Estimates for Rehabilitation Potential of Dust Sources in the Agro-pastoral Ecotone in North China

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Abstract: The Fuzzy Comprehensive Evaluation has proved in quantitive assessment. According to the situation of dust sources in the agro-pastoral ecotone in north China, the evaluation index of rehabilitation potential for dust sources was set up which adopts the proportion criteria algorithm and experts' experiences, index evaluation system was established to quantify the evaluation index. The method of analytical hierarchy process (AHP) was used to obtain the weighing of evaluating index as to calculate the rehabilitation potential. The evaluation standard was set up according to the comparative result between the sand source's situation and model's result. And then use evaluation standard system to separate the grade of potential. Finally fuzzy selection rule was used to separate the potential further. Finally the rehabilitation potential was displayed with different color which shows the different rehabilitation potential in the GIS system for the rehabilitation of dust sources the agro-pastoral ecotone in north China.

Keyword: Dust Sources, Rehabilitation Potential, Fuzzy Comprehensive Evaluation

1. Introduction

Dust weather such as sand storm frequently occurred in Beijing in recent years. People's life was severely affected by the dust weather. Rehabilitation of dust sources where there can provide a mount of sand for dust weather is an effective method to prevent dust weathers to occur. There are four main dust headstreams for Beijing dust weather, in which three headstreams locate at the agro-pastoral ecotone in north China. This research focuses on estimate the rehabilitation potential for dust sources. It can help the decision maker decide the sequence of rehabilitation based on the situation of all the dust sources [1, 2]. Fuzzy Comprehensive Evaluation can provide complex problem with an overall evaluation which is affected by multi-factors. Key feature of the algorism is that it can naturally deal with go-aheadism and fuzziness of humanity's thinking. And rehabilitation potential for dust sources covers many factors, such as soil situation, climate, landform, human and abandoned situations. Generally speaking, it's very difficult to estimate it. In order to provide comprehensive evaluation on the complex problem, it is necessary to develop appropriate index systems and models [9]. In this paper, a fuzzy comprehensive models was founded to estimate the rehabilitation potential of dust sources in the agro-pastoral ecotone in north China. First stage set up the evaluation index of rehabilitation potential which adopts the Proportion Criteria algorithm and experts' experiences. And then, a multilayer comprehensive

evaluation method and fuzzy multi-criteria is proposed with the help of Analytical Hierarchy Process (AHP), weighing of evaluating index can be calculated as to estimate the rehabilitation potential. Thirdly, Fuzzy Selection Rules was used to separate the potential further. Fourthly, the model is applied to a case of 5 dust sources. Finally, apply the model into the GIS system and a result was shown in a map.

2. Methodology

2.1 Dust Sources in the agro-pastoral ecotone in north China

Dust source is the places that can provide a mount of sand for dust weather which is the substance of the dust weather. In the agro-pastoral ecotone in north China, dust sources can be classified into five classes. They are barren, logging slash, abandoned land, degraded lawn, and abandoned land of factory and mines [3].

(1)Barren

People also label barren smooth board land. In these areas the condition of environment was either too wet or too arid. This type dust source can be divided into primary barren and secondary barren, primary barren mainly disturbed by nature, and secondary barren mainly disturbed by humanity. In the agro-pastoral ecotone in north China, the major portion of desert can be classified as primary barren because of man-made destruction.

(2)Logging slash

Logging slash is the degenerated forest which was disturbed by human. The degenerate state varies according to the intension and frequency of cut.

(3)Abandoned till

This type of dust sources is the degenerated farmland which is disturbed by human, and its degenerate state varies according to abandoned time.

(4)Degraded lawn

This type of dust sources is the degenerated lawn which due to overgrazing. And its degenerate state varies according to grazing intensity and abandoned time.

(5)Abandoned land of factory and mines

These places were not treated in time after these areas and peripheries were destroyed because of mining and construction.

In the agro-pastoral ecotone in north China dust sources mainly distributed in North Piedmont of Yinshan Mountain, west part of E's erduosi basin, and alax league, Otindag Sandy Land, Horqin Sandland, Bashang Region of Hebei Province[7,8].

