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Original Research Paper

Biodiversity and Biomass on Abandoned Lands in Loess Plateau in North Shaanxi of China

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ABSTRACT

This paper takes Hejiaou river region as the research object by time-space mutual substitution method to probe biodiversity and biomass of 29 sample abandoned lands. The results show that: (1) Biodiversity of vegetation changes along with the abandoned age of biomass. Simpson index, Shannon-Weiner index, Margalef richness index and Pielou evenness index reach the maximum when the abandoned age is 10 or 11 years. And biomass increases along with the growth of the abandoned age. (2) Biodiversity and biomass of different site types vary from one to another. For Simpson index, sunny slope>cloudy slope>semi-cloudy slope>semi-sunny slope. For Shannon-Weiner index and Pielou evenness index, sunny slope>cloudy slope>semi-sunny slope>semi-cloudy slope. For Margalef richness index, semi-sunny slope>semi-cloudy slope>cloudy slope>sunny slope. For biomass, cloudy slope>semi-cloudy slope>sunny slope>semi-sunny slope. The difference among Simpson index, Margalef richness index and Pielou evenness index is not apparent in terms of site type. But sunny slope and semi-cloudy slope of Shannon-Weiner index are distinguished from each other ($p<0.05$). And there is a great difference among biomass of four site types ($p<0.05$). (3) Simpson index, Shannon-Weiner index, Margalef richness index and Pielou evenness index have no linear correlation with biomass, indicating that biodiversity and biomass are not correlated.

INTRODUCTION

Species biodiversity is one of the important features of biotic community. It is fundamental to the operation and maintenance of the biosystem and provides basic support. Species biodiversity is defined as the richness of the species within a region. It is a common indicator of regional diversity and indicates the structural feature (Nagaraja et al. 2005), succession stage (Chapin et al. 1998), organization level (Lawton 1994), stability (Whittaker 1972) and difference of habitats (Loucks 1970) of the biotic community. Biomass is the total dry matter accumulated during a period in a biotic community. It is the best indicator to measure the productivity and gives testimony to the function of the biotic community. Biomass can directly reflect the growth condition of vegetation and changes of environment (Trenbath 1974). Therefore, species biodiversity and biomass come to be hot issues in recent years. There has been some coverage about the relationship of the two. Nagaraja and some others studied species diversity and composition in logged and unlogged rainforest of Kudremukh National Park, South India (Nagaraja et al. 2005). Marañón and García studied on species biodiversity and biomass of plant communities (Marañón & García 1997). Naeem and some others did research on species biodiversity and plant productivity in a model assemblage of plant species (Naeem et al. 1996). Tilman and his partners discussed productivity and sustainability influenced by species biodiversity in grassland ecosystems (Tilman et al. 1996). Shang Zhanhuan and some others probed into the relationship between the species diversity and the productivity of plant communities in the arid mountainous regions (Shang et al. 2005). Peng Shao-ling and his partners studied the correlation between productivity and species biodiversity (Peng & Huang 2000). There is no dearth of researches on different vegetation organizational scales (Wei et al. 2011), herbaceous species under artificial forests (Gao et al. 2011) and different vegetation restoration patterns (Zhang & Liu 2010, Zhang et al. 2011). But there lacks researches on species biodiversity and biomass of shrub and grass communities in abandoned lands in loess plateau in North Shaanxi of China.

Loess plateau's ecosystem in North Shaanxi is fragile and remains the key area to protect species biodiversity and function the ecosystem. By time-space mutual substitution method, this paper introduces the constitution of species in the biotic community, biodiversity and biomass of different abandoned ages and different site types as well as the relationship between the two in an all-round way, so as to better understand the biodiversity, biomass, their relationships and the succession feature. It intends to provide support to policies for vegetation restoration, ecosystem governance and improvement.

