study area was centered around a restoration area. The selected plant species were native plants that were present after long-term natural succession and were suitable for growth and development in the harsh environment. Therefore, the model results can be used to guide the vegetation restoration strategy for this restoration area. However, the results obtained in this study still need to be tested in practical applications in the future.

4.3. Achieve Appropriate Ecological Restoration Based on Response-Effect Trait Framing

A clear effect of response-effect trait framing on ecosystem can be described as follows: Biodiversity in the community determines the diversity of traits. Effect traits will directly affect human life through specific ecosystem functions, such as food production, or indirectly affect human life through environmental impacts, such as soil and water conservation. Accordingly, response traits can receive direct disturbance from humans, or the indirect influence of humans by changing the environment. Regardless of the direct or indirect disturbance, the biological community will be forced to change, such as the changing of the species composition, to adapt to the environment. Due to response and effect traits both exist in the species, they cannot be divided. This is a loop. So, in order to obtain a positive feedback, we should attach importance to biodiversity conservation at the community scale, ecosystem stability at the ecosystem scale, and sustainable development at the nature–society scale. This is a mutually reinforcing framework (Figure 5).

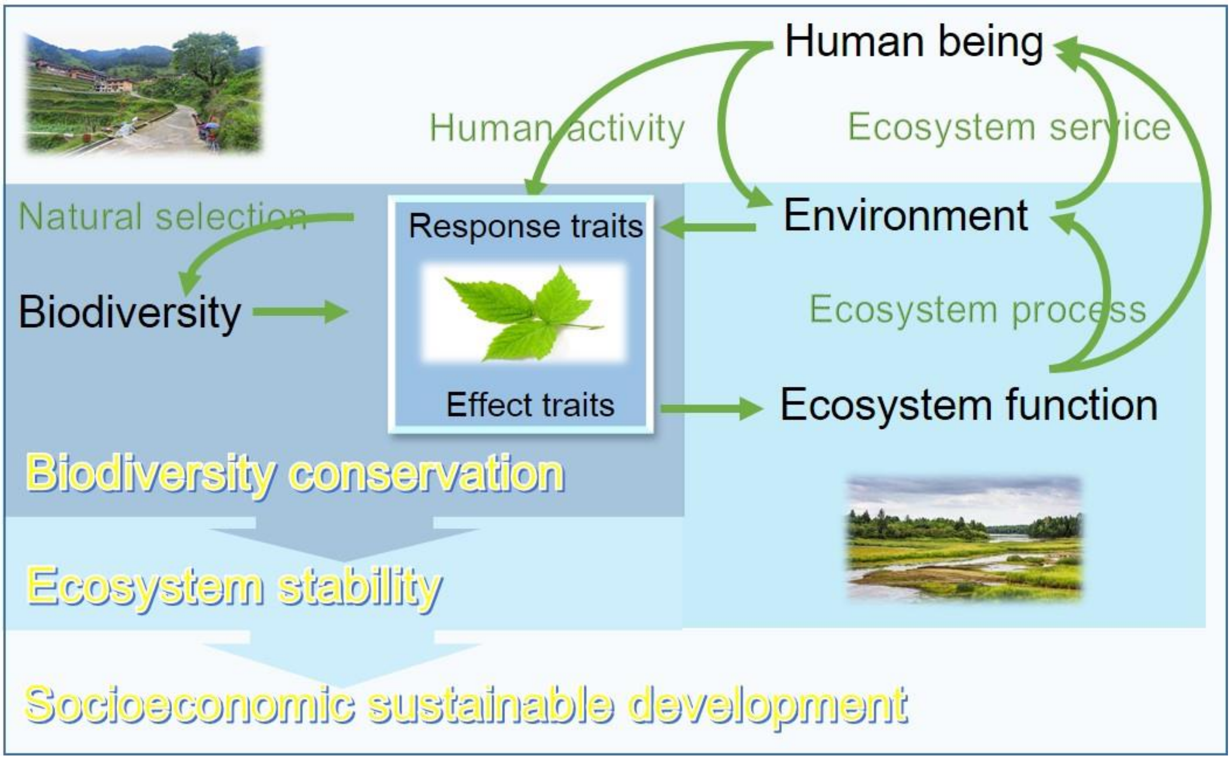

Figure 5. Response-effect trait framework.

In this study, in order to make the restoration community adapt to the mining environment and maintain the ecosystem stability, we have selected the target values of several response traits that adapt to the soil conditions in the mine area as one of the construction objectives of the restoration community. Due to the serious dust pollution caused by the development of the local mine area, it has a certain impact on people's lives. We have selected the dust capture ability of plants as the effect trait to bring into the CATS model. We hope to obtain a restoration community with higher dust capture capacity by setting a larger target value of dust capture capacity trait in the model. The results show that an 8:2 ratio of *S. grandis* to *B. dasyphylla* would be the appropriate ratio in the future target community to achieve the target function in the shady slope ecosystem of the mine area. The result of this restoration strategy is similar with the plant composition outside of the mine area. However, in the sunny slope, the results indicated that the typical xerophytic herbs *K. tragus* and *B. dasyphylla* in a ratio of 6:4 are suitable for the restoration community. Because *K. tragus* has high dust capture capacity, the restoration community of this species proportion has higher dust retention function than the communities around the mine area.

It is suggested that on the shady slope, if local species are used as the candidate species for community construction, the CATS model may not recommend the establishment of a restoration community with strong dust retention function due to the limitation of soil conditions. It is also possible that the plant communities outside of the mine area also have a fairly high dust retention function. Comparatively, it is suggested that the soil conditions on the sunny slope of the mining area can support the establishment of a community with higher dust capture function than the surrounding plant community.

5. Conclusions

This study selected restoration plants suitable for an arid mine area in western China. It was found that soil water content was important for leaf area and dry matter, while soil nitrogen and phosphorus content were important determining factors in root parameters. *S. collina* had strongest dust retention ability. The results showed that a relative abundance ratio of 8:2 for *S. grandis* to *B. dasyphylla* was best for a shady slope, while a 6:4 ratio of *K. tragus* to *B. dasyphylla* was best for repair on a sunny slope. This study provides a typical example of applying ecological theory in practice that will be useful for the current and future studies and applications. This approach will ensure that governance efforts to restore degraded ecosystems are effective and efficient.

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