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A Study on the Evaluation towards the Ecosystem of the Northlake Wetland in Changchun Based on PSR Models

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Abstract: This thesis uses PSR model as a basis for studying the response of indicators at different levels to various pressures on Northlake wetland ecosystem and selects the most prominent influencing factors to construct a scientific indicator evaluation system. The results of the study show that the Northlake wetland ecosystem is marginally healthy, as indicated by its comprehensive health evaluation index of 0.5822. And the indexes of its three subsystems, i.e. Pressure-State-Response, are respectively 0.631, 0.465 and 0.695, of which the index of the State is the lowest, implying that the Northlake wetland is in an unstable state and has a risk of the wetland degradation.

Keywords: *PSR model, Analytic Hierarchy Process, urban wetland, health evaluations of the ecosystem*

1. Introduction

Wetland is called the kidney of the earth, one of the three indispensable ecological systems of the nature, and the ecologically natural resources that human beings rely on. In the middle and late 20th century, the ecosystem of the wetland degraded, the area of the wetland decreased, and the functions of the wetland reduced, even lost in the northeast part of our country, which resulted from the inning, environmental pollution, urban construction, excessive use of biological resources and so on[1-7]. The rate of the wetland in the Sanjiang Plain in the Northeast China amounted to 49.0% in 1949, while that decreased sharply to 8.7% in 1996. The wetland degradation has occurred these years with the development of Changchun, due to the lack of the scientific guidance towards the management of the wetland, and the lack of effective evaluation of the ecological environment of the wetland. Therefore, the wetland conservation project in Changchun is urgently needed [8-14].

2. An Analysis on the Location of Northlake Wetland

Changchun Northlake National Wetland Park, located in the southwest of the high-tech development zone in Changchun and the downstream Yitong River, whose total planning area is 11.97 square kilometers. It has a temperate continental monsoon climate as well as four distinctive seasons. The mean annual precipitation is 565 millimeters and the water on the surface of the earth there is abundant. The main types of the wetland in the park include the riverine wetland, the lake wetland, the constructed wetland, as well as the marsh wetland, and its rate of wetland is 31.7%. Thus, it falls into the category of the urban wetland park with compound types (Fig.1). During the recent years, the pollution towards Yitong Rive has been aggravated, which has resulted in a constant decline in the quality of the water in the wetland and a trend of the aggravation of the water eutrophication. Meanwhile, with the opening of the Northlake Wetland Park, the number of visitors has increased, which, therefore, brings more pressure to the ecosystem.

Figure: *Satellite aerial view of the Northlake Wetland*

3. PSR Models in the Northlake Wetland

3.1. Selection of the Evaluation Index

According to the real situation of the Northlake Wetland, based on the three policies of representativeness, integrality, and operability, by means of PSR models and the partition of the hierarchy of the evaluation index, the system of Northlake wetland ecosystem health evaluation index with four hierarchies will be established, which includes Target-Norm-Factor-Index. The first one is Target, whose index is the comprehensive evaluation result of the heath situation of the Northlake wetland in Changchun. The second is Norm, which is divided into such three indexes as Pressure-State-Response. The third is Factor, including five indexes. And the fourth is Index, in which seventeen evaluation indexes will be selected.

3.2. The Calculation of the Weight in Each Index

Before forming the judgement matrix, the indexes in each hierarchy of the ecosystem should be numbered first. So the numbers, A1, B1-B3, C1-C5, and D1-

D17, are respectively given to each index in the Target-Norm-Factor-Index.

Because of the complex process of the weighted value and the consistency check, after forming the judgement matrix, the result can be seen as follows:

Table 1: *Hierarchy Single Arrangement and Consistence Check*

Judgement matrix	w1	w2	w3	w4	w5	CI	RI	CR	The consistency check
A-B	0.5098	0.3478	0.1424			0.0003	0.5200	0.0005	consistency
B1-C	0.2500	0.7500					0.0000		consistency
B2-C	0.5000	0.5000					0.0000		consistency
B3-C	1.0000						0.0000		consistency
C1-D	0.2706	0.0852	0.6442			0.0268	0.5200	0.0515	consistency
C2-D	0.4665	0.1005	0.4330			0.0028	0.5200	0.0053	consistency
C3-D	0.0595	0.0930	0.1742	0.3366	0.3366	0.0059	1.1200	0.0053	consistency
C4-D	0.4000	0.4000	0.2000			0.0000	0.5200	0.0000	consistency
C5-D	0.3196	0.1220	0.5584			0.0091	0.5200	0.0176	consistency

According to Table 1, further calculation and consistence check towards the total order sorting of the hierarchies B-C and C-D can be conducted.