OVERVIEW OF THE STUDY AREA

The research region is located in the north latitude 36°33' 33"-37°24'27" and east longitude 107°38'57"-108°32'49", Hejiagou river region in Wuqi County. It is 1233-1890m above the sea with the temperature averaging 7.8°C, the sunshine averaging 2400 hours, frostless period of 96-146days, annual rainfall averaging 478.3mm and annual evaporation averaging 400-450mm. There is much rain in July, August and September, taking up 60%-80% of total rainfall. There is plenty of yellow loessal soil (Bo et al. 2014a). The shrub and grass community is dominant with *Salsola*, *Artemisia scoparia*, *Sonchus oleraceus*, *Setaria viridis*, *Artemisia giralaii*, *Heteropappus altaicus*, *Stipa bungeana*, *Lespideza davurica*, *Potentilla chinensis*, *Bothriochloa ischaemun*, *Poa sphondylodesclon* and *Buddleja alternifolia*, etc. The shrub and grass community is easy to find in gully regions. Shrubs and arbors can be seen in the valleys (Bo et al. 2014b).

RESEARCH METHODOLOGIES

Sampling Plot and Investigation Method

In July, 2012, we investigated 291 samples in 29 sampling plots with plant communities of different abandoned ages as the research objects. We took 10 samples from each sampling plot. Grass sample is 1m × 1m in size and shrub sample is 5m × 5m in size. We have recorded longitude, latitude and height above the sea, age, gradient of slope, aspect, slope position, microtopography, soil type, numbers, coverage, height, frequency, abundance, biomass, community type and tree number (Table 1).

Data Processing

Measure of species biodiversity: Species biodiversity in the biotic community refers to the number of species and the number of individuals of each species. Richness means the number of species in the biotic community while evenness means the number of individuals and their distribution. There are several formulae for measuring biodiversity (Ma & Liu 1994) and this research adopts Margalef richness index R, Simpson index D, Shannon-Wiener index H, and Pielou evenness index E. The formulae are as follows (Whittaker 1972).

$$R = \frac{s-1}{\ln n} \quad ...(1)$$

$$D = 1 - \sum_{i=1}^{s} P_i^2 \quad ...(2)$$

$$H = -\sum_{i=1}^{s} (P_i \ln P_i) \quad ...(3)$$

$$E = \frac{-\sum_{i=1}^{s} (P_i \ln P_i)}{\ln s} \quad ...(4)$$

In the formula, s refers to the total number of species. P_1, P_i..., Ps refer to the ratio abundance of samples consisting of s species. The range of i is from 1 to s.

Measurement of biomass: This research adopts all-yield method to calculate the biomass of the grass. Specifically speaking, we collect all vegetation in the sampling plots and take them to the lab for drying (60°C, 24h) until there is no change in weight and calculate biomass by its weight.

Calculation of coefficient of variation: Coefficient of variation C_v and standard deviation SD are calculated as follows:

$$C_v = \frac{SD}{\overline{x}} \quad ...(5)$$

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})} \quad ...(6)$$

$\overline{x}$ is the average of sample, n is the number of total samples, X_i is no. i observed value.

RESULTS AND ANALYSIS

Structural feature of species in the community: In 29 sampling plots, there are 41 species attached to 13 families and 33 genera. Twenty seven species belong to 19 genera of Poaceae, Leguminosae and Compositae. These species take up 65.85% of total species and 57.58% of total families, indicating the importance the three families in the shrub and grass community. The rest of the species take up 34.15% of the total amount and belong to 10 families, including Chenopodiaceae, sedge family, Loganiaceae, Rosaceae, Labiatae, Umbelliferae, Cruciferae, Polygalaceae, Papilionaceae and Convolvulaceae.

From Table 1, we can see that in early days of abandoned lands, Therophyte such as *Salsola* and *Artemisia scoparia* of Chenopodiaceae family take the dominant po-

Table 1: Basic status of the study plots.

