Response of Herbaceous Vegetation Communities in Terraces of Ecological Isolation Zones in the Mountain Red Soil Area

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Abstract—**Through a sample survey of the research area of the Yunnan Agricultural University (YAU) Research Base in Malong Jiuxian County, we summarized the types of herbaceous vegetation communities in the terraces of the ecological isolation zone of the area, analyzed the species' importance value, Patrick index, Simpson index, Shannon-wiener index, and Pielou index, and then explored the different patterns (annual and two-years artificial sowing patterns and natural secondary community patterns) under three different slope positions at the top, middle and bottom of the slope. The results indicated that: 1) there were 34 species of vascular plants, 15 families, and 32 genera in the study area, including one family, one genus, and one species of Ferns, and 14 families, 31 genera, and 33 species of Dicotyledons, mainly in the *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart,* and *Fabaceae Lindl.* Among them, 26 species and 11 families of vegetation were at the top of the slope, mainly *Asteraceae Bercht. & J. Presl*; 23 species and 13 families in the middle, with the most significant proportion of *Asteraceae Bercht. & J. Presl*; 30 species and 13 families at the bottom, mainly *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, *Fabaceae Lindl.*, and *Rosaceae Juss*. 2) the species importance value of *Asteraceae Bercht. & J. Presl* was the largest in the study area; *Artemisia*, *Imperata cylindrica (L.) Beauv.*, *Miscanthus Sinensis Anderss.*, *Bidens Pilosa L.*, *Erigeron acris L.*, and *Galium odoratum (L.) Scop.* were the dominant species. 3) low diversity, good stability, and high evenness index of herbaceous vegetation communities planted artificially in one year; the herbaceous community with better species diversity and lower stability and decreased evenness index in the two-year artificial planting than in the one-year artificial planting; one-year natural secondary herbaceous communities with low diversity index and poor richness index; two-year natural secondary herbaceous communities had better diversity and high species richness index, but decreasing evenness. In the configuration of the ecological isolation zone community of the mountain red soil should be paid to select faster-growing species that are not easily replaced by playing the role of ecological isolation.**

Keywords—**mountain red soil area, ecological isolation zone terraces, herbaceous vegetation communities, top of the slope, in the slope, bottom of the slope**

I. Introduction

The mountain red soil on sloping farmland has severe soil erosion [1–3] and degradation [4, 5]. The land consolidation projects in this zone are faced with the problems of disturbing the soil, aggravating soil erosion, destroying the stability of the ecosystem, and lacking ecological landscape construction [6], which seriously restricts the sustainable and efficient development of agriculture and the ecological farmland construction. The concept of "ecological construction of farmland" and "ecological restoration" is essential to solving the problems of farmland ecological landscape construction, biodiversity, and soil and water conservation. Therefore, constructing ecological isolation zone terraces has become this region's primary means of sloping land consolidation.

At present, many scholars from both China and overseas have done a lot of scientific research on the ecological isolation zone, mainly focusing on the anti-erosion performance of the soil [7–10], the nutrient change of the ground [11–14], the soil microbial community [11, 15, 16], the stability of the soil aggregate structure [17–19] and the interception of pollutants [8, 20–23] after the ecological isolation zone. In contrast, there are fewer studies on the response of herbaceous vegetation communities and soils in terraces of ecological isolation zones in the mountain red soil area, and there are no studies and evaluations on the maintenance and monitoring of ecological isolation zones after their installation.

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This study proposes to set up an ecological isolation zone in the mountain red soil area, which reveals the dynamic law between the essential characteristics of herbaceous vegetation and soil factors by exploring the response of herb vegetation community characteristics and soil properties in the ecological isolation zone. Based on the field survey and experiment, this study carries out the correlation between herbaceous plant species composition and soil factors for exploring the interaction and evolution law between vegetation and soil, which supports the scientific construction of ecological isolation zone terraces and biodiversity protection measures. It will be promoted and applied in ecological farmland construction and land remediation projects in the future.

II. METHOD

In this study, through the typical sample plot investigation method, we selected a typical ecological isolation zone terrace in YAU Research Base in the Malong Jiuxian County research area and established a fixed monitoring sample plot. Three grass species, including *Astragalus sinicus L.*, *Medicago sativa L.*, and *Trifolium*, were mixedly sown on the ecological isolation zone in March 2016 on the counter-slope terraces. With PVC pipe and nylon rope in the 72 meters long and 4 meters wide of the sample in 1 m × 1 m, according to the different slopes, the slope position would be in the sample area was divided into the top, the middle, and at the bottom three categories. According to different slopes, set herb samples, and numbered each sample, sample recorded of side slope, slope position and herb species, abundance, coverage, height, and frequency.

