Research on Dynamic Evaluation Model of Environmental Capacity in Reservoir Resettlement Area

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Abstract: Based on the latest literature on Environmental capacity and related theories (Bio-Capacity, Ecological footprint), this paper examines the effect on Resettlement Environmental Capacity by taking into account factors from human society, economics, ecological environment, resources, policy and technology. On the basis of 'nature-social-economic compound system theory', the author built a conceptual model and a mathematical model for dynamically Evaluating Resettlement Environmental capacity. The model is then adjusted according to data simulation, quantitative analysis and perfected by an empirical research. The model allows us to dynamically monitor, analyze, early-alarm and assess the environmental capacity. Furthermore, it provides a basis for policy decision-making on resettlement planning and management, which is particularly important for regulatory policy and decision making.

Keywords: Resettlement; Environmental Capacity; Dynamic Evaluation Model

I. THE CHARACTERS OF CHINESE RESERVOIR RESETTLEMENT AREA

Dams constructed in china are mostly in mountainous or hilly areas. According to the survey conducted by the National Resettlement Management in June 2006, the total number of reservoir in China reaches more than 85,000 with a large number of resettlement up to more than 2280 people in total. After migration, the resettlements mainly lived on government arrangement. The reservoir areas have poor natural conditions and the common contradiction of people and limited land resource. However, due to the historical reasons, the importance of resettlement planning has been neglected in China. Limited technology, inadequate policy regulations and lack of systematical analysis on various dynamic regional difference of resettlement areas' environmental capacity lead to inconsiderate resettlement plan and implement. The insufficient environmental capacity (or land capacity) restraint the objective of resettlement and increase the difficulty for resettlement management, post-migration production and living standards improvement.

For the sake of improving resettlement management and achieving the sustainable development for the reservoir resettlement area, it is important for us to build the dynamic evaluation model to monitor and assess the change of environment capacity actively. Our research offers scientific basis for ecosystem rehabilitation in reservoir area and policy decision on resettlements' scientific management. Besides, the model also provides implications for regulation formulation and resources allocation.

II. CONCEPTUAL MODEL OF ENVIRONMENTAL CAPACITY DYNAMIC EVALUATION

The 'nature-society-economic compound system theory' implicates that the environment capacity is constraint by social, economical and natural capital factors.

A. Environmental Capacity Dynamic Evaluation model is a dynamic multi-factor time series model.

The environment capacity is a variable that can be quantified under different conditions and criterions. For one hand, decreasing farmland and mineral resources, diminishing forestland and soil result in harming the environment capacity. For the other hand, technological investment, evolving modes of social organization and the productivity revolution induce the conflicts between human development and limited natural resources supply, as well as enlarge the environment capacities. Changes in human lifestyle due to rapid growth on economic and social development also demonstrated strong effects on the environment capacity. The key question is that the capacity the ecosystem contains is limited. Only within certain threshold limits, can the ecosystem achieve sustainable development. All of these vital features of environmental capacity contribute to the dynamic multi-factor characteristic of its assessment model.

B. Variables in the model are quantifiable and assessable.

Variables in the model address several aspects from social, economics, eco-environment and natural resources. It is well established that the land and water resource are primary for resettlement environmental capacity. Regions with better economic performance and social services facilities come with larger environmental capacity. The main approaches to a diagnosis of environmental capacity are the indicators and index system. The quantifiable key indicators and criterions used to evaluate them are selected from qualitative analysis, which makes the model measureable and operational.

C. Model development is strictly constraint by the properties of nature.

The natural conditions are main constraints for the environmental capacity, including landscape, climate, and natural resources etc. Ecosystem has a finite capacity for supporting a human population. Human development is at the cost of natural resources. Aggregate usage of the environmental capacity caused by unrestraint population increase leads to unbalanced ecosystem. At this time the environment changes in capacity are not food shortage, but rather be accelerating environmental degradation, reduced regeneration of renewable resources and over-exploitation of non-renewable resources. Thus, Environmental Capacity Assessment Model is built within the threshold limits of nature.

D. Social and economic impacts are included in the model.

The rapid growth on economic has caused the sharpest contradiction between the traditional pattern of economic and social development and the growing population. In particularly, enormous pressure caused by over growing population has weakened the natural advantage of environmental capacity. It is a critical question for environmental capacity whether the traditional technology and economic systems can provide supports for the resource exploration and environment protection. Fortunately, modern economic and reforming technologies have improved resource utilize efficiency and provide a channel for transforming the potential advantage into productivity and environment capacity. As a result, the conflicts between population and environment capacities are reduced. In conclusion, the impact of Social and economic development can't be neglected in the environmental capacity dynamic evaluation model.