The calculation of the consistence check towards the total order sorting in B-C:

As CI=0, there is good consistence in the total order sorting in B-C.

The calculation of the consistence check towards the total order sorting in C-D:

$$CR_{\text{n}} = \frac{CI_n}{RI_n} = \frac{0.0068}{0.6243} = 0.0109 < 0.1$$

As CR<0.1, there is fine consistency in the total order sorting in C-D.

Through the calculation above, the table about the weight allocation in each index in the Northlake wetland ecosystem evaluation can be seen as follows:

Table 2: *The Weight Allocation in Each Index in Northlake Wetland Ecosystem Health Evaluation*

Target	Norm	Factor	Index	Weight
Health Evaluation towards Northlake Wetland (A1=1)	Pressure (B1=0.5099)	Natural Pressure (C1=0.1275)	The Number of Days with Extreme Temperature Annually (D1)	0.0345
			The Number of Hazes Annually (D2)	0.0109
			Annual Precipitation (D3)	0.0821
		Pressure from Human (C2=0.3824)	Population Density (D4)	0.1784
			Per-Capita GDP (D5)	0.0384
			The Intension of Tourism Development(D6)	0.1656
			The Intension of the Application of Chemical Fertilizer (D7)	0.0103
			The Intension of the Application of Pesticide (D8)	0.0162
	State (B2=0.3478)	The State of Environment (C3=0.1739)	The Quality of the Atmosphere(D9)	0.0303
			The Quality of the River Water(D10)	0.0585
			The Quality of the Soil (D11)	0.0585
		The State of Living Things (C4=0.1739)	Animal Diversity (D12)	0.0696
			Plant Diversity (D13)	0.0696
			The Rate of Wetland(D14)	0.0348
	Response (B3=0.1423)	Social Response (C5=0.1424)	The Proportion of the Third Industry(D15)	0.0455
			People's Degree of Education(D16)	0.0174
			The Rate of the Management of Polluted Water (D17)	0.0795

3.3 The Establishment of the Degree of Membership of Each Evaluation Index

3.3.1 The Subsystem of Pressure:

The Number of the Days with Extreme Temperature Annually

The City of Changchun, which has a long and cold winter, whose lowest temperature is about 39.8°C below zero, where some low-temperature phenomenon, such as cold damages, frost damages, as well as chilling damages and so on, will do harm to plants. Even if the plants in the Northlake wetland are mostly cold-resistant, yet long-term low temperature will be still harmful to those plants. The number of the days whose lowest temperature was below 10°C in Changchun was 106. If the degree of membership of the situation that is without extreme temperature annually is made to be 1, then that of the number of the days of the annually extreme temperature can be made to be 0.565.

The Number of the Hazes Annually Being the old industrial bases in the northeast China, the heavy industry in Changchun is developed and the emission of the industrial exhaust gas is comparatively more. These years, there have been frequently large-scale hazes in Changchun, especially in winter. The average concentration of PM2.5 exceeds 350 micrograms per store, which is serious pollution. Through overall consideration, the degree of membership of the number of the hazes can be confirmed as 0.353.

Annual Precipitation Precipitation is an important factor that influences the ecosystem health. The annual precipitation of the Northlake wetland is 565mm or so, and the weight can be confirmed as 0.53.

The Density of Population The national density of population referred in this thesis is 144 persons per square kilometer, and the degree of membership is 0.8 (in 2014), while the density of population in Changchun is 372.6 persons per square kilometer, and its degree of membership can be defined as 0.763.

Per-Capita GDP The relation between per-capita GDP and the environment is a little complicated. According to the assumption of the Environment Kuznets Curve, the relation between the economic development and environmental degeneration seems like an inverted U in shape. The per-capita GDP in Changchun is 43893 yuan each person, through overall consideration, the degree of membership of the per-capita GDP is confirmed as 0.673.

The Intension of Tourism Development The percent of the degree of membership can be confirmed according to the percent the rate of reaching the standard in the tourism's income, as well as the visitor flow volume in the wetland park. The bigger the rate of reaching the standard in tourism's income is, or the more visitors the park has, the closer the degree is to 0. By means of the analysis, the final degree of membership of the intension of tourism development is 0.496.