No.	Abandoned ages (Yr)	Aspect	Gradient of slope	Slope position	Altitude (m)	Community type
1	2	Sunny slope	5	Uphill	1588	*Salsola collina + Sonchus oleraceus*
2	3	Sunny slope	20	Uphill	1572	*Artemisia scoparia*
3	3	Semi-cloudy slope	11	Uphill	1569	*Artemisia scoparia*
4	3	Semi-cloudy slope	15	Downhill	1554	*Artemisia scoparia*
5	4	Cloudy slope	19	Uphill	1547	*Artemisia scoparia*
6	4	Semi-cloudy slope	12	Medium hill	1485	*Artemisia scoparia + Setaria viridis*
7	5	Cloudy slope	18	Medium hill	1490	*Artemisia scoparia + Heteropappus altaicus*
8	5	Cloudy slope	24	Medium hill	1551	*Artemisia scoparia + Lespideza davurica*
9	6	Cloudy slope	24	Uphill	1572	*Lespideza davurica + Heteropappus altaicus*
10	6	Semi-cloudy slope	27	Uphill	1575	*Lespideza davurica + Potentilla chinensis*
11	7	Semi-cloudy slope	19	Uphill	1525	*Lespideza davurica + Potentilla chinensis*
12	7	Semi-cloudy slope	18	Uphill	1518	*Lespideza davurica + Potentilla chinensis*
13	8	Semi-cloudy slope	23	Uphill	1522	*Lespideza davurica + Artemisia vestita*
14	8	Semi-sunny slope	20	Downhill	1498	*Lespideza davurica + Artemisia vestita*
15	10	Sunny slope	26	Uphill	1559	*Artemisia vestita + Leymus secalinus*
16	11	Semi-sunny slope	24	Uphill	1565	*Artemisia vestita + Artemisia giralaii*
17	11	Semi-cloudy slope	25	Uphill	1575	*Artemisia vestita + Artemisia giralaii*
18	12	Cloudy slope	30	Uphill	1581	*Artemisia vestita + Artemisia giralaii*
19	12	Cloudy slope	25	Medium hill	1579	*Artemisia vestita + Artemisia giralaii*
20	13	Semi-cloudy slope	31	Downhill	1510	*Artemisia vestita + Artemisia giralaii*
21	13	Semi-cloudy slope	26	Medium hill	1515	*Artemisia vestita + Artemisia giralaii*
22	14	Semi-sunny slope	25	Uphill	1531	*Artemisia vestita + Artemisia giralaii*
23	14	Semi-sunny slope	27	Medium hill	1510	*Artemisia vestita + Stipa bungeana*
24	17	Cloudy slope	26	Medium hill	1560	*Artemisia vestita + Stipa bungeana*
25	19	Semi-cloudy slope	28	Uphill	1546	*Bothriochloa ischaemun + Artemisia vestita*
26	22	Cloudy slope	30	Uphill	1556	*Bothriochloa ischaemun + Artemisia vestita*
27	29	Semi-cloudy slope	25	Downhill	1549	*Bothriochloa ischaemun + Poa sphondylodes*
28	40	Semi-sunny slope	30	Medium hill	1513	*Buddleja alternifolia*
29	43	Semi-cloudy slope	35	Medium hill	1510	*Buddleja alternifolia*

sition in the community. The rest are *Sonchus oleraceus*, *Setaria viridis*, *Heteropappus altaicus*, *Lespideza davurica*, etc. The source of Propagules and their numbers determine how long the succession stage will last which is usually 2 to 5 years. As the succession carries on, soil and other conditions start to change, other species invade, grass of Chenopodiaceae family begin to disappear. As a result, perennials such as *Lespideza davurica* become the main species and forms the community, and other species are *Potentilla chinensis*, *Artemisia gmelinii* and *Heteropappus altaicus*. This stage usually lasts 6 to 8 years.

When the abandoned age turns to 10 to 17 years, *Artemisia gmelinii* becomes dominant with *Aneurolepidium dasystachys*, *Artemisia giralaii*, *Stipa bungeana* being the majority. After 19 to 29 years, *Bothriochloa ischaemun* becomes dominant with *Artemisia gmelinii* and *Poa sphondylodesclon* being the majority. After 40 to 43 years, *Buddleja alternifolia* becomes the dominant with other perennial such as *Bothriochloa ischaemun*. This is the last succession stage. Several species appear repeatedly in different abandoned ages and show the strong succession among communities, indicating that the succession rate is relatively slow.