III. MATHEMATIC MODEL OF ENVIRONMENTAL CAPACITY DYNAMIC EVALUATION

Mathematic model of dynamic evaluation on environmental capacity is built on the former conducted conceptual model. Following the indicator selection methodology, we introduce key indicators by the principles of evaluation indicator and establish the weight for each factor. A quantificational evaluation model of the environment capacity is established after data dimensionless and index synthesis process. We adopt the model to dynamically monitor and diagnose the environmental capacity based on the index generated by the mathematic model.

A. Indicator Selection

The main approaches to an objective and accurate evaluation results are the indicator species and index system. The first task for multi-indicator evaluation is choosing accurate and comprehensive indexes to represent the four subjects.

There are two methods of indicator selection: qualitative approach and quantitative approach according to the source of the original data. Quantitative approach selects the representative indicators utilizes statistical calculation according to the source of original data and eliminates the man-made factor. This approach applies techniques such as the stepwise discriminant analysis, generalized minimum variance, cluster analysis, principal component analysis, measure of dispersion, and the mean-square deviation decision method. Qualitative approach identifies key indicators under instructions from theoretical and practical experience, which is a relatively mature method used in current studies.

B. Calculation of Indicators Weight

1) Decision-making matrix

In FAHP, in order to determine indicator weights quantitatively, the key is to make every two programs quantitatively comparable on the relatively advantages. According to the SA association table, we consulted six senior experts in relevant areas and compare four 1st level indicators of environmental capacity one by one under the rules of the table. The decision-making matrix is presented in Table Ⅰ.

TABLE I. DECISION-MAKING MATRIX OF 1ST LEVEL INDICATORS

B1	Society	Nature	Economic	Resources
Society	1	1/3	1/4	1/2
Nature	3	1	1/2	1/2
Economics	4	2	1	2
Resources	2	2	1/2	1

Standardization of indices and the general term is obtained by:

$b_{ij}=b_{ij}/\sum_1^n b_{ij}$ (i,j=1,2,….n). The decision-making matrix after normalization is presented in table Ⅱ and table Ⅲ:

TABLE II. STANDARDIZED DECISION-MAKING MATRIXES

B2	Society	Nature	Economics	Resources
Society	0.10	0.06	0.11	0.13
Nature	0.30	0.19	0.22	0.13
Economics	0.40	0.38	0.44	0.50
Resources	0.20	0.38	0.22	0.25
∑	10.00	5.33	2.25	4.00

TABLE III. INDICATOR WEIGHTS

B3	Society	Nature	Economics	Resources	W
Society	0.10	0.06	0.11	0.13	0.40
Nature	0.30	0.19	0.22	0.13	0.83
Economic	0.40	0.38	0.44	0.50	1.72
Resource	0.20	0.38	0.22	0.25	1.05
∑					4.00

Standardized weight is obtained by:

$$W=(W_1, W_2\ldots\ldots W_n)_t$$

$$W_i= W_i/\sum_1^n w_{ij} \quad (i =1, 2, \ldots, n)$$

$W=(W_1, W_2, \ldots\ldots, W_n)_t$

Thus W is the approximate value of the maximum eigenvector, i.e. the initial weight coefficient is calculated by:

$W= (W_1, W_2, \ldots., Wn)_t = (0.10,0.21,0.43,0.26)_t$

2) Consistency Test of the Matrix

In the matrix, bij is determined by statistical calculation, expert opinions and systematic analysts after repeated seminars. Other than that, a consistency test of judgment progress is necessary.

λmax=Σ1n(BW)i/nWi

=0.41/(4*0.10)+0.85/(4*0.21)+1.77/(4*0.43)+1.09 /(4*0.26)＝4.118

C.I.=(λmax-n)/(n-1)=(4.118-4)/3=0.039;

C.R.=C.I/R.I.=0.044;CR<0.10.

Thus the decision-making matrix has acceptable consistency.

Other environmental capacity indicator weights are obtained according to the same procedure.

3) Dimensionless Processing

After referring to domestic related research information, we choose an improved form of exponential efficacy function, the mathematical form of which is as follows:

$d=Ae^{(x-xs)/(xh-xs)B}$

In the function, d stands for the value of the original evaluation (Efficacy scores); x stands for the actual value of the original indicator; xs stands for unaccepted value; xs stands for unaccepted value; xh stands for accepted value (allowable value). Unaccepted value and accepted value together are referred to threshold value or reasonable range of values; A and B are two parameters to be determined.

The values of A and B is determined by the critical point. If x=xs, x reaches the 'unaccepted value'. According to linear efficacy function, d=60, so A=60.

If $x=x^h$, x reaches the 'accepted value'. d=100 and $100=Ae^B$, so B=-ln0·6.

