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Tree Richness and Climatic Dominance in Different Districts of Beijing City, China

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Abstract

Nonparametric richness estimators, generalized linear models, canonical correspondence analysis and indicator species analysis were applied for revealing the tree diversity and structure in the districts of Beijing City, China. The results indicated that Mentougou has the highest richness of tree species, occupying 75.8% of total species concerned. Based on the non-parametric richness estimators, the tree richness in Beijing area was estimated around 71-79. From the dendrogram of Ward's minimum variance algorithm, the studied districts can be grouped into three main groups, the first two of which have representative species as selected by indicator species analysis. Group III (including districts Yanqing and Pinggu) does not have representative species, implying that this areal group is not valid if more species' distribution is added in the cluster analysis. Environmental correlation based on generalized linear models found that the current tree richness in Beijing City is significantly associated to the following factors: minimum temperature of coldest month, mean temperature of driest quarter and precipitation of driest quarter, which can take account of 95.8% of the total deviance in species richness. Based on complementary principle, the most valuable districts for tree conservation in Beijing were Mentougou, Miyunxian, Haidianqu and Yanqingxian respectively.

Keywords: tree richness, Beijing, generalized linear models, richness estimation

Introduction

Urban landscapes play an important role in supporting biodiversity in cities with high human population (Savard *et al.*, 2000) and they provide an increasingly urban-based human population with chances to meet wildlife and natural areas (Dunn *et al.*, 2006; van Heezik *et al.*, 2008).

Urban districts play an important functional role in the operation of the whole meta-city of Beijing, which have individual political departments, different urban development strategies and harbor a variety of green lands or natural parks. As we know, green lands/natural parks in an urban area are an essential part of the urban ecosystem and serve as the "green lung" for citizens (Colding *et al.*, 2006). Understanding the species distribution and richness patterns in urban areas are a key step for better conservation of urban ecosystems and biodiversity for different districts and the whole city. Nowadays, ecologists are gradually paying attention to the biodiversity of urban areas (Mortberg and Wallentinus, 2000; Brown and Freitas, 2002; van Heezik *et al.*, 2008).

Beijing is a rapidly developing metropolitan area in the world. As one of the largest cities of the world, the study on biodiversity analysis and comparison of different political districts has broad implications to cantonal substantial development and design for other cities.

In this study, by using the tree distribution data collected from Beijing City, the capital of China, we aimed to reveal the tree biodiversity and analyze the impacts of bioclimatic factors on eight districts of Beijing. We tried to identify the representative tree species and the most dominant environmental factors patterning tree distribution in the city and predict the tree richness of the whole city by statistical techniques.

Materials and methods

Areas

The studied areas include eight representative districts of Beijing City, which are Changping, Fangshan, Yanqing, Pinggu, Haidian, Mentougou, Miyun and Huairou (Fig. 1).

Distribution comparison and richness estimation

The presence/absence data for each reserve was collected based on the previous literature mentioned. Then the simple richness comparison was performed.

Richness estimation was also introduced based on nonparametric estimation. The following richness estimators are considered in our study: Chao 2 (Chao, 1987), first-order Jackknife (Burnham and Overton, 1978), Incidence-based Coverage Estimator (ICE) (Lee and Chao, 1984), and a bias-corrected form of Chao2 (Chao2-bc) (Chao, 2005; Kaeser and Kirkman, 2009)

Environmental correlation

We collected the data on surrounding environment for the districts we studied. We used the averages to reflect the

Fig. 1. Geographic map of Beijing districts (Ma and Liu, 2002). The eight districts in the study is present

environmental envelop of each district. In total, 19 bioclimatic factors are considered in the present study. The data were generated by ArcView using the dataset downloaded from WorldCLIM database (http://www.worldclim.org/).

The tree richness was fitted with generalized linear models (GLM) (McCullagh and Nelder, 1989) for exploring a function of environmental factors. A normal error distribution was assumed and a logarithmic link function was used (Liu *et al.*, 2005). For making the results more reliable, the collinearity of the employed factors was tested with Pearson correlation coefficients. Only one factor was used from pairs of inter-correlated factors ($r>0.7$, $p<0.01$) (Liu *et al.*, 2005).

The factors were put into the model by a forward procedure (Liu *et al.*, 2005). Because the relationships between species richness and environmental factors are often curvilinear (Pausas and Austin, 2001), the simple polynomial function of each environmental factor is also tested. The goodness of model was measured with the change in deviance after including a variable in the model and was tested with an F-ratio test at the confidence level of 0.05 (Liu *et al.*, 2005).