Species biodiversity and biomass of different abandoned ages: From Figs. 1 to 5, we can see that species diversity index changes along with the abandoned age of biomass, among which Simpson index and Shannon-Weiner index show similar changing trend (Figs. 1 and 2) while Margalef richness index and Pielou evenness index show similar changing trend (Figs. 3 and 4). But the changing trend of biomass varies from Simpson index, Shannon-Weiner index, Margalef richness index and Pielou evenness index (Fig. 5). The changing trend of Simpson index and Shannon-Weiner index along with the abandoned age is from high to low to high to stable (Figs. 1 and 2) while that of Margalef richness index and Pielou evenness index is from low to high to low (Figs. 3 and 4). The changing trend of biomass along with the abandoned age is from low to high (Fig. 5).

From Figs. 1 and 2, we can see that in the second year of abandoned age, Simpson index and Shannon-Weiner index are relatively high, of 0.86 and 2.19 respectively. In the third year, they drop to 0.49 and 1.34. With the increase of abandoned age, these two indices rise and reach the maximum in the 11th year, of 0.88 and 2.25 respectively. In the 17th

year, they become stable.

From Figs. 3 and 4, we can see that in early days of abandoned ages, the Margalef richness index and Pielou evenness index are low, of 0.95 (in the 5th year) and 0.26 (in the 3rd year) respectively. In the 10th or 11th year, these two indexes reach the maximum, that is 1.58 (in the 10th year) and 0.58 (in the 11th year) respectively. After that, they lower somewhat. After 40 years in the shrub stage, Margalef index is at its lowest (0.91) and Pielou evenness index is a little higher than that in early days.

From Fig. 5, we can see that biomass increases along with the abandoned ages, which means that the biomass reaches the maximum when the succession reaches the shrub stage. This indicates that Simpson index, Shannon-Weiner index, Margalef richness index, Pielou evenness index and biomass have variation features along with the abandoned ages.

Species biodiversity and biomass of different site types: Figs. 6 to 10 are species diversity and biomass of different site types. From Fig. 6, the gap of Simpson index of different site types is not obvious. Simpson index sits from 0.49 to 0.88, averaging 0.75. The coefficient of variation is 10.99%. For Simpson index, sunny slope (0.83)>cloudy slope (0.76)>semi-cloudy slope (0.74)>semi-sunny slope (0.72).

From Fig. 7, the gap of Shannon-Weiner of different site types is obvious. Sunny slope (2.12) and semi-cloudy slope (1.75) have obvious difference ($p<0.05$). Shannon-Weiner index sits from 1.34 to 3.35, averaging 1.83. The coefficient of variation is 14.16%. For Shannon-Weiner index, sunny slope (2.12)>cloudy slope (1.88)>semi- sunny slope (1.78)>semi-cloudy slope (1.75).

From Fig. 8, the gap of Margalef richness index of different site types is obvious. Margalef index sits from 0.91 to 1.58, averaging 1.34. The coefficient of variation is 15.06%. For Margalef richness index, semi-sunny slope (1.38)>semi-cloudy slope (1.35)>cloudy slope (1.34)>sunny slope (1.20).

From Fig. 9, the gap of Pielou evenness index of different site types is not obvious. Pielou evenness sits from 0.241 to 0.58, averaging 0.45. The coefficient of variation is 22.47%. For Pielou evenness index, sunny slope (0.52) >cloudy slope (0.48)>semi-sunny slope (0.43)>semi-cloudy slope (0.41).

From Fig. 10, the gap of biomass of different site types is obvious. Sunny slope (95.13), cloudy slope (165.62), semi-cloudy slope (162.31) and semi-sunny slope (159.90) have obvious difference ($p<0.05$). Biomass sits from 54.41 to 277.42, averaging 155.78. The coefficient of variation is 22.80%. For biomass, cloudy slope (165.62)>semi-cloudy slope (162.31)>semi-sunny slope (159.90)>sunny slope (95.13).