2.2 Evaluate index

The ecosystem of dust area was morbidity which had been degenerated or is degenerating. According to a mount of analysis form literatures and expert's advises, the influence factors for rehabilitation were estimated. It's a foundation to set up the evaluation index. The factors can be grouped under five heads As Fig. 1 shows. They are soil situation, climate, landform, human factors and abandoned status. The evaluate index (Fig. 2) was set up which contains 16 index from all the upon influence factors from the 24 influence factors (Fig. 1).

2.3 Algorithms

2.3.1 The set of evaluated index

Generally speaking, evaluation index can be classified into three types, each of them should be standardized treating first, or else they couldn't be used in the model. The standardized treating formula shows as follow.

Type 1: The value is higher, situation is better.

$$x_{ij} = \frac{x_{ij}^{'} - \min x_{ij}^{'}}{\max x_{ij}^{'} - \min x_{ij}^{'}} \qquad (1)$$

Type 2: The value is lower, situation is better.

$$x_{ij} = \frac{\max x_{ij}^{'} - x_{ij}^{'}}{\max x_{ij}^{'} - \min x_{ij}^{'}} \qquad (2)$$

Type 3: The value is a property scope.

$$x_{ij} = 1 - \frac{\left|x_{ij}^{'} - y_i\right|}{\max\left|x_{ij}^{'} - y_i\right|} \qquad (3)$$

Most of he evaluated index ascribed to the third type,

such as rainfall, temperature, accumulated temperature, light intensity, altitude, PH, soil constructer, organic matter, nutrient element, people increasing speed and agricultural population. Vegetation coverage and soil texture were ascribed to the first type. Gradient and slope were ascribed to second type.

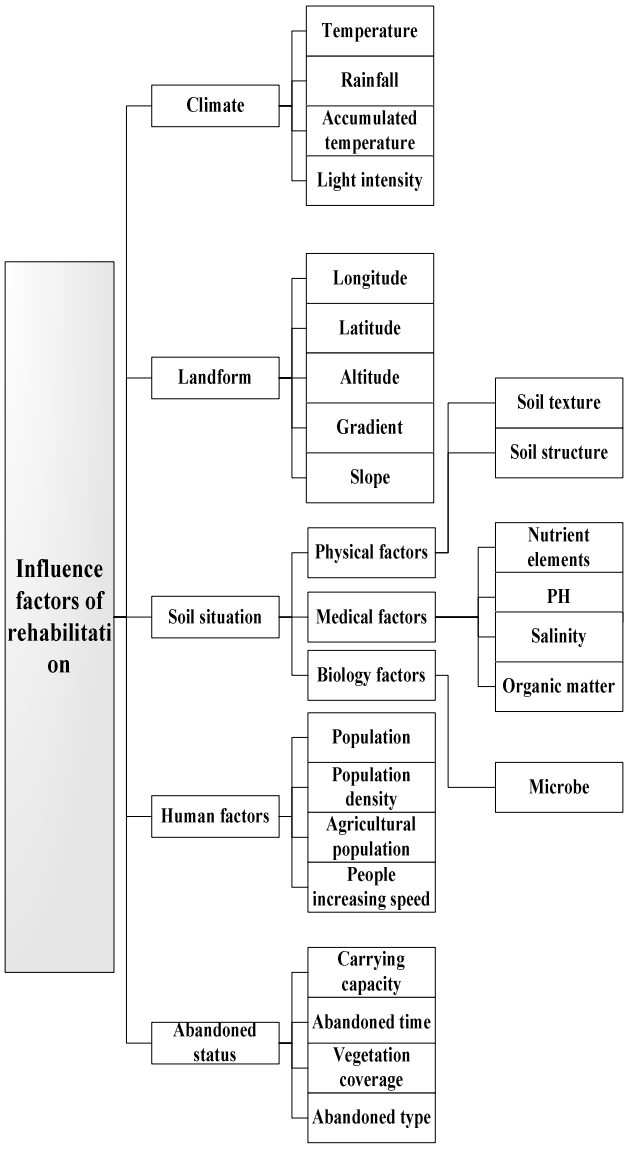

Fig.1 Influence factors of rehabilitate

And then, ameliorate AHP to estimate weighing of index. The entire indexes were divided into 5 categories as Fig 2 shows which are climate, landform, soil situation, human factors and abandoned status. The five categories were treated as first stage for AHP and the evaluated indexes were treated as the secondary-stage for AHP. Firstly evaluate the weighing for first-stage indexes, and then the second-stage indexes, finally evaluate the ultimate weighing of index. In this way, it can expedite and optimize calculating speed for models. The AHP framework shows in Fig. 3.

