Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Earth and Planetary Science 5 (2012) 180 – 187

Procedia
Earth and Planetary Science

2012 International Conference on Structural Computation and Geotechnical Mechanics

Analysis on Slope Revegetation Diversity in Different Habitats

ZOU Mi, ZHU Kai-hua, YIN Jin-zhu, GU Bin[a], a*

School of Life Sciences, Sichuan University, Cheng Du 610064, China

Abstract

Quarrying for constructions has left many bare rocky slopes, in order to recreate biodiversity, artificial revegetation methods have been widely used in the ecological restorations. The study selected several rocky slopes in Zhoushan City for vegetation survey, recorded vegetation species and habitat factors in different sample plots. Based on vegetation data, community parameters such as vegetation diversity indices were computed for statistical analysis, then the relationship between the habitat factors and the slope re-vegetation were revealed. The results showed, the changes of vegetation community diversity in different habitats were obvious, furthermore, for the four habitat factors, significant correlations between slope aspect and vegetation diversity, also slope position and vegetation diversity had been found. Thus, revegetation of rocky slope must be based on characteristics of different local habitats, which can make significant contribution to maintain species diversity and community stability of vegetation.

Keywords: Rocky slope; Revegetation; Community diversity; Habitat factors; Correlation

1. Introduction

In recent years, construction of roads, railways, mining has led to bare slope, exacerbated the degradation of ecosystems and loss of biodiversity. Natural restoration is a slow progress which may take hundreds of years [1]. Therefore, the effective restoration of damaged mountain environment needs scientific human intervention. Nowadays, slope reconstruction of degraded ecological environment has become one of focus studies. Artificial revegetation methods have been widely used to rehabilitate the landscape of rocky slopes [2]. During the restoration progress, biological diversity is an important

* Corresponding author: GU Bin. Tel.: +86 13908070579; fax: +86-028-85470021
E-mail address: amakusa@126.com.

 doi:10.1016/j.proeps.2012.01.032

indicator which reflected the community succession of vegetation. The relationship between environmental factors and vegetation diversity is an important composition of biodiversity research [3]. The study selected rocky slopes in Zhoushan City which have been artificial reconstructed already for survey, analyzed community characters and the changes of vegetation diversity to reveal the relationship between habitat factors and rocky slope re-vegetation. The information gathered from this study could provide help for carrying out better restoration proposal of rocky slopes in different habitats.

2. Materials and methods

2.1. Study area

The study area is located in Zhoushan city, Zhejiang province. Zhoushan islands is in the East China Sea, outer edge of Hangzhou Bay, consisting of 1390 islands, which are mainly low hills under 250meters. This area belongs to the subtropical northern monsoon climate zone, the annual average temperature is 16.3 Celsius, mild and humid climate; abounds in rain, the annual rainfall is 1318.8 mm. These rocky slopes in the study area are located between 29 ° 55' N and 30 ° 05'N latitude, between 121 ° 59' E and 122 ° 21'E longitude, which ranging from 3m to 179m above the sea level.

As digging the mountain for constructions, shipbuilding industry, building oil reserve libraries, etc., Zhoushan has generated a lot of rocky slopes. After years of endeavours, by using construction techniques on the slope, simultaneously combined with comprehensive planting methods, slope eco-restoration work has achieved an initial success [4].

2.2. Fieldwork

From March to July 2011, vegetation community survey was conducted at several rocky slopes which have been artificial restored already. According to different slope positions (the upper slope position, the middle slope position, the lower slope position), each slope was divided into three sample plots. 5 m×5 m quadrats were set for woody plants, and two 1 m×1 m quadrats on the diagonal lines of 5 m×5 m quadrat for herbs. The name, amount, cover, height of every plant species, also with habitat factors of each quadrat, such as slope aspect, slope angle, slope position, altitude, latitude and longitude, restoration years were recorded in detail. As to ensure that habitat factors of plots were comparable, 14 slope vegetation sample plots were selected for statistical analysis.