Because of the differences in vegetation growth in adjacent years during the succession process, and to protect the vegetation growth in the experimental sample plots, the vegetation selected for this study was mainly the vegetation two years after the ecological isolation zone was set up (2018). The sampling time was August 2018 (peak plant growing season). In mid-August 2018, within each sample square, each species of herbaceous plant was mowed flush by taking the above-ground parts of large, medium, and small plants, putting them into envelopes, marked, brought back to the laboratory, and baked to constant weight at a constant temperature of 75°C for 48 h. We weighed the dry mass on a one-in-ten thousand balance and calculated the biomass.

All data in this study were obtained from field surveys, sampling, laboratory assays, and analyses. Among them, the vegetation survey data were primarily based on field surveys and identification with the cell phone software. EXCEL 2016 was used to organize and analyze the data obtained from the research. SPSS21.0 and R (programming language) vegan package to calculate vegetation dominance and species diversity index. Cluster analysis of herbaceous vegetation diversity used K-means. The study of quantitative relationships among herbaceous vegetation diversity indexes used kernel density and correlation matrix. The drawing was done with Origin10.5.

A. Calculate the Critical Value Index

The important values calculate the important value index according to the relative density, height, and coverage of species in the community [24], to determine the dominant species of the community. Calculated as follows:

Relative coverage (%) = (Total cover of a particular plant species / Sum of all species cover)×100% (1)

Relative height (%) = (Total height of a particular plant species / Sum of all species height)×100% (2)

The important values (%) = (relative coverage + relative height + relative frequency)/3×100% (3)

B. Species Diversity Index

Regarding the species diversity index calculation, three leading indices are used to represent biodiversity: species richness index, species diversity index, and species evenness index [25]. This paper took the calculation formula of species diversity indices using the Patrick index, Simpson index, Shannon-wiener index, and Pielou evenness index [24]. Calculated as follows:

$$\text{Patrick index: } D=S \quad (4)$$

$$\text{Simpson index: } D = 1 - \sum_{i=1}^{s} P_i^2 \quad (5)$$

$$\text{Shannon-wiener index: } Hp = -\sum_{i=1}^{s} P_i \ln P_i \,, \quad P_i = \frac{n_i}{N} \quad (6)$$

$$\text{Pielou evenness index: } J_{sw} = (-\sum p_i \ln p_i) / \ln s \quad (7)$$

where N_i is the number of individuals of species i; N is the number of individuals of all species in the zone; P_i is the relative importance value of species i; S is the number of species in the sample square.

C. Community Similarity Index (CSI)

Used the similarity index to compare the species similarity between planted and natural secondary communities after setting up ecological isolation zones. This paper used the Jaccard index for statistical analysis [26]. Calculated as follows:

$$SC = C/(A+B-C)\times 100\% \quad (8)$$

where S represents the similarity index of two plant communities, A and B respectively represent the total number of species in two different plant communities, and C represents the number of species co-existing in two plant communities [27].

D. Community Stability Index

The community stability index was determined using the M. Godron stability assay. Relative species frequency in the ecological isolation zone was set up for one and two years in artificial sowing and natural secondary community modes. The first was calculating relative frequency according to different plants by arranging them in a small order for accumulation. Then two modes of community species took the reciprocal sum, the accumulated arrangement according to the type of species, made corresponding species relative frequency and the number, the result showed what percentage of species had the how much of a cumulative relative frequency [28]. According to the related data, the scatter plot and trend line were made, and the intersection point between the line $y=100-x$ and the trend line was obtained. M. Gordon believed that when the intersection point of the two lines was (20, 80), the community structure was in the most stable state, and the closer the intersection point was to the end (20, 80), the more stable the community was; otherwise, the community stability was worse.

III. Results

A. Species Composition and Essential Characteristics

A total of 34 species of Vascular plants, 15 families and 32 genera, were found through the survey, including one family, one genus, and one species of Ferns, and 14 families, 31 genera, and 33 species of Dicotyledons. Dominated the vegetation in the study area by *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, and *Fabaceae Lindl.*, whose species accounted for 53.0% of the total plant species, occupying a dominant position. The central plants of the *Asteraceae Bercht. & J. Presl* family that appeared are *Artemisia*, *Bidens Pilosa L.*, *Erigeron acris L.*, *Senecio scandens Buch.-Ham. ex D. Don*. The significant plants of the *Asteraceae Bercht. & J. Presl* family were *Imperata cylindrica (L.) Beauv.*, *Miscanthus Sinensis Anderss.*, *Arthraxon hispidus (Trin.) Makino*. It was noteworthy that *Astragalus sinicus L.* sown in the ecological isolation zone does not appear in this survey. *Medicago sativa L.* appeared in small amounts, only in 13 sample plots. The *Galium odoratum (L.) Scop.* occurred in more than 50% of the sample plots, which might be because *Astragalus sinicus L.* is unsuitable for local growth and gradually disappeared in the surveyed sample plots after two years of vegetation succession.