The Intension of the Application of Chemical Fertilizer The Northlake wetland is located in the suburb. The chemical fertilizers that are used by the villages around will cause the eutrophication of the water and the farm chemicals they use will generate much highly toxic substances as well as refractory chemical substances. Using farm chemicals and chemical fertilizers a lot will bring about soil pollution, groundwater pollution and air pollution. Meanwhile, harmful substances exist and gather in the bodies because of the ingestion of water and food, which will seriously harm the health, even cause the change of the quantity and variety of living things and hence influence the stability of the environment. The more the chemical fertilizers and farm chemicals are used, the smaller the correspondent degree of membership is. Through analysis, the degree of membership of using chemical fertilizers is 0.433 and that of using farm chemicals is 0.379.

3.3.2 The Subsystem of State

The Quality of the Atmosphere Air pollution is an important index of the ecosystem health. Air pollution will harm the surface of plants, weaken the photosynthesis and make plants wither even dead. Air pollution will harm animals' respiratory tracks, which will cause respiratory tract infection, weaken their corporeity and even make them dead. Air pollution can also kill the microorganisms in the soil by means of acid rain, which will decrease the soil fertility and cause the wetland degeneration. These years, the quality of the air in Changchun is not that favorable and Changchun was in the middle-level pollution or even high in half a year in 2015.

The calculating formula of the degree of membership of the air pollution is as follows:

$$P = \frac{\sum a_i b_i}{n}$$

In this formula, a_i refers to the number of the days with a certain air quality annually, while b_i means its correspondent membership value of the air quality, and the evaluation of the membership value is involved in Table 3. The letter n refers to the total number of days yearly and the letter P means the degree of membership of the air quality.

Table 3: *The Value of the Degree of Membership of Air Quality*

Air Quality	Good	Fine	Mild Contamination	Middle-level Pollution	High-level Pollution	Severe Contamination
The Value	1	0.8	0.5	0.4	0.2	0.1

After calculation, the final degree of membership of the air quality is 0.718.

The Quality of the River Water The analysis of the quality of the river water adopts the calculating ways of comprehensive pollution index, whose calculating formula is as follows:

$$P_i = \frac{C_i}{C_{io}} \qquad P_n = \sum_{i=1}^{n} P_i \qquad P = \frac{P_n}{n}$$

In these formulas, P refers to the mean value of the comprehensive index of water pollution of n items. P_n refers to the total value of the comprehensive index of water pollution of n types. P_i means the polluting index of the pollutants of i items. C_i refers to the annually mean value of the pollutants of i items on j fracture surface. C_{io} refers to the evaluation standard of the pollutants of i items. And n is the number of items of pollutants that are evaluated. Analyzing the water quality of Yitong River, it can be concluded that the degree of membership of the water quality of the Northlake wetland is 0.213, belonging to the situation between high-level pollution and middle-level pollution.

The Quality of the Soil Soil is the fundamental factor for terrestrial plants. When the content of different pollutants in the soil exceeds the carrying and purifying capacity, the ecological equilibrium of the soil itself will be destroyed, which will change the structures and elements and hence deteriorate the soil quality. The evaluation of the soil quality adopts the ways of comprehensive pollution index, according to the degree that heavy metal influences the environment, dividing the polluting factors into three and numbering them 3, 2, and 1 to be the weight of this pollution. According to the real situation of the Northlake wetland, the types and the weight of the heavy metals are as follows in Table 4.

Table 4: *The Classification and Weight of the Metal Pollutants towards the Environment*

	Hg	Pb	Cd	As	Zn	Cu	Cr	Ni
Classification	I	I	I	I	II	II	II	II
Weight	3	3	3	3	2	2	2	2

The formula of the comprehensive pollution index of the soil is as below:

$$P_i = \frac{C_i}{S_I} \qquad P = \frac{\sum_{i=1}^{n} w_i P_i}{\sum_{i=1}^{n} w_i}$$

In this formula, P_i refers to the polluting index of the i heavy metal. C_i is the real value of the content of heavy metals. S_I is the standard value of the environmental quality of the soil. w_i is the weight of the i heavy metal. And n is the number of items of pollutants that are evaluated. P is the comprehensive pollution index of the soil. After calculation, it can be concluded that the degree of membership of the soil quality is 0.312, which belongs to the middle-level pollution.

Animal Diversity and Plant Diversity The diversity of animals and plants is crucial to the stability of the ecosystem. Biologically, the diversity index is adopted to evaluate the diversity of species.

Diversity Index: $H = -\sum p_i \ln p_i$

In this formula, pi refers to the proportion of some species and H means the index of its diversity.

There are 144 kinds of wild vertebrates in the Northlake wetland park, attached to 5 classes, 21 orders, and 47 families. Meanwhile, it has 268 kinds of wild plants which are attached to 2 classes, 57 families. All of these reflect the fine diversity of species. Through calculation and a comprehensive analysis, the weight of the diversity of animals is 0.634 and that of the plants is 0.653.