To reduce collinearity effect and only use dominant environmental factors, principal component analysis (PCA) and Pearson's correlation analysis were performed individually to select the typical environmental factors. The most contributive factors accounting for the first two axes of PCA and the least-collinear factors for the Pearson's correlation were combined to form the subset of environmental factors as GLM model input.

Indicator species analysis

Indicator species analysis (INDVAL) method aims to identify representative species which can characterize each district of Beijing (Dufrene and Legendre, 1997). INDVAL was performed using INDVAL for PC package (http://biodiversite.wallonie.be/outils/indval/home.html). The significance was calculated using the method of computing the weighted distance between randomized values and the observed value (t-test). Monte Carlo test was run using 1000 random iterations and 500 seeds for random number generator. The significance level were set at $P<0.05$ (Casazza *et al.*, 2008).

Results and discussion

Tree distribution pattern and richness estimation

Based on the dataset, Mentougou has the highest tree richness (totally 50 species) also because of the fact that it is a mountainous region. The whole district has 1455 km^2, of which 96% is mountains. The natural parks include Linshan, Baihuashan, Miaofengshan, in which Baihuashan Nature Reserve is a key biodiversity protected area in the stone mountainous areas in North China. The various mountainous parks in the district are a reason for explaining its highest tree richness. Yanqingxian has the lowest richness based on our species dataset, as only eight native tree species are found based on the literature searching.

Based on the Ward's dendrogram using Jaacard index, we can see that the eight districts of Beijing can be classified into three regions based on their species compositional similarity (Fig. 2). Miyun, Mentou and Huairou is one group (I); Changping, Haidian and Fangshan can be divided as another group (II); while Yanqing and Pinggu form the last group III. From the geographical aspect, the clustered groups do not have remarkable geographic patterns. Districts in the Group II are aggregated together, but districts in the Group I and III have overlapped each other.

Based on the nonparametric estimators, we estimated that the tree richness in Beijing is within the range of 71-79 (Tab. 1). Chao2-bc estimator has the most conservative prediction, while 1st order Jackknife estimator predicted a highest richness value. The prediction is significantly different from the observed richness ($p<0.05$).

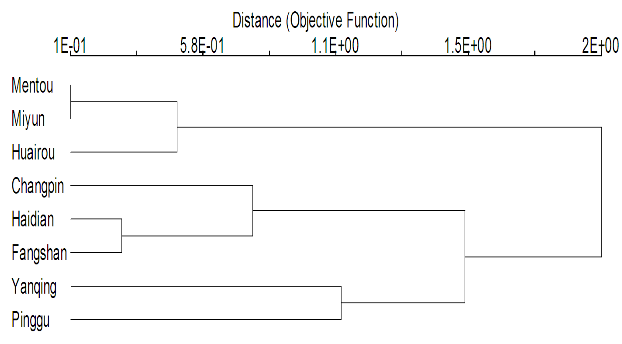

Fig. 2. The dendrogram for clustering the districts of Beijing based on tree composition Jaccard similarity using Ward's algorithm

Indicator species for the districts

By applying indicator species analysis, we found that some species have significant preferential distribution in some districts. The results showed that, 8 species can be the indicator species of the three areal groups, of which six species (*Salix caprea, Ostryopsis davidiana, Ulmus laciniata, Populus davidiana, Sorbus pauhuashanensis, Tilia mongolica*) are found in all groups. One more species (*Pyrus betulifolia*, indicator value=100, p<0.05) represents the group II and one species (*Ulmus davidiana*, indicator value=50, p<0.05) is widely distributed in Group I and II, but not present in Group III. Finally, Group III does not have any preferential species, implying that this areal group may not be supported if more species' distribution is added in the cluster analysis.

Tab. 1. Tree richness estimation of Beijing City based on different nonparametric estimators

Estimator	Estimated Richness	S.D.	95% Confidence Interval
Choa2	71.8	4.1	67.7-86.1
Chao2-bc	71.1	3.9	67.4-85.1
ICE	73.4	2.5	69.8-80.2
1st order jackknife	79.1	5	72.4-92.9

Priority settings

To set conservation priority ranking, we used the complementary principle in the setting. The rarity complementary selection identified that the following four districts are the most valuable for setting conservation of tree plants in Beijing: Mentougou, Miyunxian, Haidianqu and Yanqingxian. All have some species that are not found in other regions.