Comparing the characteristics and evolution of herbaceous vegetation under two planting methods (ecological isolation zone and common field ridge) in different years clarified the herbaceous vegetation characteristics and its evolution process under other planting methods. It revealed the differences between different planting patterns. Herbaceous species composition in the ecological isolation zone was divided into three communities according to the species' importance value and the number of occurrences (Table I).

According to the survey of herbaceous vegetation in the ecological isolation zone, the distribution of different species of vegetation in different slope positions differed. There were 26 vegetation species on the top of the slope, with 11 families. The main species that appeared are *Artemisia*, *Imperata cylindrica (L.) Beauv.*, *Miscanthus Sinensis Anderss.*, *Bidens pilosa L.*, *Erigeron acris L.*, *Galium odoratum (L.) Scop.*, and the most dominant vegetation species on the top of the slope was *Asteraceae Bercht. & J. Presl*, followed by *Poaceae Barnhart*. There were 23 herbaceous vegetation species with 13 families in the middle of the slope. The main species were *Artemisia*, *Imperata cylindrica (L.) Beauv.*, *Bidens pilosa L.*, *Miscanthus Sinensis Anderss.*, *Galium odoratum (L.) Scop.*, and *Arthraxon hispidus (Trin.) Makino*. Among them were *Asteraceae Bercht. & J. Presl* accounted for the most significant proportion, followed by *Poaceae Barnhart* and *Fabaceae Lindl*. At the bottom of the slope were 30 species of herbaceous vegetation with 13 families. The main species were *Imperata cylindrica (L.) Beauv.*, *Artemisia*, *Galium odoratum (L.) Scop.*, *Centella asiatica (L.) Urban*, *Arthraxon hispidus (Trin.) Makino*, *Erigeron acris L.*, mainly *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, *Fabaceae Lindl.*, and *Rosaceae Juss*. Thus, the minor variety of herbaceous vegetation and the lowest vegetation cover occurred in the middle of the slope.

TABLE I. Species Composition of Herbaceous Vegetation Community in the Ecological Isolation Zone

Position	Gradient	Community	Importance value of the top 5 species
The top	27 to 37	1. *Artemisia + Imperata cylindrica (L.) Beauv.+ Miscanthus Sinensis Anderss.*	*Artemisia + Imperata cylindrica (L.) Beauv.+ Miscanthus Sinensis Anderss.+ Bidens pilosa L. + Erigeron acris L.*
In the middle of the slope	13 to 25	2. *Artemisia + Imperata cylindrica (L.) Beauv.+ Bidens pilosa L.*	*Artemisia + Imperata cylindrica (L.) Beauv.+ Bidens pilosa L.+ Miscanthus Sinensis Anderss.+ Galium odoratum (L.) Scop.*
bottom	3 to15	3. *Imperata cylindrica (L.) Beauv. + Artemisia + Galium odoratum (L.) Scop.*	*Imperata cylindrica (L.) Beauv.+ Artemisia + Galium odoratum (L.) Scop.+ Centella asiatica (L.) Urban + Arthraxon hispidus (Trin.) Makino*

B. Important Value Characteristics of Herbaceous Vegetation Species in the Ecological Isolation Zone

The important value of plants is an essential indicator for judging the status and dominance of plants in the community [29]. It can see from Fig. 1 that the important values of the widespread species in the study area varied widely. Among them the species' importance value of *Asteraceae Bercht. & J. Presl* was the largest as a whole, and the species *Artemisia* had the highest importance value in the study area, with its importance value of 35.735. The species importance values of *Bidens Pilosa L.* and *Erigeron acris L.* were 6.156 and 3.987. The species importance value of *Poaceae Barnhart* was as follows, *Imperata cylindrica (L.) Beauv.* and *Miscanthus Sinensis Anderss.*'s importance values were 15.981 and 12.276. *Rubiaceae Juss.*, *Rosaceae Juss.*, and *Fabaceae Lindl.* all had lower species importance values. The important value of *Galium odoratum (L.) Scop.*, a species of *Rubiaceae Juss.*, was 5.71. The important values of *Botrychiaceae*, *Boraginaceae Juss.*, *Amaranthaceae Juss.*, and *Lamiaceae*

Martinov were less than 1. It could see that *Artemisia*, *Imperata cylindrica (L.) Beauv.*, *Miscanthus Sinensis Anderss.*, *Bidens pilosa L.*, *Erigeron acris L.*, and *Galium odoratum (L.) Scop.* were the dominant species in this study area.