2.3. Habitat factors selection

Vegetation diversity and its change are closely related to the natural environment and human activities [5, 6, 7]. Different habitats have decisive effects on vegetation composition and structure. Habitat factors which affect vegetation according to their source can be divided into four major types: climatic, soil, geo-morphological type, organisms (Liu Tangrui, et al., 1983) [8]. All the rocky slopes in the study area which are located in a relatively small spatial range have the same climatic conditions; and the relative difference of the altitude among sample plots is less than 200 meters, therefore, the effects of altitude on vegetation can be ignored [9]. The surface of restored rocky slopes are covered by artificial soil disposed in certain percentage of planting soil, organic matter, fertilizers, adhesives, and other mixed grass seeds, thus the soil conditions have no regional disparity. Topographic factors which including slope aspect, slope angle, slope position have indirectly impacts on composition, structure, diversity of vegetation, so that they are assumed as the main factors affecting the development of vegetation. Vegetation of slopes in different restoration years are at different succession stages, also have different species diversity.

Summing up the above, the study chose four habitat factors: slope aspect, slope angle, slope position, and restoration years. In order to make sure the qualitative factors involved in the correlation analysis, habitat factors which varied with the degree were divided: the values of sunny slope, semi-sunny slope, semi-shady slope, shady slope were respectively represented by 4, 3, 2, 1; the values of the lower slope position, the middle slope position, the upper slope position were respectively represented by 3, 2, 1 [10]. Habitat factors of each sample plot are listed in the Table 1.

Table 1. Habitat factors of each sample plot

Slope name	Plot number	Slope aspect	Slope angle	Slope position	Restoration years
Liang kang	1	semi- sunny slope	50°	the middle slope position	1a
Hui fengsi	2	semi- sunny slope	53°	the middle slope position	2a
Xiao ling	3	semi- sunny slope	50°	the middle slope position	3a
Tian ao	4	semi- shady slope	50°	the middle slope position	3a
Bai quan	5	shady slope	45°	the middle slope position	3a
Fu chi 1	6	sunny slope	35°	the middle slope position	3a
Fu chi 2	7	sunny slope	50°	the middle slope position	3a
Bi jiajing	8	shady slope	50°	the lower slope position	4a
Qing feng	9	semi-shady slope	45°	the lower slope position	4a
Qing feng	10	semi-shady slope	45°	the middle slope position	4a
Qing feng	11	semi-shady slope	45°	the upper slope position	4a
Cheng shui bei ku	12	shady slope	65°	the lower slope position	4a
Bai shan 1	13	semi- sunny slope	45°	the middle slope position	4a
Bai shan 2	14	semi- sunny slope	47°	the middle slope position	6a

2.4. Data progressing

Species diversity is an important feature of community structure, not only reflects species richness and evenness of community. α diversity index has characterized community composition as an important indicator [11]. In this study, community diversity was measured by Margalef richness index, Simpson dominance index, Shannon-Weiner index and Pielou evenness index. These indices were calculated in the following formulas [12]:

Simpson dominance index:

$$D=1-\sum Pi^2 \qquad (i=1，2，…，s) \qquad (1)$$

Shannon-Weiner index:

$$H'=-\sum (Pi\ln Pi) \qquad (i=1, 2，…，s) \qquad (2)$$

Pielou evenness index:

$$J= H/\ln(S) \qquad (3)$$

Margalef richness index:

$$R=(S-1)/\ln(N) \qquad (4)$$

Where, "S" is the total number of species in each quadrat; "N" is sum of all individuals of species; "Ni" is the number of individuals of each species; Pi = Ni / N.

Vegetation diversity indices of each plot were calculated by Excel for statistical analysis. Then SPSS software analyzed the Correlation between habitat factors and diversity indices.

