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Article 4: A Methodology of Assessing Spatial and Functional Heterogeneity in A Ecosystem / 生态系统的空间和功能异质性评价方法研究

Author: Liu Huan, Master of Science (First Class Honours, 2009), The University of Auckland

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Abstract

As pointed out by Chinese Biodiversity Conservation Strategy and Action Planning (2010-2030), degradation of ecosystem function is one of three problems threatening biodiversity conservation in China. Under this background, this article presents a matrix to assess the spatial and functional heterogeneity in a ecosystem, which also provides the route of conservation strategy for ecosystem restoration.

1.Introduction and Significance

Liu et al., (2010) applied β Sorenson index on the investigation of the variability of plant communities of grass land in Ordos, Inner Mongolia of China, which was restored from grazing land [2]. However, the β Sorenson index does not well represent the spatial heterogeneity in ecosystem, which has been revised by this research and the species significance has been integrated into the β Sorenson index.

To date fewer research have assessed the functional heterogeneity in ecosystem, which has been included in this research. A novel matrix and functional heterogeneity index are presented, reflecting the interaction between ecological function of each botanical species and spatial distribution. In a national forest park representing the background value of a ecosystem, the application of both spatial and functional heterogeneity index helps to select the reference communities for restoration of ecosystem function degradation in local area. Additionally, a new methodology of assessment of water conservation function in a ecosystem is also presented in appendix 1 as case study for ecological function assessment.

2.Assessment of Spatial Heterogeneity

The method to assess spatial heterogeneity of botanical community: Significance of species (S) = Density + Frequency + Dominance [1]. The spatial heterogeneity index between community B and C = $2\times\Sigma Si1/(\Sigma Si2+\Sigma Si3)$, i1 = 1,2,… a; i2 = 1,2,… b; i3 = 1,2,… c.

In this equation, S i1 is the significance of a species existing concurrently in both community B and C; a is the total amount of common species between community B and C; Si2 is the significance of a species in community B; b is the total amount of species in community B; Si2 is the significance of a species in community C; c is the total amount of species in community C.

3. Assessment of Functional Heterogeneity

This method is to assess the functional heterogeneity,

Matrix T1 (Species i is a species existing concurrently in both community B and C):

	Function 1	Function 2	.....	Function x
Species 1	Value	Value	Value	Value
Species 2	Value	Value	Value	Value
.....	Value	Value	Value	Value
Species i	Value	Value	Value	Value

Matrix T2 (Species j is a species existing in community B):

	Function 1	Function 2	.....	Function x
Species 1	Value	Value	Value	Value
Species 2	Value	Value	Value	Value
.....	Value	Value	Value	Value
Species j	Value	Value	Value	Value

Matrix T2 (Species k is a species existing in community C):

	Function 1	Function 2	.....	Function x
Species 1	Value	Value	Value	Value
Species 2	Value	Value	Value	Value
.....	Value	Value	Value	Value
Species k	Value	Value	Value	Value

Matrix F1 (Si is the significance of a species existing concurrently in both community B and C):

	Function 1	Function 2	.....	Function x
Species 1	Value×S1	Value×S1	Value×S1	Value×S1
Species 2	Value×S2	Value×S2	Value×S2	Value×S2
.....	.....	.....	.....	.....
Species i	Value×Si	Value×Si	Value×Si	Value×Si

Matrix F2 (Sj is the significance of a species existing in community B):

	Function 1	Function 2	.....	Function x
Species 1	Value×S1	Value×S1	Value×S1	Value×S1
Species 2	Value×S2	Value×S2	Value×S2	Value×S2
.....	.....	.....	.....	.....
Species j	Value×Sj	Value×Sj	Value×Sj	Value×Sj

Matrix F3 (Sk is the significance of a species existing in community C):

	Function 1	Function 2	.....	Function x
Species 1	Value×S1	Value×S1	Value×S1	Value×S1
Species 2	Value×S2	Value×S2	Value×S2	Value×S2
.....	.....	.....	.....	.....
Species k	Value×Sk	Value×Sk	Value×Sk	Value×Sk

In above matrix, i=1,2,3,...a; j=1,2,...b; k=1,2,....c; a is the total amount of common species between community B and C; b is the total amount of species in community B; c is the total amount of species in community C.

Function 1, 2,...x is the ecological function of conservation of water, conservation of soil, conservation of endangered birds, carbon sink.....etc, which is assessed as a value for each plant species in matrix.

Assessment of functional heterogeneity index between community B and C:
Matrix F = F1 × (F2+F3)T, where (F2+F3)T is the transpose of a matrix. The calculation method of heterogeneity index follows Zhang et al., (1988) [3] on the basis of Matrix F.

Examples of calculation (F2+F3):
Matrix F2

	Function 1	Function 2	Function 3
Species 1	1	2	3
Species 2	2	3	4
Species 3	3	4	5

Matrix F3

	Function 1	Function 2	Function 3
Species 1	1	2	3
Species 4	2	3	4
Species 5	5	4	5

Matrix F2+F3

	Function 1	Function 2	Function 3
Species 1	1+1=2	2+2=4	3+3=6
Species 2	2	3	4
Species 3	3	4	5
Species 4	2	3	4
Species 5	5	4	5

4. Discussion of Methodology

In this article, the calculation scope of species significance is the whole ecosystem in local area which can be classified into several communities by multivariate cluster analysis. Then, the spatial and functional heterogeneity index can be calculated between any two communities. However, if the two communities are independent community pre-defined for restoration purpose (e.g. a background community and a restored community), then the calculation scope of species significance is within the pre-defined two communities only. In this case, there is an exception that the spatial heterogeneity index would always remain constant when the two communities own the same species, regardless of proportion and spatial distribution of species. Apparently, the spatial heterogeneity index does not work in this case, so it is just a rough indicator to measure spatial heterogeneity.

Additionally, in Matrix F2, $\Sigma\Sigma Valuej \times Sj$ is a simple community indicator of restoration for ecosystem function degradation, although this indicator lacks of reflecting the effect of interactions among species on ecosystem function. However, the application of functional heterogeneity index on restoration process should strengthen the whole ecosystem function (e.g. to select several communities with satisfactory spatial and functional heterogeneity index in a national forest park as the background samples

for ecosystem restoration). In the appendix of this article, a novel method of ecological function assessment is designed as a case study.

Appendix 1. Assessment of water conservation function in a ecosystem/生态系统的水源涵养功能的评价方法

The quantitative assessment of ecosystem function for conservation of water will follow these steps: in a national forest park which is the source of a river, the drainage area is calculated by 3S technology; the depth of runoff (= the runoff volume over a period ÷ drainage area) is calculated; estimation of total water evaporation over the drainage area; record of total rainfall volume over the drainage area; the ecological function for conservation of water is assessed by the ratio: (total rainfall volume – total water evaporation) ÷ the depth of runoff. In addition, to assess the effect of topography on conservation of water in ecosystem, the drainage area should be calculated as the area of curved surface by GIS for the depth of runoff, and as the projection area for the total water evaporation and rainfall volume. The methods of GIS application on this calculation is advised [4]. However, the application of static differential GPS on digital elevation correction is also advised before this [5].

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