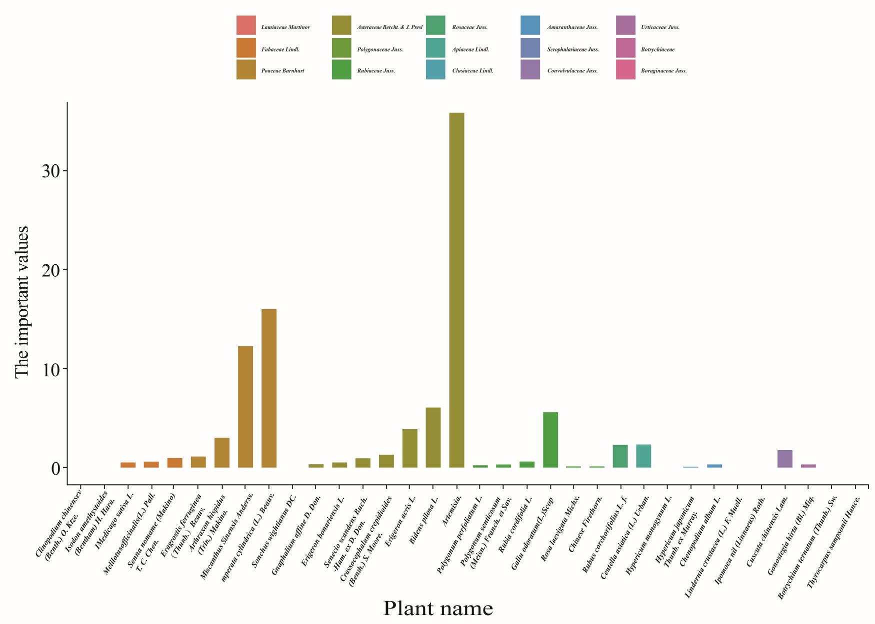

Figure 1. Distribution of plant species important values in the study area.

C. *Characteristics of Herbaceous Communities in Ecological Isolation Zones under Different Patterns*

We researched the herbaceous condition in ecological isolation zones under two patterns: artificially sown grass seed and natural secondary growth. Twenty-three species and ten families of herbaceous vegetation were found in the 2016 survey, including seven species and five families of herbaceous vegetation of natural secondary vegetation. In 2018, 34 species and 15 families of herbaceous vegetation were found. Among them were 11 species and five families of natural secondary vegetation. The natural secondary vegetation in 2018 added four new invasive species: *Trifolium*, *Erigeron acris L.*, *Eragrostis ferruginea (Thunb.) Beauv.*, and *Senecio scandens Buch.-Ham. ex D. Don*.

As shown in Table II and Fig. 2, the diversity of the herbaceous vegetation community of the artificial planting in one year was low at 0.746, and the stability of the community was better. In the first year, grass seeds were first sown with a high species evenness index of 0.621 and few native invasive species. The diversity of the herbaceous vegetation community of the artificial planting in two years was better at 0.851, and the number of invasive species increased. Compared with the one-year artificially planted herbaceous vegetation community, the stability was worse, and the species evenness index dropped to 0.591. The native invasive species of *Imperata cylindrica (L.) Beauv.*, *Miscanthus Sinensis Anderss.*, *Artemisia*, and *Bidens pilosa L.* occupied a large number of resources, with high coverage of 65% and a community similarity of 67.64%. The one-year natural secondary herbaceous community diversity index and species richness index were low, 0.812 and 2.878. The natural secondary vegetation was mostly native dominant species before land consolidation. Most of them were annual herbaceous vegetation, with a fast recovery rate and a community similarity of 43.75%. The second-year natural secondary herbaceous community, with a better diversity of 0.848 and a high species richness index of 3.625, indicated that new species were constantly invading. The herbaceous vegetation community was enriching, but the species evenness index had decreased, indicating that despite the invasion of new species, the native herbaceous vegetation still occupied a dominant position and the latest invasive species were in an inferior competitive place with a community similarity of 47.82%. The similarity increased.