3. Results

3.1. The species composition of community

In the survey of 14 slope plots in Zhoushan city, 71 plant species were found, which belonged to 31 families and 67 genera, including 24 species of herbs in which Leguminosae, Poaceae and Asteraceae plants were dominant, while the majority of woody plants was Leguminosae, followed by Oleaceae, Rosaceae, Euphorbiaceae. Constructive species of herbs were *Festuca arundinacea*, *Medicago sativa L.* and *Amorpha fruticosa L*, *Indigofera pseudotinctoria Mats*, *Robinia pseudoacacia L*, *Ligustrum lucidum Ait., Rhus chinensis Mill* were crucial species in the woody layer. All these plants, there were 10 species of Leguminosae, accounting for 14.1%; Poaceae, Oleaceae, Asteraceae each had 6 species, accounting for 8.45% of the total respectively. The four families had 28 species, accounting for 39.4% of all. It had indicated that Leguminosae, Poaceae, Oleaceae, Asteraceae not only did greatest contribution during the process of slope re-vegetation, but also occupied an important position in plant flora of the study area.

3.2. The changes of community diversity in different habitats

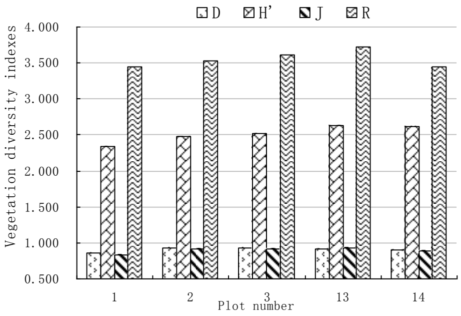
In order to obtain the impacts of each single habitat factors on slope revegetation diversity while other site conditions were the same, the study selected a set of rocky slopes which had one different habitat factor and other three similar or related habitat factors as a group, analyzed the changes of vegetation diversity in each habitat.

3.2.1. Community diversity in different restoration years

It can be seen from Fig. 1 that obvious changes of vegetation diversity have been found in plot 1, 2, 3, 13, 14, as slopes in different restoration years. With the increasing of restoration years ranging from one year to six years, the changes of Simpson index and Pielou index of vegetation community had the same tendency; they increased firstly then decreased. Shannon-Wiener index and Margalef index had shown an overall upward trend, except for a decreasing of the four indices in plot 14, due to human activities disturbance.

Plot 1 was in the early succession stages of slope revegetation; herbs which thrived on the slope had played a vanguard role and provided initial vegetation cover in a short time. With the increasing of restoration years, the herbaceous species of sample plots were more abundant; in addition to the main constructive species of *Festuca arundinacea*, *Medicago sativa L.*, perennial herbs such as *Paspalum natatu*, *Boehmeria nivea*, *Artemisia argyi* and *Vicia amoena*, etc, had invaded into the sample plot. Although the growth of woody plants was slow relative to herbs, the species and amount of plants significantly increased along the restoration years， values of total vegetation cover in plot 14 reached 85%, the average height of vegetation was more than 2 meters.

In the succession process of vegetation community, the invasions of local native species, such as *Miscanthus sinensis Anderss*, *Acta Phytotax. Sin.*, *Sapium sebiferum (L.) Roxb.*, *Broussonetia papyrifera*, etc, had contributed to the significant increasing of species diversity. But the proportion of four most families had showed a decreasing trend, indicating that the species composition had gradually developed in the complex direction.



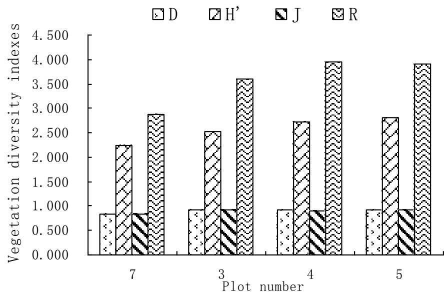


Fig. 1. Vegetation diversity indices in different restoration years (left)
Fig. 2. Vegetation diversity indices in different slope aspects (right)