Species biodiversity and biomass of different site types: From Fig. 11 to 14, we can see that the relationship between biomass and Simpson index, Shannon-Weiner index, Margalef richness index and Pielou evenness index. These entire four indexes are proved to be unrelated to biomass in loess plateau in North Shaanxi.

DISCUSSION AND CONCLUSION

In 29 sampling plots, there are 41 species attached to 13 families and 33 genera. Twenty seven species belong to 19 genera of Poaceae, Leguminosae and Compositae. Several species belong to the same family, and some species belong to more than two families. Most species belong to one genus. These are corresponding with the results of Kou et al. (2013) and Qin et al. (2008). Several species appear repeatedly in different abandoned ages and show the strong succession among communities, indicating that the succession rate is relatively slow. Thus, it is necessary to re-grass species in later stage of succession to shorten the succession time and accelerate the restoration of the abandoned lands, which will help with the water and soil erosion in North Shaanxi.

In the analysis of species biodiversity and biomass of different abandoned ages, Simpson index, Shannon-Weiner index, Margalef richness index and Pielou evenness index increase first and decrease later along with the abandoned ages. This is in accordance with the results of Loucks (1970) and Auclair & Goff (1971). But biomass increases along with the abandoned ages, indicating that the vegetation productivity becomes greater and greater, and the plant community tends to be stable. Our research results show that Simpson index, Shannon-Weiner index, Margalef richness index, Pielou evenness index and biomass have variation features along with the abandoned ages. This is significant to improve the eco-environment and increase the stability and productivity of the ecosystem.

In the analysis of species biodiversity and biomass of different site types, Simpson index, Margalef richness index and biomass have shown different changing trends while Shannon-Weiner index and Pielou evenness index have similar trends, which is sunny slope>cloudy slope>semi-sunny slope> semi-cloudy slope. But the gap between Shannon-Weiner index and biomass of different site types is obvious ($p<0.05$). This is mainly because there are different species in different sampling plots, and their growth condition, biomass, coverage vary from each other. Besides, due to different microtopography, a combination of factors

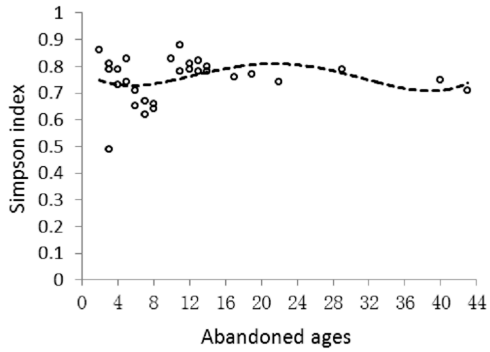

Fig. 1: The changing trend of Simpson index along with different abandoned ages.

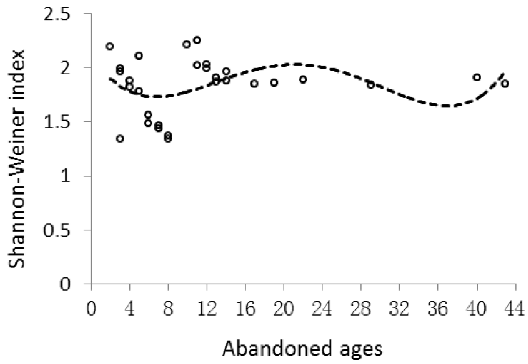

Fig. 2: The changing trend of Shannon-Weiner index along with different abandoned ages.

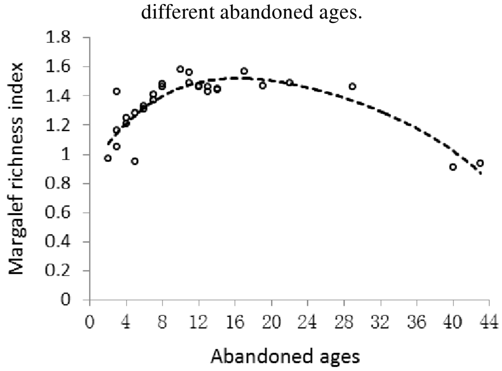

Fig. 3: The changing trend of Margalef richness index along with different abandoned ages.