TABLE II. CHANGES IN THE OVERALL CHARACTERISTIC INDICATORS OF ECOLOGICAL ISOLATION ZONE COMMUNITIES OF DIFFERENT MODES IN DIFFERENT YEARS

Indicators	Plant herbaceous communities for a year	Artificial planting herbaceous community for two years	Annual natural secondary community	Natural secondary community in 2000
Community species diversity index	0.746	0.851	0.812	0.848
Community species richness index	3.124	3.603	2.878	3.625
Community species evenness index	0.621	0.591	0.539	0.471
Similar to the one-year community	1	67.64%	43.75%	47.82%
Community stability index	(19, 80)	(16, 85)	(37, 61)	(33, 68)

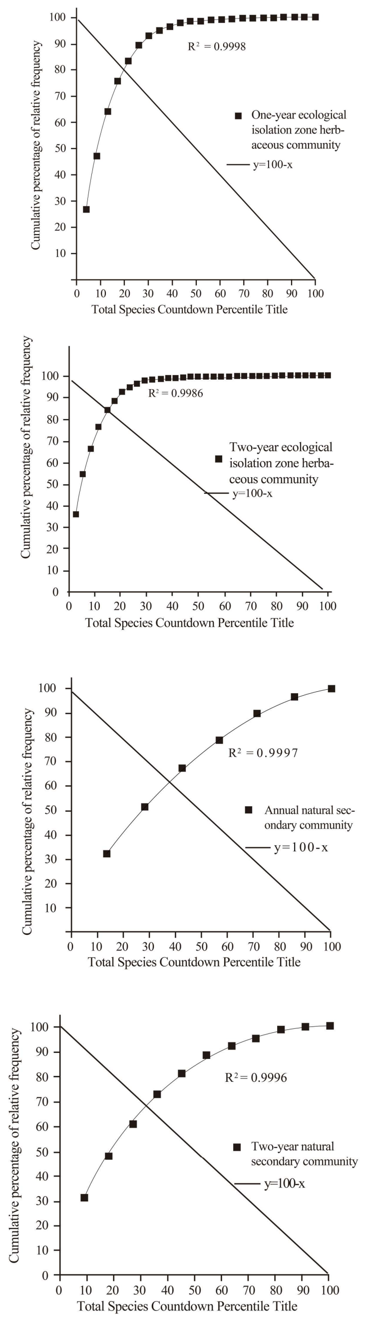

Figure 2. Diagram of the stability of each community.

Overall, new invasive species were more numerous in planted and natural secondary herbaceous communities. Since the ecological isolation zone was built after land consolidation, most invasive species were typical local herbaceous vegetation such as *Artemisia*, *Erigeron acris L.*, *Miscanthus Sinensis Anderss.*, *Imperata cylindrica (L.) Beauv.*, and *Rubus corchorifolius L. f.* The high setting time of the ecological isolation zone and the continuous strengthening of the competitive effect among species gradually enriched the herbaceous vegetation communities in species. However, the artificially planted vegetation species and the natural secondary herbaceous vegetation communities had a high degree of species similarity because there was no artificial intervention for growth after the artificial sowing of grass seed.

IV. Discussions

A. *Analysis of Dominant Species of Herbaceous Vegetation Communities in Ecological Isolation Zones*

Based on the analysis of the above results, the characteristics of herbaceous vegetation in the ecological isolation zone had the following changes. After passing the land consolidation and other projects in 2016, set up an ecological isolation zone and three kinds of herbaceous vegetation, including *Astragalus sinicus L.*, *Medicago sativa L.*, and *Trifolium*, were mixed and sown in March 2016. The one-year ecological isolation zone was invaded by annual growth, mainly including *Imperata cylindrica (L.) Beauv.* and *Miscanthus Sinensis Anderss.* of the *Poaceae Barnhart*; *Artemisia*, *Bidens pilosa L.*, and *Erigeron acris L.* of the *Asteraceae Bercht. & J. Presl*; *Amaranthus spinosus L.*, *Rubus corchorifolius L. f.*, *Melilotusofficinalis (L.) Pall.*, *Cuscuta chinensis Lam.*, *Cynodon dactylon (L.) Pers.*, *Selaginella uncinata*, and *Chinese Firethorn* of the other species. The originally sown *Astragalus sinicus L.* and *Medicago sativa L.* proportions were relatively small, and the *Trifolium* was growing better. More invasive annual herbaceous and perennial vegetation appeared in the ecological isolation zone during the two years. A total of 10 new invasive herbaceous vegetation species emerged, among which there were mainly *Senna nomame (Makino) T. C. Chen*, *Polygonum perfoliatum L.*, *Gonostegia hirta (Bl.) Miq.*, *Ipomoea nil (Linnaeus) Roth*, *Hypericum monogynum L.*, *Eragrostis ferruginea (Thunb.) Beauv.*, and so on. Two years after the ecological isolation zone was built, *Imperata cylindrica (L.) Beauv.* and *Miscanthus Sinensis Anderss.* of the *Poaceae Barnhart* and *Bidens pilosa L.* of the *Asteraceae Bercht. & J. Presl* gradually became the dominant population, and the species richness increased significantly. At the same time, the distribution of vegetation species differed according to the slope position. As the ecological isolation zone grew over time, local invasive species became more and more dominant. The previously artificially sown *Astragalus sinicus L.* gradually disappeared in the ecological isolation zone during the two years. *Medicago sativa L.* only appeared in 11 sample plots, and *Trifolium* was mainly found in the sample plots in the middle and bottom of the slope.