3.2.2. Community diversity in different slope aspects

The changes of community diversity of different slope aspects have showed in Fig. 2. From the sunny slope, semi-sunny slope, semi-shady slope to the shady slope, Simpson index and Pielou index increased undulately, with the ranges of 0.845～0.925, 0.829～0.924, no diametrical changes. But Shannon-Wiener index and Margalef index increased significantly. Field work also found that plot 7 had a few plant species; mainly the artificial plants like *Medicago sativa L.*, *Indigofera pseudotinctoria Mats*, *Amorpha fruticosa L.*, *Cassia tora Linn*, etc. Relatively, the plant species of semi-sunny slope, semi-shady slope were more abundant and distributed more evenly, in which the distribution differences of woody plants were particularly evident. In plot 5 located in the shady slope, the species and amount of plants had reached a maximum, most dominated by woody plants.

3.2.3. Community diversity in different slope angles

Plot 6 with plot 7, and plot 8 with plot 12 are gathered respectively as two groups for the purpose of comparing the changes of vegetation diversity in different slope angles. As shown in Fig. 3, the four diversity indices of gentle slope were higher than that of steep slope, in which Simpson index and Pielou index had slightly differences, but Margalef index had changed most significantly. The results indicate that diversity indices decrease in general as the increase of slope angle; it reveals that the gentle slope is more conducive to ecological restoration of rocky slope than the steep slope.

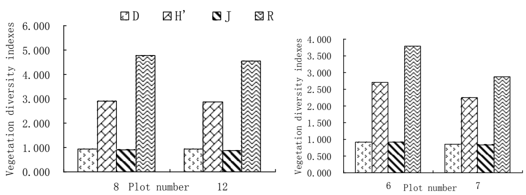


Fig. 3. Vegetation diversity indices in different slope angles

3.2.4. Community diversity in different slope positions

Fig. 4 shown here has revealed significant difference of vegetation diversity in different slope positions. From the lower slope position, the middle slope position to the upper slope position, the values of Simpson index, Pielou index, Shannon-Wiener index and Margalef index all dropped significantly. The lowest vegetation diversity indices of all slopes were found in plot 11 (D= 0.776, H'= 2.007, J= 0.741, R= 2.914). Inconsistency of growth conditions in different slope positions were also been found in field work.

Some herbs covered the upper slope, and some plants were gradually withering; in the middle position of slope, there was a certain amount of shrubs with common quantity and richness; but in the lower position of slope, plant species were the most abundant with best growth condition, vegetation community structure had been stratified which composed by herb-shrub-arbor.

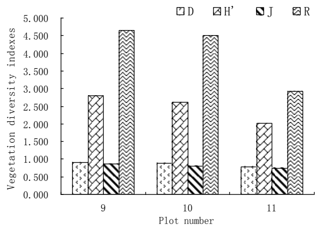


Fig. 4. Vegetation diversity indices in different slope positions

3.3. Correlation between habitat factors and vegetation diversity

The analysis on correlation between habitat factors and vegetation diversity has revealed important information about the effects of habitat factors on vegetation diversity. Correlation coefficients are presented in Table 2. The result showed that the slope aspect had significantly positive correlation with Shannon-Wiener index ($P < 0.05$), and very strongly positive correlation with Margalef index ($P < 0.01$), but no correlation with other two indices, which indicated that Shannon-Wiener index had a remarkable increment while Margalef index increased significantly, from the sunny slope, semi-sunny slope, semi-shady slope to the shady slope. Slope angle had no correlation with vegetation diversity. However, slope position was positively correlated with vegetation diversity, which had significantly positive correlation with Simpson index ($P < 0.05$), and highly significantly positive correlation with Shannon-Wiener index, Margalef index ($P < 0.01$). Restoration years was negatively correlated with Simpson index and Pielou index, positively correlated with Margalef index and Shannon-Wiener index, but there was no significant correlations. Great influences of slope aspect and slope position on vegetation diversity are indicated by correlation analysis.