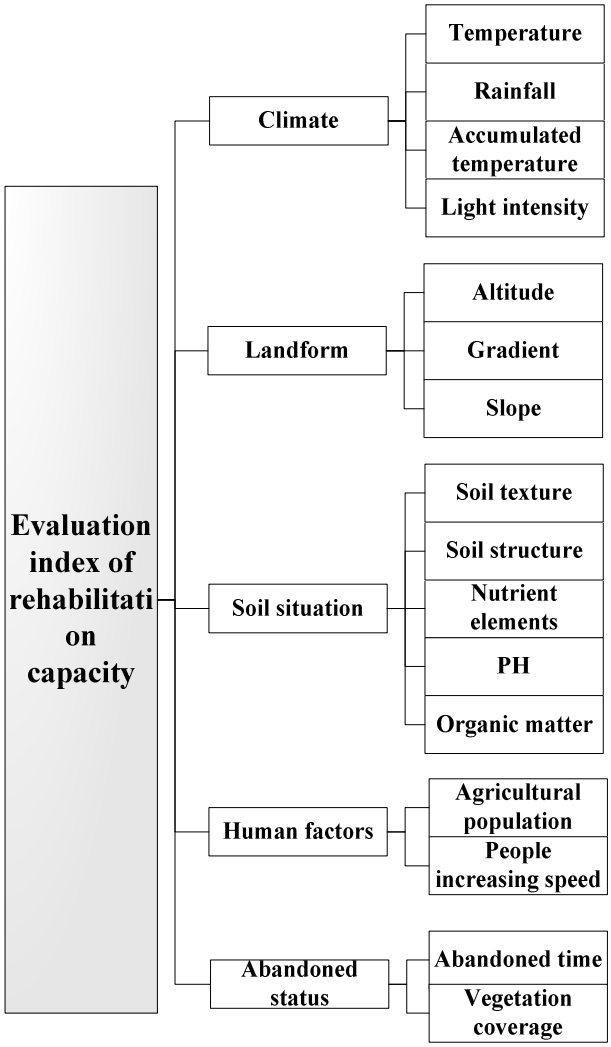

Fig. 2 Evaluation index of rehabilitation potential

$B_1 \ldots B_n$ indicate weighing of first stage□n is the number of the influence groups. C11……C1m and Cn1……Cnk express ultimate weighing of index, m and k is the number of the evaluate index in the corresponding group.

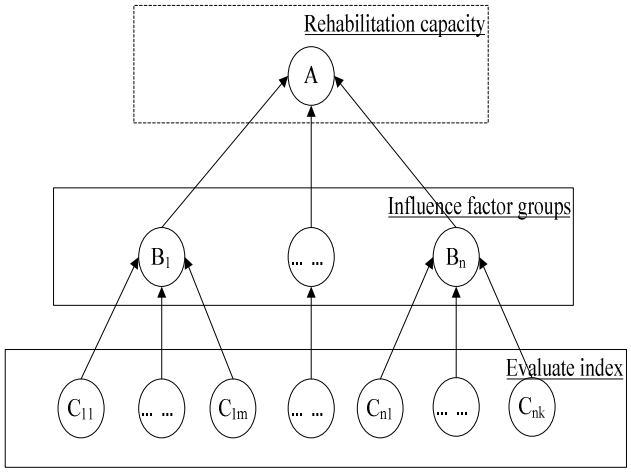

Fig.3 The framework of AHP

Based on Proportion Criteria, the entire index was given a value by expert. The stipulation of Proportion Criteria is: If one is the same important with the other, expert use "1" to represents the relationship between them, if one is a bit more important than the other, expert use "3" to represent the relationship between them. The same, "5" represents one is more important than the other. "7" represents much more important than the other, and "9" represents extremely more important than the other. If the importance is more important than "3", but less important than "5", we use "4" to represent the relationships. And "4, 6, 8" represent the relationship between the index by analogy.

According to the rules shows above, the consultation table for expert was designed. Experts evaluate it with his experience. Use "median" to express s_{ji}.

In this step, use proportion criteria algorithm to deal with the set of $A_1, A_2 \cdots A_m$ and $B_1, B_2 \cdots B_n$. Let the median be the center of s_{ji}. s_{ji} is measure of index that experts give.