Selection of environmental factors

By applying principal component analysis and Pearson's correlation analysis, 10 environmental factors were excluded because they are weak in explaining the variation in the dominant principal components or have high degree of co-linearity. The remaining nine factors, including Annual Mean Temperature, Temperature Seasonality, Min Temperature of Coldest Month, Mean Temperature of Driest Quarter, Annual Precipitation, Precipitation of Driest Month, Precipitation of Wettest Quarter, Precipitation of Driest Quarter and Precipitation of Warmest Quarter, were kept for further studies.

Environmental determinants

By applying the GLM model to the remaining nine environmental factors, we found that the following environmental factors have significant relationships to the tree plant richness: minimum temperature of coldest month, followed by mean temperature of driest quarter and precipitation of driest quarter. These three factors can take 95.8% of the total deviance of species richness (Tab. 2). Individual polynomial regression for each important factor is showed in Fig. 3. It can be conclude that tree richness of Beijing showed a positive linear correlation with precipitation of driest month and positive humped correlations with minimum temperature of coldest month and mean temperature of driest quarter.

In general, temperature was the most significant environmental factor influencing plant richness. Such a pattern is also illustrated in previous research works (Austin *et al.*, 1996; Wang *et al.*, 2009). Precipitation is also an important factor in influencing tree richness in Beijing City, similar to previous results. The underlying mechanism of such a pattern may be due to the metabolism function of trees, i.e., the metabolic theory of ecology (Wang *et al.*, 2009).

Tab. 2. GLM environmental models for Beijing tree richness

Models	df	Resi. Dev.	Dev. Explained (%)	F	Pr(>F)
NULL	7	53.989			
Annual Mean Temperature	6	53.527	0.85573	0.4625	0.49645
Temperature Seasonality	5	53.464	0.97242	0.0623	0.80296
Min Temperature of Coldest Month	4	46.876	13.17491	6.5885	0.01026 *
Mean Temperature of Driest Quarter	3	41.075	23.91969	5.8007	0.01602 *
Annual Precipitation	2	40.713	24.59019	0.3625	0.54713
Precipitation of Driest Month	1	2.245	95.84175	38.4675	5.567e-10 ***

(Resi. Dev. = residual deviance; Dev. Ex. = deviance explained; * denotes p<0.05; *** denotes p<0.001)

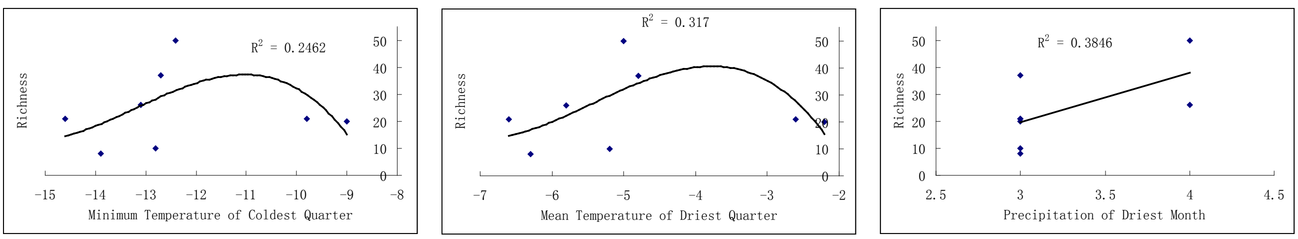

Fig. 3. Scatter plots of species richness with selected environmental factors for Beijing trees

It should be noted here that we did not include geographic latitude or longitude as environmental factors, because in this study the geographic coordinates are not bioclimatic factors and more importantly, they can bring spatial autocorrelation into the analysis and lead to misunderstandings.

Perspectives

In our study, we integrated geographic information system, ecological simulation modeling and richness estimation to reveal the tree diversity structure in Beijing urban areas. We also assessed the possible landscape change under the climatic change and human population growth. We estimated the richness based on available tree distributional information. Some aspects can be enhanced further so as to deeply reveal the ecological impacts of city development and human expansion on urban biodiversity. For example, the model we used can be further improved by integrating some complex factors. Also, we can predict possible landscape change based on socioeconomic data and models.

The study on tree diversity of urban landscapes/districts will be a great contribution to current forest conservation and substantial development.

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