Table 2. Correlation analysis of habitat factors and vegetation diversity indices

Correlation coefficient	Simpson dominance index	Shannon-Wiener index	Pielou evenness index	Margalef richness index
Slope aspect	0.434	0.609*	-0.119	0.678**
Slope angle	0.327	-0.037	-0.104	-0.041
Slope position	0.577*	0.758**	0.072	0.763**
Restoration years	-0.07	0.319	-0.204	0.303

Note: * and ** noted a significant correlation at level of P = 0.05 and P = 0.01, respectively.

4. Discussion

Through the analysis of the vegetation community diversity we can see, Simpson index and Pielou index of all sample plots changed a little, 78% of the values were ranging from 0.86 to 0.94. Meanwhile, correlation analysis also showed that various habitat factors had no significant relationship with Simpson index and Pielou index. This maybe because during ecological restoration of rocky slope, the seeds of herbaceous and shrub species were hydroseeded by engineering methods, while the trees were evenly artificial established in a fixed density. Therefore, in different habitat conditions, the community evenness of revegetation on rocky slopes varied very slightly.

In the early stage of restoration, intra-specific and inter-specific competitions of vegetation community are not intense, so that the values of species diversity indices were low. As the invasion of native species, species richness and evenness increased gradually. Some native species may have allelopathic effects on invasive plants that can reduce the cost of roadside vegetation management [13]. It can be seen, native species has played an important role in diversity and stability of vegetation communities. As a result, native species should be developed and made use of for rocky slope re-vegetation vigorously. With the increasing of restoration years, spatial heterogeneity of communities had enhanced, the species evenness index decreased clearly, since distribution pattern of plant populations had varied into cluster [14]. And due to human disturbance, diversity index decreased. Thus we appeal to regular maintenance of slope vegetation to assure positive succession towards steady community.

Slope aspect has significantly positive correlation with vegetation diversity. From the sunny slope, semi-sunny slope, semi-shady slope to the shady slope, the species and richness gradually increased. The sunny slope suffers from higher temperature than shady slope for receiving direct solar radiation for long time [15]. With low transpiration, the shady slope has higher moisture content, which is the major factor limiting vegetation on different slope aspects. During the stages of revegetation, some irrigation measures, such as automatic drop irrigation is needed to improve revegetation success, especially in hot summers.

Rocky slope are mostly abandoned quarries by mining, with the slope angle of 45 ° ~ 70 °, which makes it more difficult for revegetation. The steeper a slope is, the less stability it will be, the shallower soil is by loss of nutrients. Thus, backfilling techniques with soil and substrate can reduce the slope angle. The shortage of soil on steep rocky slopes is a major cause of revegetation failure [16]. Some study observed that concaves and cracks of natural cliff, which facilitate soil accumulation, made it possible for plants to establish [17]. On the steep rocky slope, drilling ecological holes filled with artificial organic substrates which mimic the natural concaves would provide sites for plant species to survive. But the rock type and geological structure of rocky slope must be evaluated to ensure the slope stability before drilling ecological holes.

Soil accumulation on the rocky slope surface is a key factor for vegetation establishment in the early successional stages [18]. Slope position is positively correlated with vegetation diversity. The soil of upper slope position is poor due to rainfall and high rates of wind erosion. Plants of fabaceae with deep roots which survive longer than the grass especially in arid habitat [19], can be used as the pioneer species in artificial revegetation,. In addition, local climbing species with high resistance, rapid growth and leaf area should be established on the upper position of slope; it can cover the slope quickly, and also improve the vegetation cover.

5. Conclusion

The results of this study demonstrate that the changes of habitat factors have brought about differences of the distribution and vegetation diversity on rocky slopes which have been artificially restored. So it is essential to investigate the conditions of the rocky slopes before carrying out the eco-restoration scheme. Habitat characteristics of each rocky slope should be considered to select improvement measures and the most appropriate plant species for revegetation.