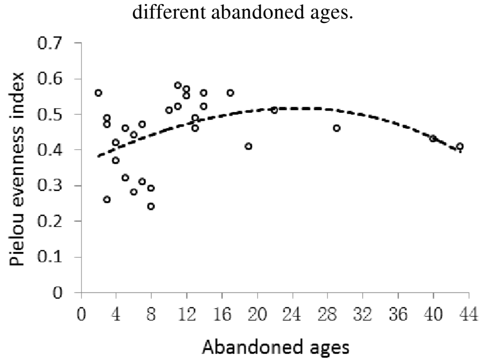

Fig. 4: The changing trend of Pielou evenness index along with different abandoned ages.

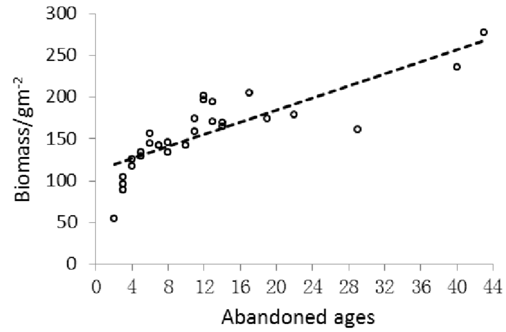

Fig. 5: The changing trend of biomass along with different abandoned ages.

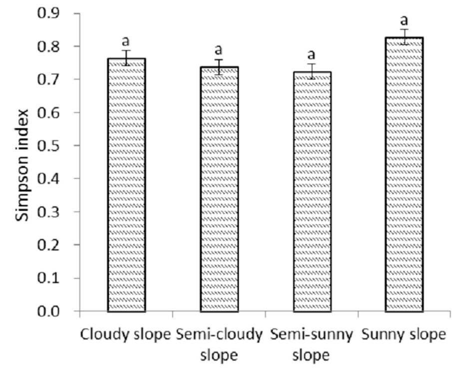

Fig. 6: Simpson index of different site types.

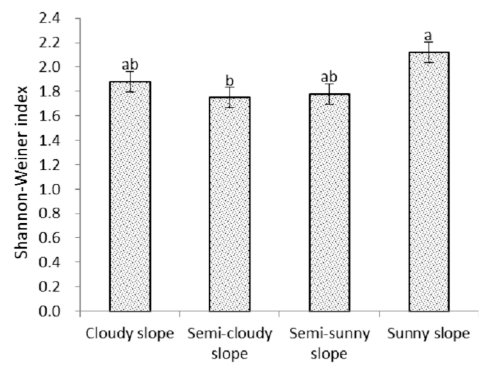

Fig. 7: Shannon-Weiner index of different site types.

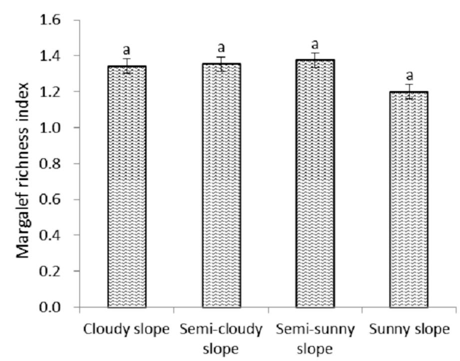

Fig. 8: Margalef richness index of different site types.

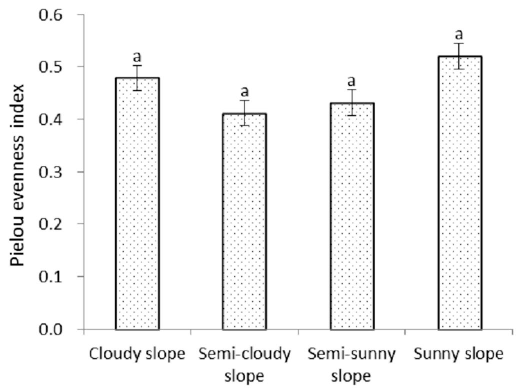

Fig. 9: Pielou evenness index of different site types.