Therefore, the improved exponential efficacy function can written as:

$d=60e^{-(x-xs)/(xh-xs)\ln 0\cdot 6}$

We referred to lots of statistical literature and determine the threshold value of index values of dynamic evaluation of environmental capacity by following rules: for positive indicator, the maximum value of the value range is accepted value (x^h); for reverse indicator, the minimum value of the value range is unaccepted value (x^s);

4) Synthesis of Environmental Capacity Index

we decide to choose weighted geometric average model out of following reasons: Firstly, this model is applicable to situations that all indicators have strong correlations with each other; Secondly, considering that the product of indexes represent object's overall level, this model emphasizes the consistency of index values for the objects being evaluated; Thirdly, it meets the requests that differences among the various indicators of the objects being evaluated should be small and there should be none nullified indicators; Fourthly, this model requires lower level of accuracy of indicators' weight than weighted arithmetic average model, meanwhile also be able to offer a more sensitive indication of the index value change, which gives a comprehensive evaluation of higher validity and reliability.

The weighted geometric average model is as follows:

$$G = \sum f \sqrt{X_1^{f_1} \times X_2^{f_2} \times \ldots \times X_n^{f_n}} = \sum_{i=1}^{n} f \sqrt{\prod_{i=1}^{N} X_i^{f_i}}$$

G stands for the evaluated value of comprehensive evaluation of things;fi stands for the normalized weight of evaluated indicators; xi stands for evaluation value of individual index;n stands for the number of index.

Using the above formula, we can obtain the composite index of indicators of level Ⅲ, level Ⅱ and level Ⅰ; after that we can get the environmental capacity index (E) of resettlement area.

5) Evaluation of Environmental Capacity Index

We use 5 scoring method, which compartments the indicate value into 5 grades, to evaluate the environmental capacity of resettlement area. We set up five ranges for the environmental capacity: 0~60, 60~70, 70~80, 80~90 and 90~100. The index value is proportional to the size of the environmental capacity. The E value is indicated by the colors of the blinker as in the following table:

TABLE IV. ENVIRONMENTAL CAPACITY INDEX

E value	**E<60**	**60≤E<70**	**70≤E<80**	**80≤E<90**	**E≥90**
Blinker	Red	Orange	Yellow	Blue	green

If E≥90, the blinker turns green, which indicates that the environmental capacity is sufficient and the migrants have enough living space for the development of production; if 80≤E＜90, the blinker turns blue, which indicates that the environmental capacity is adequate but can't meet the follow-up development needs of immigrants well; if 70≤E＜80, the blinker turns yellow, which indicates that the environmental capacity is penurious for the development of migrants; if 60≤E ＜ 70, the blinker turns orange, which indicates that the environmental capacity is relatively limited and may cause severe impact on the living and production of migrants; if E＜60 the blinker turns red, which indicates that the environmental capacity is extremely limited and may cause great difficulties to the surviving of local residents. According to the E value, immigration offices at all levels could take appropriate measures to create favorable conditions for the sustainable development of migrants and reservoir.

IV. EMPIRICAL STUDY

A. Methods of Data Collection and Update

For managing, which needs high level of accuracy, the data used to evaluate the environmental capacity should be collected by Census; for the purpose of decision-making, which focuses on the trend of pattern, the data should be collected by survey. Since the main function of our model is supporting decision-making, we collected data by the calibers of individual migrants, migrant households, village, township (town), county, etc.

The data of individual migrants and migrant households is mainly collected by survey. The data is collected from a certain proportion (30% is suggested) of migrants in every chosen village according to the questionnaire and interview outline. The collecting process should be accompanied by the staff members of local immigration office. We suggest that professional officer accountants should be in charge of inputting data and get trained ahead. To ensure the integrity and accuracy, the collected data should be audited by the superintendents of both village and township (town).

B. Model Calculation and Results

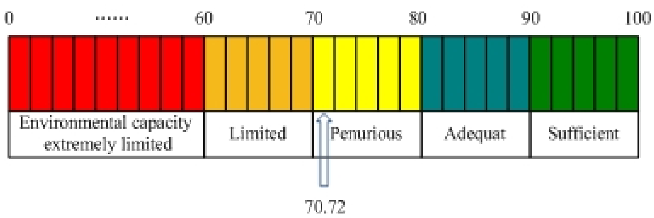
Data from more than 200 migrant households of a county in Three Gorges Reservoir Area are collected in the empirical study. The calculation results by applying the model with empirical data is presented in table Ⅴ.

