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The Research of Evaluation for Growth Suitability of Carya Cathayensis Sarg. Based on PCA and AHP

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Abstract

In this paper, the 8 indexes which include elevation, slope, aspect, surface curvature, humidity index, solar radiation index, soil types, and soil textures are selected to evaluate the growth suitability of Carya Cathayensis Sarg. The results show that, the descending order sorted by weight of each index which calculated by AHP is: soil types(0.2373), soil textures(0.1983), elevation(0.1888), aspect(0.1387), slope(0.0911), solar radiation index(0.0697), humidity index(0.0452) and surface curvature(0.0309), and in comparison to the results calculated by PCA : except for the slope and aspect, the other indexes are in the same order. It prove that, the AHP method in evaluating the Carya Cathayensis Sarg's growth suitability is effective to some extent.

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1. Introduction

Carya Cathayensis Sarg.is a species of economic forest which have better economic benefits. In recent years, Zhejiang, Anhui and other provinces set off a wave of its industrial development, but the research of Carya Cathayensis Sarg. land suitability evaluation is still at the qualitative stage being short of information about quantitative relationship between its distribution and its land suitability, which result in

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the failure of introduction and cultivation. The quantitative research on suitable environment of Carya Cathayensis Sarg. is very important.

2. Evaluation based on PCA and AHP

2.1. Methods comparison

The methods on the multi-index comprehensive evaluation at home and abroad can be divided into 2 categories[1]: the 1st is subjective weighting method, such as comprehensive scoring method, AHP, Delphi, etc[2];the 2nd is objective weighting method, such as principal components analysis[3], factor analysis[4] and so on. In this paper there was a comparison of method PCA and AHP (shown in table 1).

Table 1. Comparison of method PCA and AHP

	PCA	AHP
Advantages	Determine the principal components according to the rate of variance contribution avoiding the artificial factors; Can calculate the relative importance of each index.	There is no specific restrictions and requirements to the sample data; Can determine the index weight coefficient directly.
Disadvantages	There is a specific restrictions and requirements to the sample data; Can not measure the principal components directly.	Sometimes the order of the results can not reflect the real relationships between objects because of the exaggerate or reduce the role of some indexes.

2.2. Theories

- PCA

The concept of the principal component(PCA) is first proposed by the British biostatistician Karl Pearson in 1901, but it was limited to the discussion of non-random variables, and then Hotelling extended it to random variables[5]. In many research fields, in order to avoid missing important information, we often selected the many more related indexes to analysis, and those indexes may have some relevance to each other, the information reflected by the statistical data overlapped to some extent, also bring unnecessary trouble to computation and analysis. The effective way to solve the above problems is the PCA method. It is multivariate statistical analyses which take a best comprehensive simplified on multivariate data, with the ideas of reduced order, and changed the various indicators into few composite indicators under the principle of ensuring the data losses minimum.

The steps of principal component analysis: standard the original data and then calculate the correlation matrix of the sample data, then according to the correlation matrix, calculate it's the eigenvectors and eigenvalues, as well as the contribution rate, at last select the principal components[6].

- AHP

The concept of the analytic hierarchy process(AHP) was proposed by the US operations researchers in 1970s.It is a practical decision analysis method combining the qualitative and quantitative together. Its basic theory is that divide the various elements of the related programs of the evaluation system into several levels, and use the upper level's demands as the demands of the next same level, then judge and calculate the weight of each factors by using the pairwise comparison method. According to the way of using the maximum comprehensive weight to determine the optimal scheme[7]. This way is particularly effective to decision problems whose structures of the targets (or factors) very complex and lack of the necessary data, it gets widely attention and widely used all around the world[8].

3. The Carya Cathayensis Sarg's growth suitability evaluation index system

3.1. The initially identify of index system

Reference to the previous research results[9], determine the impact of Carya Cathayensis Sarg's growth index system initially was as following:(1)Climatic conditions: the annual average temperatures, the hottest monthly average temperatures, the coldest monthly average temperatures, the absolute maximum temperatures, the absolute minimum temperatures, the annual frost-free period, the annual rainfall, the sunshine hours;(2)Soil conditions: soil types, parent material, soil thickness, soil organic matter contents, and PH values;(3)Topography: slope, aspect, slope position, property values of elevation.

3.2. The reduction of evaluation index set

Since the index evaluation system established in 2.1 is much more complicated to carry out the quantitative analysis, so on the premise of that ensure the high reliability, the index evaluation was need an appropriate reduction. Reference to available researches, learnt from the experiences of local scientists and villagers who planting the Carya Cathayensis Sarg, then combined with fields investigations and orther available data, 8 evaluation factors is selected to analyze which include: elevation, slope, aspect, surface curvature, humidity index, solar radiation index, soil types and soil textures.

4. Empirical Studies

4.1. PCA

- Data sources

There are 4571 topological polygon data as the sample data in Lin'an City, and each topological polygon offers the data about above 8 factors (shown in 3.2).

- Data processing

We use the PCA to draw the variance contribution with SPSS (shown in table 2). In the 8 factors, the 4 principal components are: soil types(27.813%), elevation(20.638%), solar radiation index(19.138%) and humidity index(17.575%), and the cumulative contribution rate is over 85%.

