Relationship between Vegetation Diversity and Soil Microbial Functional Diversity in Native Mixed-Korean Pine Forests

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Abstract: Experiments were carried out on a serial of original korean pine forest compared to adjacent artificial forest. The experimental designed five plots (HD, HZ, HY, LY and BH) of 800 m^2. The model contains fifteen factors including diversity and evenness of vegetation and soil microorganism. Using the model, the integrated eco-environmental stability index (ESI) of study area in five forest types were computed. According to the numerical results, the stability of the three original korean pine mixed forest types treatments (HD, HZ and HY) demonstrated significantly higher (P <0.05) compared with both the artificial pure forest types (LY and BH).

Keywords: Native Mixed-Korean Pine Forests; Vegetation Diversity; Microbial Diversity; Biolog; Eco-Environmental Stability

1. Introduction

Aboveground and belowground components of terrestrial ecosystems are opment process. A change in the composition of a plant community leads to a change in litter quality, which alters the local nutrient cycling process and soil conditions; the changed soil conditions may in turn drive a further change in plant community composition. Those two processes taken together form a plant–soil feedback (PSF), a major driver of plant community dynamics and nutrient cycling . plant–soil feedback (PSF) determines the structure of a plant community and nutrient cycling in terrestrial implicitly dependent on each other. A plant community and local soil conditions are understood as an outcome of the plant–soil codevelecosystems. Microbial communities exhibit distinct compositions [1-3]and/or functions[4], depending on the litter quality and plant species with which they are associated with. It has been hypothesized that flexibility in the community composition and function of microbial decomposers either reinforces or weakensplant control over nutrient mineralization. If the dominant species favors nutrient-rich sites and produces a quickly decomposing litter, then the accelerated nutrient cycling maintains a competitive advantage, preventing competitor invasion and enhancing species dominance[5].

2. Materials and Methods

2.1 Study Area

Liangshui Nature Reserve (47°10′50″N, 128°53′20″E), a preserve which is located in Yichun city, Heilongjiang province of China. It had the efficacy of protecting korean pine broad-leaved mixed forest ecological system. The area is 6394 hm^2, its temperate type belongs to the continental climate. In this area, the latitude is higher, average annual temperature is only -0.3℃ while the annual average minimum and maximum temperatures are -6.6℃ and 7.5℃ respectively . Eight sampling locations surrounding each original korean pine mixed forest types (type: HY: korean spruce & korean pine forest; HZ: oak & korean pine forest; HD: linden-korean pine forest) in Liangshui Nature Reserve, which were chosen based on previous studies conducted in this site. Two adjacent artificial forest types (type: BH: birch pure forest; LY: larch pure forest) was chosen to represent background .

2.2 Vegetation Diversity Calculations

The following diversity indexes were calculated : species richness (S), Shannon's index (H), Simpson's index (D) and Pielou's index (U). These four indexes were calculated for both (i) all the plant species present in the sampling plots considered as a whole and (ii) each of the three different growth forms here considered (i.e., herbs, shrubs, trees).

2.3 Soil Microbial Analysis and Diversity Calculations

Biolog ECO microtiter plates (Biolog, Hayward, CA, USA) were used to assess microbial functional diversity as described previously. The slurry was diluted to 10^{-3}, and used to inoculate Biolog Eco plates with 150 μL per well. Plates were incubated at 25℃ in darkness. Carbon substrate utilization was measured every 24 h for 240 h as quantified by absorbance at a wavelength of 590 nm using an automatic plate reader (Biolog Microstation Elx808BLG, BIO-TEK Instruments Inc., USA)[6].