The vegetation survey showed 23 species and ten families of herbaceous vegetation species in the ecological isolation zone of the experimental area in August 2017, among which were mainly *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, *Rosaceae Juss.*, and *Fabaceae Lindl.* There were ten species of *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, and *Fabaceae Lindl.*, accounting for 43% of the species in the entire herbaceous community. A total of 33 species and 15 families of herbaceous vegetation occurred in the ecological isolation zone of the experimental area in August 2018, mainly *Asteraceae Bercht. & J. Presl*, *Poaceae Barnhart*, *Rosaceae Juss.*, and *Fabaceae Lindl.* accounted for 54.5% of the entire community species. The species richness of vegetation in the ecological isolation zone gradually increased in two years, and species of *Asteraceae Bercht. & J. Presl* and

Poaceae Barnhart accounted for the most significant proportion of the community in the whole experimental area. *Astragalus sinicus L.* and *Medicago sativa L.* gradually decreased with the invasion of local herbaceous species, indicating the local invasive *Asteraceae Bercht. & J. Presl* and *Poaceae Barnhart* played a more significant role in the experimental area's ecological isolation zone setting process. They occupied a vital position in the flora of the region.

B. *Analysis of Species Diversity under Microtopography in the Ecological Isolation Zone*

Inconsistent changes in diversity indices of grassland communities on different slope positions. There were some differences in the four diversity indices at different slope positions. Still, there was no apparent regularity of fluctuations (Fig. 3). The field survey found noticeable differences in vegetation growth on different slopes. The Patrick richness index had clear differences in a "√" shape trend. There were minor vegetation types in the middle of the slope. The widest variety of vegetation was at the bottom of the slope, with good growing conditions and the highest vegetation cover. The species of vegetation at the top of the slope was higher, and the coverage was not as high as in the middle. Low species richness, diversity index, and low biomass dominance appeared in the slope in the middle of the slope.

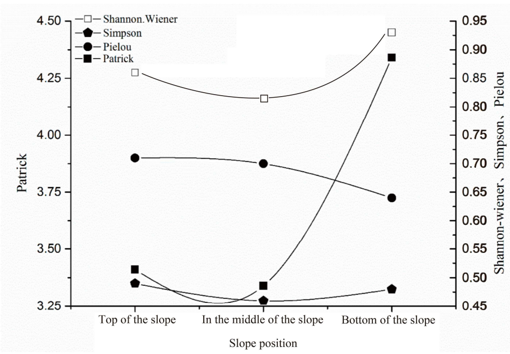

Figure 3. Variation diagram of herbaceous diversity index curve at different slope positions.

Shannon-Wiener index in the study area was at the bottom of the slope (0.928) > on the top (0.858) > in the middle (0.820), with an average value of 0.87, a variation coefficient of 6.40%. There was a gradual upward trend from the top to the bottom of the slope. The maximum value was at the bottom of the slope. It might be that the bottom was considered less disturbed and had more water retention. The top slope was closest to the field surface, with more species. The minimum value was in the middle of the slope, and the dominant species in the middle was the *Bidens pilosa L.*, who liked to grow in warm and humid areas. The root system was developed and had a solid ability to absorb soil water and nutrients. When the *Bidens pilosa L.* grew, it would seize the resources of other species, making it difficult for other species to grow in the slope, so the Shannon-Wiener index in the slope was low. The distribution range of the Pielou index in the study area was 0.64–0.74, with an average value of 0.64 and a coefficient of variation of 7.26%. The changing trend from the top to the bottom of the slope was not evident. The Simpson index did not change significantly, with an average value of 0.48 and a coefficient of variation of 2.08%.