Table 2 Total variance explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.225	27.813S	27.813	2.225	27.813	27.813
2	1.651	20.638	48.450	1.651	20.638	48.450
3	1.531	19.138	67.588	1.531	19.138	67.588
4	1.406	17.575	85.163	1.406	17.575	85.163
5	0.596	7.450	92.613	0.596		
6	0.304	3.800	96.413	0.304		
7	0.152	1.900	98.313	0.152		
8	0.135	1.688	100.000	0.135		

Table 3 Co mponent matrix

Component	1	2	3	4	5	6	7	8
property values of elevation	-0.092	0.869	0.423	0.543	0.112	0.412	-0.086	-0.079
slope	0.523	0.683	0.379	-0.160	0.512	-0.207	0.061	0.117
aspect	0.063	0.428	0.769	-0.276	-0.398	0.136	-0.043	0.218
surface curvature	0.472	-0.098	-0.098	-0.658	-0.056	0.111	0.286	-0.007
humidity index	-0.485	0.357	0.157	0.776	-0.012	0.102	0.389	0.007
solar radiation index	0.453	-0.119	0.683	0.384	0.106	0.134	-0.022	0.258
soil types	0.840	0.295	0.328	0.295	-0.206	-0.350	0.057	0.017
soil textures	0.755	-0.091	-0.091	0.042	0.325	0.066	-0.008	0.001

4.2. AHP

- Processing steps

(1) Establish hierarchy model

The hierarchy model is divided into 3 layers: target layer, rule layer and project layer (e.g. Fig. 1) .

The suitability evaluation of Carya Cathayensis Sarg is as the target layer; 8 evaluation factors, which include: elevation, slope, aspect, surface curvature, humidity index, solar radiation index, soil types and soil textures, is selected as the rule layer; The project layer is divided into 4 areas: best, good, fair, and poor.

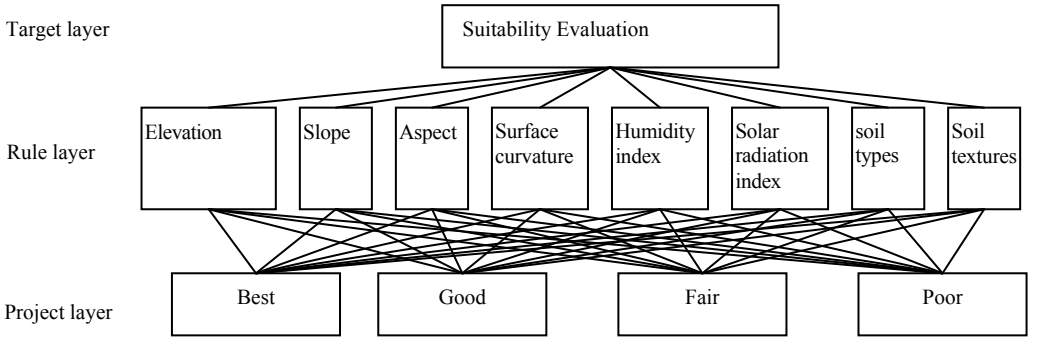

Fig. 1. Hierarchical structure of PCA

(2) Construct judgment matrix

Compared in pairs between the 8 evaluation factors with the scores given by the experts, the judgment matrix is constructed in MATLAB(e.g. Table 4), and the result of CR=0.0523 is accessed (it met the demand of CR＜0.1). Then, each evaluation factor weight is calculated by MATLAB (shown in table 5).

Table 4 Evaluation factor comparison matrix

	Elevation	slope	aspect	surface curvature	humidity index	solar radiation index	soil types	soil textures
Elevation	1	3	2	6	5	4	1/3	1/2
slope	1/3	1	1/2	3	3	2	1/2	1/3
aspect	1/2	2	1	5	3	2	1	1/2
surface curvature	1/6	1/3	1/5	1	1/2	1/3	1/5	1/4
humidity index	1/5	1/3	1/3	2	1	1/2	1/3	1/4

solar radiation index	1/4	1/2	1/2	3	2	1	1/3	1/2
soil types	3	2	1	5	3	3	1	2
soil textures	2	3	2	4	4	2	1/2	1

Table 5 Evaluation factor weights

Elevation	slope	aspect	surface curvature	humidity index	solar radiation index	soil types	soil textures
0.1888	0.0911	0.1387	0.0309	0.0452	0.0697	0.2373	0.1983

5. Interpretation of results

The results Indicate that, in general, the descending order of factor's weight calculated by the PCA is: soil types, soil textures, property values of elevation, slope, aspect, solar radiation index, humidity index, surface curvature. In comparison, the descending order of factor's weight calculated by the AHP method is: soil types, soil textures, property values of elevation, aspect, slope, solar radiation index, humidity index, surface curvature. The results obtained by the two methods are basically the identical. So it can be concluded that the AHP method is effective. Based on the research result in this paper, if each factor grade can be obtained by membership function in fuzzy mathematics and the comprehensive evaluation model of adaptability of the Carya Cathayensis Sarg can be established, the growth suitability evaluation of the Carya Cathayensis Sarg is feasible.

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