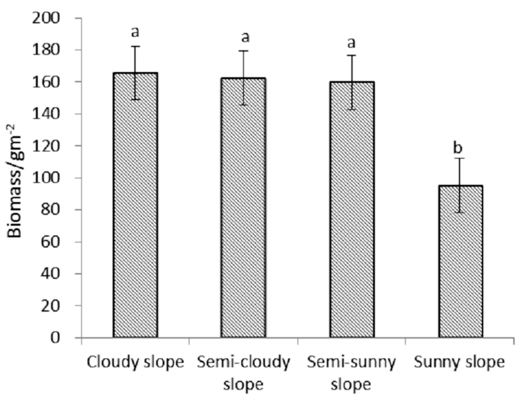

Fig. 10: Biomass of different site types.

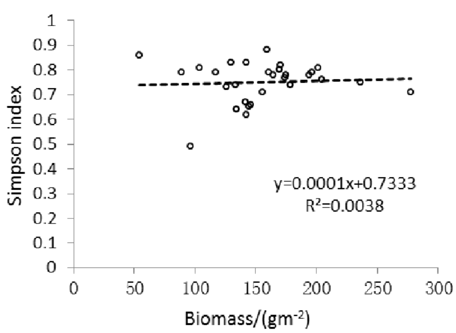

Fig. 11: Relationship between Simpson index and biomass.

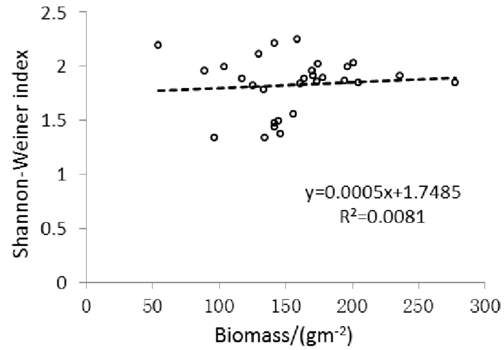

Fig. 12: Relationship between Shannon-Weiner index and biomass.

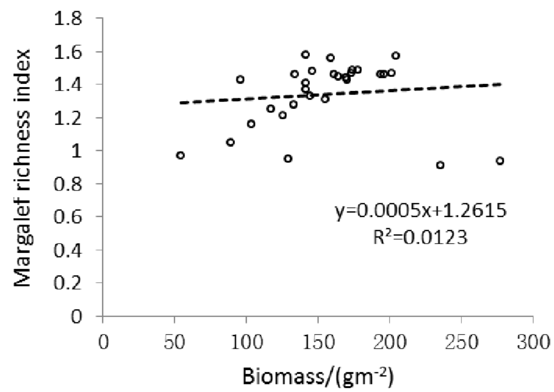

Fig. 13: Relationship between Margalef richness index and biomass.

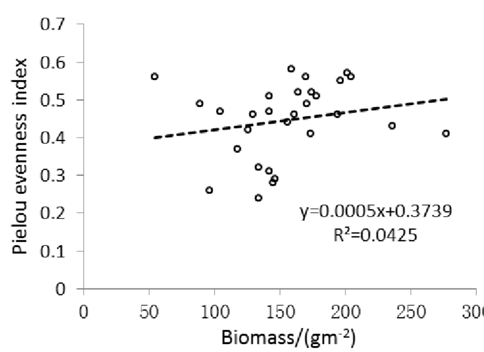

Fig. 14: Relationship between Pielou evenness index and biomass.

such as water, nutrient, sunshine, temperature leads to a different changing trend in species biodiversity and biomass of different sites. In a word, factors that affect species biodiversity and biomass are complicated and need further research so as to provide more important theories for the restoration of the ecosystem.

In our analysis, biomass has no correlation with species biodiversity. This accords with the results of Baskin (1994) and Lawton (1994). It suggests that not every species plays a role in the ecosystem. Thus, for most of the ecosystems, the extinction of some species will not damage their ability of production.

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