Community species composition is an essential indicator of changes in community structure and is one of a community's fundamental characteristics [30]. Differences in ecological factors (illumination, temperature, soil nutrients, and water) in grassland communities under microtopographic conditions affect the distribution patterns of species and community types. The resources that vary significantly from the top to the bottom of the slope are mainly light and water. The different environmental resources and environmental heterogeneity are one of the main reasons for the differences in community distribution patterns. The top slope in the study area was dominated by light-loving and drought-tolerant crops such as *Artemisia*, *Imperata cylindrica (L.) Beauv.*, and *Miscanthus Sinensis Anderss*. There were 26 species of herbaceous vegetation. The middle of the slope was dominated by a mixture of light-loving, drought-tolerant, and moist-loving crops such as *Artemisia*, *Imperata cylindrica (L.) Beauv.*, *Bidens pilosa L.*, *Miscanthus Sinensis Anderss.*, and *Erigeron acris L.*, with 23 species of herbaceous vegetation. The bottom was dominated by shade-loving species such as *Imperata cylindrica (L.) Beauv.*, *Artemisia*, *Galium odoratum (L.) Scop.*, *Centella asiatica (L.) Urban*, and *Arthraxon hispidus (Trin.) Makino*, 30 species of herbaceous vegetation. The plant species at the bottom of the slope were more abundant than those in the middle and top. The reason was the soil moisture and nutrient conditions at the bottom of the slope were better, which was suitable for the survival and growth of more plant species. The soil in the middle of the slope easily washed to the bottom, and nutrients were lost with water and soil, so the biodiversity in the middle was the lowest. Because the top part of the slope was closer to the field surface, and the soil moisture and nutrient content of the field surface were higher, the top had higher biodiversity than the middle. The micro-topographic factor changed the soil properties of the topsoil through the fluctuation of the ground and rainfall scouring, thus could form evident habitat heterogeneity in a tiny area, which provided an essential mechanism for the formation and succession of species diversity in grassland communities on a regional scale. In this study, the Pielou evenness index and Patrick richness index of the community showed increasing trends from the top to the bottom of the slope. Values were the largest at the bottom and the smallest in the middle and generally showed that: bottom > top > middle of the slope. However, the trend of several types of diversity indices was not noticeable, which might be due to the small study area of the ecological isolation zone and the interference of many factors, such as human activities, which led to the slow growth and succession of vegetation.

C. *Kernel Density Curves to Estimate Diversity Characteristics*

Kernel density estimation is a non-parametric method for estimating the probability density function of random variables [31, 32]. It is an effective method to observe the distribution of continuous variables and compare the differences among groups. It is using the sm. density. compare () function in the sm package in R (programming language), it is possible to visualize the shape of the distribution of values contained in different groups and the degree of overlap between other groups.

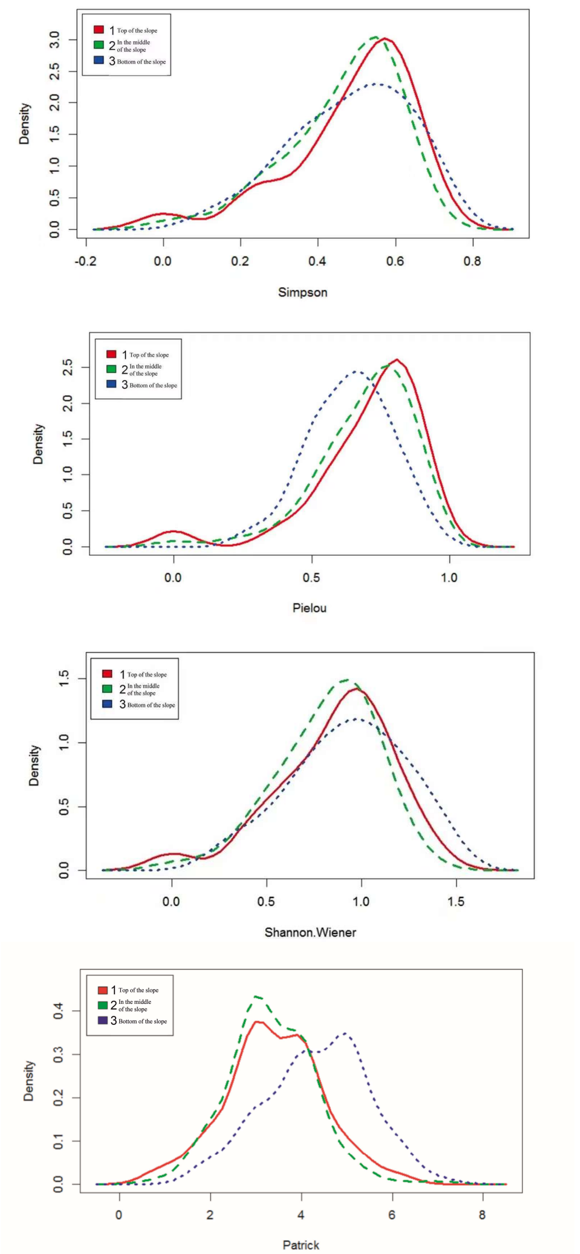

Figure 4. Variation of nuclear density curve of species diversity index at different slopes.