Overall colour development expressed as average well colour development (AWCD), was calculated as the mean of the blanked absorbance values for all the 31 wells per reading time. AWCD=∑(C−R)/N where C is colour production with each well , R is the absorbance value of the plate's blank well, and N is the number of substrates (ECO plates, N=31). Three replicates per treatment and sampling time were performed. Kinetics of AWCD were used to determine the speed and the level of development of the bacterial communities using the 31 provided substrates. Moreover, the absorbance value of each well at 72 h of incubation was then divided by the AWCD in order to normalize the values and to minimize the influence of inoculum density between plates. These data from 72 h were used to calculate the functional diversity using Shannon's functional diversity index: Shannon's index (H) =−Σ[Pi*Ln Pi], where Pi is the ratio of the blanked absorbance value of each well to the sum of absorbance values of all wells. $\sqrt{\left(\sum ni^2\right)}$ Simpson's index (D) $= \sum_{i=1}^{N}\left[ni(ni-1)/N(N-1)\right]$, McIntosh's index (U) = where ni is the ratio of the blanked absorbance value of each well (i.e.,C-R), where N is the sum of absorbance values of all wells (i.e., Σ(C-R)).

3. Results

3.1 The Interrelationships between Vegetation and Soil Microbial Community Functional Diversity

Species diversity for the soil of suface was similar (shannon's index, simpson's index and mcintosh's index) (Tab. 1), among which had a extremely negative correlation with the species richness of the tree layers (*P*<0.01). Shannon's index for the soil of 0-10cm layer had a extremely positively correlation with the pielou's index of the tree layer (*P*<0.01). Shannon's index for the soil of 10-20cm layer had a positively correlation with the pielou's index of the tree layer (*P*<0.05). Species diversity for the soil of 0-10cm and 10-20cm layers (simpson's index and mcintosh's index) had a positively correlation with the pielou's index of the tree layers (*P*<0.05).

Table 1. The Partial Correlation Coefficients of the Species and Soil Microbial Diversity

	S-Q	S-G	S-C	SW-Q	SW-G	SW-C	SP-Q	SP-G	SP-C	Jsw-Q	Jsw-G	Jsw-C
SW-0	-.591**	.244	.190	-.053	-.348	.188	.168	-.366	.140	.336	-.387	.040
SW-10	-.220	.270	-.478	.197	.215	.269	.347	.153	.305	.868**	.123	.407
SW-20	-.364	.287	-.153	.254	.176	.044	.495	.129	.243	.550*	.082	.154
SP-0	-.703**	.148	.164	-.100	-.360	.122	.160	-.347	.111	.355	-.382	-.006
SP-10	-.371	.076	-.440	-.015	-.131	.250	.255	-.191	.347	.683*	-.153	.394
SP-20	-.126	.053	-.322	-.046	.089	.013	.139	.007	.068	.641*	.042	.177
MI-0	-.664**	.337	.124	-.041	-.366	.293	.150	-.373	.233	.362	-.424	.124
MI-10	-.250	.156	-.470	.049	.105	.181	.260	.048	.233	.564*	.051	.352
MI-20	-.246	.363	-.201	.148	.137	.106	.399	.031	.290	.606*	.030	.249

Notes: *.Correlation is significant at the 0.05 level (2-tailed).**.Correlation is significant at the 0.01 level (2-tailed). S = species richness; SW = shannon's diversity; SP = simpson's diversity; MI = mcintosh's evenness; Jsw = pielou's evenness. Q: tree layer; G: shrub layer ; C: herb layer. 0: suface soil; 10: 10cm soil depth; 20: 10-20cm soil depth.

3.2 Evaluation Model and Factors

How to convert the criteria of water-heat condition, land use, landform, and human interfere into an integrated evaluation index is a key point of environmental evaluation as well as a problem difficult to solve [7]. At present, there are several methods such as the indices weight method (IWM)[8] and the analytical hierarchy process (AHP)[9] be used to achieve the practical success. However, these methods depend on experts' evaluation to weigh the importance of factors and the level of experts influences the final evaluation results directly. The principal component analysis (PCA) using coefficients of linear correlation offers the possibility to weight the contribution of factors [10]. This study has developed an eco-environmental stability evaluation (EVE) model by SPCA method which is a modified PCA approach, whose schematic representation is shown in Fig. 2.

The corresponding results are shown in Table 2. Then an evaluation function can be set up to compute an integrated evaluation index on the basis of selected components.