The Rate of Wetland The wetland is playing an important part in the Northlake wetland ecosystem, whose rate can reflect the health level of the wetland ecosystem to a certain degree. The rate of the wetland is used as an evaluation index in this thesis, and the rate of wetland which reaches 50% is stipulated to the degree of membership with 0.8. The rate of wetland is 0 what the degree of membership is 0. The rate of the Northlake wetland is 31.9%, and hence its degree of membership is 0.51.

3.2.3 The Subsystem of Response

The Proportion of the Third Industry The third industry refers to the service industry, whose proportion can reflect the degree of the environmental protection to some extent in the total industry chains. The formula below is adopted to calculate the degree of membership of this index.

$$P = A\% + B\%/3$$

In this formula, P refers to the degree of membership, A means the proportion of the third industry, and B is the proportion of the second industry. The proportion of the second and third industry is respectively 51.43% and 41.5%. Thus, the final degree of membership of the third industry is 0.586.

People's Degree of Education People's degree of education matters the implementation of policies and laws. Therefore, the level of people's education is classified into a Response index.

The calculation formula of the degree of membership of people's degree of education is defined as follows:

$$P = \sum a_i b_i$$

In this formula, a_i refers to the proportion of the number of educated people in the headcount, and b_i means the degree of membership with this degree of education. P refers to the degree of membership of the level of people's degree of education. After calculation, the degree of membership of people's degree of education is 0.492.

The Rate of the Management of Polluted Water The management towards the waste water is humans' active response to the ecological damage. The proportion of the rate of the management towards waste water is regarded as the proportion of the degree of membership and the degree of membership of the rate of the management towards waste water is 0.8.

3.3 A Comprehensive Evaluation towards the Northlake Wetland Ecosystem Health

According to the weighted average calculation by means of the formula of the comprehensive index, the comprehensive health evaluation index of the Northlake wetland ecosystem can be like this:

$$S = \sum_{i=1}^{n} w_i P_i = 0.5822$$

The Northlake wetland is on the edge of health, and it has a trend to decrease to sub-health. Therefore, preserving the Northlake wetland has no time to delay.

Simultaneously, the three subsystems, Pressure-State-Response, are respectively evaluated and the results of each index are 0.631, 0.465 and 0.695 respectively. The subsystem, State has the lowest value, which indicates the situation of the Northlake wetland is unstable and that it has a risk of wetland degeneration. Thus, certain measures are urgently needed.

4. Conclusion

PSR model is used as a fundamental frame in this thesis, on whose basis the health evaluation system has been established by means of the analytic hierarchy process in fuzzy mathematics and the health evaluation of the Northlake wetland ecosystem has also been studied. After calculation, the comprehensive index of the Northlake wetland ecosystem health evaluation is 0.5822, which equals a critical value, the edge of health.

It can be seen that the subsystem, State has the lowest score by means of comparing the evaluation results of the three subsystems, Pressure, State, and Response, whose reason is that the quality of the river water is comparatively bad and that the soil pollution is severe, for which there are two main reasons: One is that Yitong River is the main river system of the Northlake wetland's surface and what Yitong River suffers is severe contamination, whose pollution indexes are ammonia nitrogen, total phosphorus and five-day biochemical oxygen demand. While flowing through the Northlake wetland, Yitong River decreases the quality of its water and soil. The other is that the pollution of the water and soil in the scenic spot has been aggravated with the increasing visitors to the Northlake wetland, the increasing cars along the banks, the frequent use of yachts in the lake as well as the mishandling of the waste water and garbage caused by visitors.

As for the subsystem Pressure, the reasons of the low value are haze, and the use of farm chemicals and chemical fertilizers. Since winter, the hazes in Changchun have scarcely dissipated. The average concentration of PM2.5 exceeds 350 micrograms per stere, which equals severe pollution. The Northlake wetland park is located in the suburb and surrounded by the cropland. With the increasingly using rate of the farm chemicals and chemical fertilizers as well as the increasing pressure of the subsystem Pressure, the system will become weak or even breakdown if not improved.

As for the subsystem Response, the reason of the low value is people's degree of education, which has a close relation with the level of the economic development. With the gradual development of economy in Changchun, the level of people's degree of education is improving as well. Compared with the other two subsystems, Response has a higher value, which indicates that people are active towards the environmental problems and are taking correspondent measures to make changes. All of these will benefit the stability of the whole system.

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