TABLE V. ENVIRONMENTAL CAPACITY EVALUATION TABLE

Level Ⅰ Indicators	Level Ⅱ Indicators	Level Ⅲ Indicators	Level ⅣIndicators	Origin-al value	Standar-d value	Wei-ght
Social Environment Indicators					**34.98**	**0.12**
	Population				34.75	0.82
		population density		125.03	30.98	0.61
		adult illiteracy rate		0.25	32.19	0.27
		rate of college and higher educational level		0.10	59.71	0.12
	Ethnicity				36.00	0.18
		distinct ethnic customs		2	36.00	1.00
Natural Environmental Indicators					**41.09**	**0.21**
	Suitability				42.68	0.20
		living suitability		3	42.68	0.60
		planting suitability		3	42.68	0.40
	Environmental Quality				40.03	0.60
		rate of soil erosion area		0.05	36.03	0.54
		water quality		3	46.48	0.34
		Air Pollution Index		58	39.74	0.12
	Endemic				42.68	0.20
		Integrated disease severity		2	42.68	1.00
Economic Environmental indicators					**54.09**	**0.39**
	Infrastructure and Social Services				41.33	0.31
		preparation works of construction(PWC)			38.96	0.65
		PWC	rate of road through the village level	1.00	36.00	0.30
		PWC	water conditions	2	42.68	0.41
		PWC	electricity coverage	0.98	36.00	0.15
		PWC	radio and TV coverage	0.95	36.93	0.08
		PWC	telephone coverage	0.88	38.38	0.06
		educational conditions			43.78	0.20
		educational conditions	Enrollment rate of school-age children	1.00	36.00	0.70

		educational conditions	Classroom area per capita	0.35	61.93	0.30
		Medical conditions			48.30	0.15
		Medical conditions	hospital beds per 10000 persons	11.06	38.57	0.30
		Medical conditions	doctors per 10000 persons	22.48	52.47	0.70
	Industry Structure				67.71	0.52
		Output structure			62.36	0.49
		Output structure	proportion of primary industry Output value	0.85	81.70	0.40
		Output structure	proportion of Secondary and tertiary industry Output value	0.15	49.46	0.60
		Practitioners Structure			54.79	0.31
		Practitioners Structure	proportion of primary industry practitioners	0.22	112.32	0.40
		Practitioners Structure	proportion of Secondary and tertiary industry practitioners	0.38	16.44	0.60
		income source ratio			100.84	0.20
		income source ratio	proportion of agricultural income	0.05	180.36	0.25
		income source ratio	proportion of planting income	0.02	66.67	0.20
		income source ratio	proportion of forestry income	0.02	66.67	0.15
		income source ratio	proportion of animal husbandry and fishery income	0.01	64.27	0.15
		income source ratio	proportion of Secondary and tertiary industry income	0.95	91.08	0.25
	Level of Economic Development				35.68	0.17
		per capita net income		2909.0	11.26	0.40
		per capita share of grain		421.14	26.92	0.40
		GDP per capita		8857.76	102.05	0.20
Resource Environmental Indicators					**82.01**	**0.28**
	Land Resources				71.01	0.52
		total arable land per capita		1.29	86.07	0.50
		total forest land per capita		1.50	82.60	0.25
		total grassland per capita		0.18	64.30	0.25
	Water Resources				50.41	0.48
		water per capita		0.03	66.67	0.47
		rate of agricultural water assurance		1.00	36.00	0.30
		rate of industrial water assurance		1.00	36.00	0.23

According to the model calculation and evaluation criteria, the standardized index of immigrant village environmental capacity of this county is 70.72, in the yellow area, which indicates the current environmental capacity has just met migration's need of production and living development, but might have some drawbacks on the sustainable development. The index of immigrant village environmental capacity of this county is marked in graph 1:



Graph 1 Environmental capacity index compartmentalization

V. Conclusions and Suggestions

The evaluation of environmental capacity of reservoir resettlement area has always been a controversial issue.

Previous approaches have evident limitations because of the unilateral evaluation standard by land area or land output only [i] without dynamic analysis. This paper gives a comprehensive consideration including social, economic, ecological environment, resources, policy, technology and many other factors, which have notable effects on the environmental capacity of resettlement area. Based on the ‘nature-society-economy’ compound systems theory, our dynamic evaluation model can simulate and quantitatively analyze environmental capacity under different conditions, the outcome of which is proved intuitively clear, reliable and authoritative for dynamic analysis, monitoring and early warning. This model can also meet the requirements for fundamental information demanded by resettlement planning, monitoring evaluation and migration management and is particularly helpful for macroeconomic decision, policy-making, and sustainable development in resettlement area. This model, which is established for the immigration resettlement area, has universal applicability for other fields of economic activities.

The environmental capacity of reservoir resettlement area is a broad concept with systemic character. It is necessary to expand the environmental monitor and evaluation to a deeper, broader and longer practice in the future. In so doing, it becomes possible to find the environmental capacity deficiencies that may cause ecological degradation and affect the secure prosperity of immigration, and to give early-warning and provide basis for decision-making and management.

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[i] Wei Liao. Analysis of reservoir resettlement and environmental capacity. Environmental Economy, 2007,(6): 30-31.

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