From Fig. 4, the Shannon-Wiener index kernel density curve plots had a relatively uniform distribution of three-level frequencies at three different slope positions: top, middle, and bottom, and the kernel density curves had the highest overlap and were all normally distributed, indicating that the mean and plural of the original data were more similar. However, it could see that the Shannon-Wiener diversity index at the bottom of the slope was higher than that at the bottom and was more frequent than the higher values (> 1.5) at the middle and top. From the Simpson index kernel density curve, the kernel density curves at the top and middle of the slope were highly overlapping, indicating that the original data distribution of the Simpson dominance index was relatively uniform. Still, it could see that the Simpson dominance index at the bottom of the slope was more comprehensive than that at the top and middle, indicating that the distribution of the bottom of the slope was more uniform. The Pielou index kernel density plot was similar to the Simpson index kernel density plot, which overlapped the density curves at the top and the middle of the slope, with the highest value distributed around 0.9. In contrast, the highest value of kernel density distribution at the bottom of the slope appeared at about 0.6, indicating that the average value of Pielou uniformity original data at the bottom of the hill was lower than at the top and bottom. The distribution of the kernel density curve of the Patrick richness index also showed a higher overlap between the top and middle of the slope, and the kernel density curves of the top and middle of the slope showed a left-skewed normal distribution. In contrast, the bottom of the slope showed to the right. The normal uneven distribution indicated that different slope positions significantly influenced the Patrick richness index. Patrick richness index was mainly distributed between three and four at the top and middle of the slope and between four and five at the bottom. The reason for these situations was the different natural factors of different slopes, mainly sunlight and moisture. The southern mountain red soil area was more suitable for the growth of vegetation species that prefer shade and humidity, so the species richness of the bottom of the slope was higher than that of the top and middle of the slope.

V. Conclusion

During the construction of the ecological isolation zone, the diversity of herbaceous plants and shrubs always increases rapidly in the early stage of construction. It reaches a high stage after a period of growth, and then the diversity starts to decline or shows a parabolic trend: y = at2 + bt + c [33]. This phenomenon reflects that the change in population structure is due to the intense interspecific competition in the early stage of community growth. It isn't easy to detect the pattern of the vegetation community in this study for the time being because of its short growth time. From this study area alone, the two-year ecological isolation zone has more prosperous herbaceous vegetation species than the one-year ecological isolation zone. Still, at the same time, two artificially sown species, *Medicago sativa L.* and *Astragalus sinicus L.,* are gradually decreasing, especially *Astragalus sinicus L.*, which has disappeared in the experimental plot. The herbaceous vegetation species of *Asteraceae Bercht. & J. Presl* and *Poaceae Barnhart* increased by 33.33% and 100%, respectively, compared to the one-year ecological isolation zone, which shows that *Poaceae Barnhart* and *Asteraceae Bercht. & J. Presl* are the main dominant species in this study area. Over time, the species of *Asteraceae Bercht. & J. Presl* and *Poaceae Barnhart* will also increase.

Regarding the vegetation diversity index trend, the current ecological diversity index of the ecological isolation zone is rising. Still, according to the research of different scholars, the vegetation diversity will show a trend of rapid increase and then gradually decrease or increase again, mainly because with the succession of vegetation, its community structure changes from single to complex stability gradually increases. When the community diversity rises to a certain level, some faster-growing species will progressively strengthen the competition for soil nutrients and light, replacing slower-growing species. The vegetation diversity index of terraces with ecological isolation zones will still increase, which is a manifestation of the improvement of community structure in the process of vegetation succession after the installation of ecological isolation zones.

This paper takes the mountain red soil as the background. Through quantitative experiments and two years of follow-up monitoring, to study the current situation of the ecological isolation zone for two years from the structural characteristics of the herbaceous vegetation community to provide a theoretical basis and data support for future research on the relationship with the vegetation community and environment, ecological monitoring and evaluation of ecological isolation zone.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Gengjie Zhang and Huiyong Hu conducted the research; Honggang Zheng and Shuxia Liu analyzed the data; Xingmei Huang and Gengjie Zhang wrote the paper. All authors had approved the final version.

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