Select one group of the data that experts give. Construct judgment matrix H of the data.

$$H = \begin{Bmatrix} h_{11} & \cdots & h_{1p} \\ \vdots & \ddots & \vdots \\ h_{p1} & \cdots & h_{pp} \end{Bmatrix} \qquad (4)$$

Thereinto, $h_{ij} = \dfrac{\dfrac{x_i}{x_i + x_i}}{\dfrac{x_j}{x_i + x_i}} = \dfrac{c_i}{c_i}$, and we can easily get the result that $c_i + c_j = 100\%$, p is the number of index that the expert input. h_{ij} is the compare between factor i and factor j, h_{ji} is the compare between factor j and factor i. Assume that $(1)\, h_{ii} = 1, (2)\, h_{ij} = 1/h_{ji}, (3)\, h_{ij} = h_{ik} \times h_{kj}$.

Largest eigenvalue $\lambda_{\max} = n$ can be gotten. The $W = kH$ is the largest eigenvalue($\lambda_{\max} = n$)'s eigenvectors. k is a constant, $H = [h_1 h_2 \cdots h_n]^T$. According to the theory of AHP, normalized W, $\overline{W}$ is the weighing of the index.

The next step is to get the rehabilitate potential G.

$$G = \sum \overline{W}_{6i} \bullet \overline{X}_i \quad i = 1,2 \cdots 5 \qquad (5)$$

Thereinto, $\overline{X}_i$ is the set of index or the index groups, that is $\overline{X}_i = \{x_1, \cdots, x_l\}$.

At last, based on the fuzzy selection rules, use the following formula to estimate the rehabilitate potential.

$$N(b_i, G) = \bigvee_{j=1}^{k} N(b_j, G) \qquad (6)$$

If G is closer with b_i, the G will be the most similarity with b_i, so we can confirm that G is in the same grade with b_i.

2.4 Questionnaire for weighing estimate

Cooperating with the algorithms to estimate the weighing, the author designed a questionnaire to estimate the evaluation index. The result was gotten by having an information discussion with domain experts or the experts fill the questionnaire himself

and feedback the result.

3. Results

In this work the estimate for rehabilitation potential model was integrated into GIS software ArcGIS, a simplified spatial system was created to evaluate rehabilitation potential of dust sources. This application was embedded in ArcGIS (i.e. ArcMap) as a toolbar (DLL), which made it flexible for users to manipulate. The DLL technique was adopted here to embed the system as a toolbar in ArcGIS. The data and simulation results could be automatically transferred between the GIS database and the models. along with forest growth. This DSS also can identify and visualize (e.g. using charts and maps) rehabilitation potential automatically over time.

The research area is in the north of Fuxin which is located at the west side of Liaoning Province in Northeastern China. The region is an abandoned land of factory and mines which is mostly classified with the semi-arid and semi-wetness continental monsoon climate. The annual average temperature is between 6.5°C and 7.5°C, with the lowest average minimum temperatures occurring in January(-37.9°C) and the highest average maximum temperatures in july(40.9°C).The annual rainfall reaches 448.8 mm, but the annual average amount of evaporation reaches 1644.9 mm.Furthermore, the precipitation shows obveriously asymmetrical distribution in spatial and temporal extension, descending from south to north and focus on june to September. The annual mean wind speed is 2.84 m/s while the predominant wind direction is SSW. And the annual frost-free period covers 150 days. Take this research area as a example, the weighing of the index was calculated based on the feedback of questionnaire and AHP algorithms. The result was shown in table 1.

Use the simulate data to validate the above models. And the models applied in the GIS system, result was shown in Fig. 5. Different colors on the map represent different rehabilitation potential, such as red is hard, yellow is middle, green is easy.