Table 2. The Results of Spatial Principal Component Analysis in the Study

Project	Selected principal components			
	Factor 1(I)	Factor 2(II)	Factor 3(III)	Factor 3(IV)
Eigenvalue λi	5.234	3.891	2.742	1.099
Contribution ratios (%)	34.890	25.939	18.281	7.329
Cumulative contribution (%)	34.890	60.829	79.110	86.439

Index S is defined as sum of a couple of weighted principal components shown as below:

$$S = \alpha_1 Y_1 + \alpha_2 Y_2 + \cdot \alpha_m Y_m \quad (1)$$

In the formula, Y_i is no. i principal component, while α_i is its corresponding contribution.

According to each component's weight and generated stack , the algebra computation is worked out and evaluation indexes are put out pointing the situation of regional eco-environmental stability, defined in this paper as eco-environmental stability index.The higher the ESI value, the more vulnerable eco-environment is.

Derived from Table 1 and formula (1), the linear formulas for computing ESI is created as follows:

$$ESI = 0.3489 \times A_1 + 0.2594 \times A_2 + 0.1828 \times A_3 + 0.0733 \times A_4 \quad (2)$$

In the formula, ESI is eco-environmental stability index, A_1–A_4 are four principal components sorted out from fifteen initial spatial variables in 1972. The cumulative contribution of the four components is 86.44%. It lays in 85–95% which accord with the convention of choosing factors by PCA method with a high reliability. However, there is still an information loss of about 13.56% when the number of selected components reaches four, which shows that the initial factors have relatively independent function on evaluation.

Finally, construct the comprehensive Evaluation model of Forest ecosystems stability (ESI):

$$ESI =0.0820 \times X_1 + 0.0907 \times X_2 + 0.1199 \times X_3 - 0.0063 \times X_4 + 0.1720 \times X_5 + 0.0220 \times X_6 + 0.1448 \times X_7 + 0.1877 \times X_8 + 0.1104 \times X_9 + 0.1785 \times X_{10} + 0.1856 \times X_{11} + 0.0301 \times X_{12} - 0.1000 \times X_{13} + 0.1490 \times X_{14} - 0.0241 \times X_{15} \quad (3)$$

In the formula, X_1–X_3 are species richness for tree, shrub, and herb layers; X_4–X_6 are simpson's diversity index for tree, shrub, and herb layers; X_7–X_9 are shannon's diversity index for tree, shrub, and herb layers; X_{10}–X_{12} are pielou's evenness index for tree, shrub, and herb layers; X_{13} is mean simpson's diversity index for the soil; X_{14} is mean shannon's diversity index for the soil; X_{15} is mean mcintosh's evenness index for the soil.

Successively substituting the data which is standardized by SPSS in the formula (3) get all the values of eco-environmental stability index(ESI) corresponding the five forest types. Significant analysis showed that the three original korean pine mixed forest types treatments (HD, HZ and HY) demonstrated the significantly higher (P<0.05) level of ESI compared with both the artificial pure forest types (LY and BH).

4. Conclusions

This study focused on an idea about Vegetation types influence the soil microbial community functional diversity through difference of plant diversity and catabolic diversity.From the study, we draw the following conclusions:

1. Species diversity of the vegetation and soil among the treatments indicated that the original Korean pine mixed forest types (HD, HZ, and HY) were similar and significantly higher than the artificial pure forest types (LY, BH).
2. The study confirmed that plant diversity and natural vegetation types had a positive effect on soil microbial function in terms of catabolic capability. It implied that high plant species richness, evenness as well as natural

vegetation types support soil microbial community with higher catabolic diversity.

3. Eco-environmental stability in study area apparently showed that the original Korean pine mixed forest types (HD, HZ, and HY) were similar,and significantly higher than the artificial pure forest types (LY, BH).

The study of the effects of vegetation type on soil microorganisms has implications for ecosystem restoration in the north of China.The results indicated it is urgent that, besides the improvement and reinforcement of compensation mechanism construction, the work of eco-environmental recovering and rebuilding should be carried out according to enhancing eco-environmental stability of the regionalization.

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