Single habitat factor as a composition of ecological environment, which is interrelated and constraint with each other, the relationships are complicated. This study compared the changes of vegetation diversity and its interaction with each single habitat factor; however, the changes of vegetation diversity influenced by multiple habitat factors remains to be further studied. Ecological restoration of rocky slopes is a long process, in order to deeply study the succession of vegetation community and the interaction between habitat factors and vegetation diversity, future studies should be based on continuously monitoring for a long time, expand the range of spatial and temporal scale.

Acknowledgements

The study was supported by the National Natural Science Foundation, China (No. 40971057).

References

[1] Zhong-Qiang Wang, Liang-Huan Wu, Ting-Ting Liu, 2009. Revegetation of steep rocky slopes: Planting climbing vegetation species in artificially drilled hole. Ecological Engineering 35, (2009) 1079–1084.

[2] Petersen, S.L., Roundy, B.A., Bryant, R.M., 2004. Revegetation methods for high-elevation roadsides at bryce canyon national park. Utah Restor. Ecol. 12, 248–257.

[3] Nie Ying-ying, Li xin- e, Wang Gang, 2010. Variation mode of α diversity and β diversity of Plant community in different habitat gradients from south-facing slope to north-facing slope and its relation with different environmental factors. Journal of Lanzhou University (NaturalSeiences), 0455-2050(2010)03-0073-07.

[4] Xu Xiao-juan, Zhu Kai-hua, Yin Jin-zhu, et al. Plant Diversity Analysis on Repaired Side-slope of Mine in Islands. Northern Horticulture, 2011(07):106-109.

[5] Yang Xiao-cheng, Chen Zhang-he, Zhou Xian-ye. Changes of species diversity during vegetative restoration in Heishiding mountain. Journal of Cheng Du University of Technology, 1671-9727(2008)02-0220-05.

[6] Lausi, D., Nimis, T., 1985. Roadside vegetation in boreal South Yukon and adjacent Alaska. Phytocoenologia 13 (1), 103–138.

[7] Ullman, L., Bannister, P., Wilson, J.B., 1995. The vegetation of roadside verges with respect to environmental gradients in southern New Zealand. J. Veg. Sci. 6, 131–142.

[8] Li Yi-wei. Study on the habitat characteristics and vegetation succession of mined wastelands in the west of Beijing. 2007,06.

[9] LI Yu-Yuan, SHAO Ming-An. The change of plant diversity during natural recovery process of vegetation in Ziwuling area. ActaEcologica Sinica,2004,24(2):252-260.

[10] Zhao Rong-hui, Shen Pen-yuan. Classification of Site types amount of Juglans mandshurica plantation in Liaodong mountainous. Acta Ecologica Sinica, Vol8, No.1,Mar, 1988

[11] Magurran．Ecological diversity and its measurement[M]. USA：Princeton University Press，1988，

[12] Ma Ke-ping. Measurement of biological community diversity_measurement of α diversity. Chinese Biodiversity, 1994，2(3):162~168.

[13] Mallik, A.U., 2000. Restoration of Trans-Canada highway and secondary roadsides, Scenic look out and facility grounds of Terra Nova National Park, Newfoundland using indigenous plants. St. John's.

[14] Su Dong-ka. Study on ecological restoration on vegetation of Jinfu expressway slope. 2007,05.

[15] Adolfo,C., Raul,N., Ibone,A., et al. 2002. Local topoclimate effect on short-term cutslope reclamation success. Ecol. Eng. 18, 489–498

[16] Esther, B., Patricio, G.F., 2004. Factor controlling vegetation establishment and water erosion on motorway slopes in Valencia Spain. Restor. Ecol. 12, 166–174.

[17] Wiegleb, G., Felinks, B., 2001. Primary succession in post mining landscapes of lower lusatia-change or necessity. Ecol. Eng. 17, 127–199.

[18] Aronson, J., Floret, C., Floch, E.L., et al. 1993. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. I. A view from the south. Restor. Ecol. 1, 8–17

[19] OU Yun-feng, WANG Hong-liang, WANG Gong, et al. Research on Vegetation Restoration of Ecological Slope Protection of Highway in Loess Plateau Area. 1671-4431(2007)09-01624)5.