Table 1 Weighing of index

The first grade indicator	Weighing	the proximate grade indicator	Weighing	The final weighing
Climate	0.21	Temperature	0.15	0.032
		Rainfall	0.60	0.126
		Accumulated temperature	0.20	0.04
		Light intensity	0.05	0.01
Landform	0.11	Altitude	0.20	0.02
		Gradient	0.30	0.03
		Slope	0.50	0.06
Soil	0.45	Soil texture	0.10	0.05
		Soil structure	0.20	0.09
		Nutrient elements	0.40	0.18
		PH	0.20	0.09
		Organic matter	0.10	0.05
Human factors	0.10	Agricultural population	0.40	0.04
		People increasing speed	0.60	0.06
Abandoned situation	0.13	Abandoned time	0.70	0.09
		Vegetation coverage	0.30	0.04

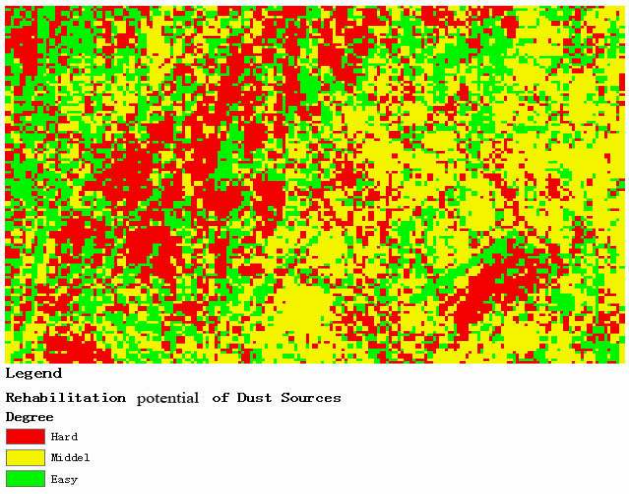

Fig. 5 Rehabilitation potential results in GIS system

4. Conclusions

Fuzzy Mathematics has conquered the illegible information while delimiting the scales of Recovery ability. It is a new application that Fuzzy comprehensive assessment applied to the dust source's rehabilitate potential, and the result shows that the model can meet the anticipated goals. In the process of estimate the rehabilitate potential, it's is very important to choose estimate indices, because they directly to the veracity and scientific character. The actual estimate indices are applicable in evaluation rehabilitation potential of dust sources in the agro-pastoral ecotone in north China, whereas the choice of parameters should be taken into account. Furthermore, the original source codes of the models in the ArcGIS will be revised

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References

[1] Li, Xin Rong; Ma, Feng Yun; Xiao, Hong Lang; Wang, Xin Ping; Kim, Ke Chung. Long-term effects of revegetation on soil water content of sand dunes in arid region of Northern China[J], Journal of Arid Environments, Vol.57, No. 1, 2004, pp. 1-16.

[2] Zhang,J. Zhao, H.; Zhang, T.; Zhao, X.; Drake;S. Community succession along a chronosequence of vegetation restoration on sand dunes in Horqin Sandy Land[J], Journal of Arid Environments, Vol.62, No.4,2005, pp.555-566.

[3] SHENG Xue-bing, LIU Yun-xia, SUN Jian-zhong. Relation between some variations of soil and surface vegetation and desertization in agriculture-pasture interlacing zone—An example from Kangbao County[J], North Hebei, Journal of Environmental Scieces. Vol.15, No. 1, 2003, pp.112-115.

[4] K.D. Sharma, Larry P. Gough. Rehabilitation of Gypsum-Mined Lands in the Indian Desert[J], Arid Land Research and Management, Vol.15, 2001,pp. 61-76.

[5] Parshotam, A.E. Hewitt. Application of the Rothamsted carbon turnover model to soils in degraded semi-arid land in New Zealand[J], Environment International, Vol.21, No.5, 1995, pp. 693-697.

[6] Leslie A. Yetka, Susan M. Galatowitsch. Factors Affecting Revegetation of Carex lacustris and Carex stricta from Rhizomes[J], Restoration Ecology, Vol.7, No.2, 1999, pp.162-171.

[7] Geerken, Roland; Ilaiwi, Mohammad. Assessment of rangeland degradation and development of a strategy for rehabilitation[J], Remote Sensing of Environment. Vol.90, No.4, 2003, pp.490-504.

[8] Montani, Stefania; Magni, Paolo; et. Integrating model-based decision support in a multi-modal reasoning system for managing type 1 diabetic patients[J], Artificial Intelligence in Medicine, Vol.29, No,1-2, 2003, pp.131-151.

[9] Venkata Rao, R. Evaluation of metal stamping layouts using an analytic hierarchy process method[J], Journal of Materials Processing Technology, Vol.152, No.1, 2004, pp.71-76.