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Analysis of ecological construction driving force based on Gray Correlation Degree - a case study of Sichuan in China

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Abstract

With the social and economic development, the ecological environment is getting worse and requires more importance. Research involved in ecological environment has become a hot field. The driving force of ecological construction in Sichuan province was analyzed by means of the Gray Correlation Degree. The results showed that economical and social factors had great influence on ecological construction in Sichuan province.

Introduction

Under the influence of population growth, socio-economic development and global change, ecosystem degradation and environmental damage are so serious that human well-being and sustainable development are threatened. The problems attract worldwide attention. In order to mitigate the ecological degradation and environmental damage and improve sustainable development, many countries have made positive policy. The Chinese government have paid great attention to ecological and environmental problems and made many decisions and policies, such as *Decision of Issues on Environmental Protection*, *National Ecological and Environment Construction Plan* and *National Ecological and Environmental Protection Program* and so on. The Ministry of environmental protection promulgated *Criteria of Construction of Ecological County, Ecological City and Ecological Province*. The Chinese government has considered ecological construction and environmental protection as one of the key special programmes of the national economic and social development plan and will make huge investment for improving the environment (Lv *et al.*, 2006).

Ecological construction is a systematic and social process, which is driven by particular force, and consists of a series of steps and procedures (Wu *et al.*, 2002) and is also a course of changing, moving and developing of ecological environment. Sound policy and management interventions can often reverse ecosystem degradation and enhance the contributions of ecosystems to human well-being, but knowing when and how to intervene requires substantial understanding of both the ecological and the social systems involved.

The driving and influencing factors of ecological construction viewed as a complex giant system, was analyzed in this study from natural, economic, social and cultural aspects through grey system theory. The study will be helpful in understanding the mechanism of the complex giant system of ecological construction, and it may also be important in making policy and management on ecological construction.

Methods and procedures

Methods: Grey system theory proposed in 1982 (Deng, 1982) uses relatively small data sets and does not demand strict compliance with certain statistical laws, which is a truly multidisciplinary and generic method for dealing with systems characterized by poor information and/or for which information is lacking. Grey relation analysis (GRA), an essential part of the grey systems theory, deals with poor or incomplete data, or uncertain problems of some systems. It was successfully applied to evaluate the effect of environment factors and agricultural factors in different systems (Liu, 2010).

The concept of Niche was introduced into human ecosystem research since the mid-1970s. Urban niche is the fitness of urban environment to economic development and living activities. It is a set of available ecological factors (such as climate, hydrology, land, energy) and ecological relationships (such as economic level, living conditions, infrastructure, environmental conditions and the relationship with external systems). Urban niche reflects a city's characteristics, status, role, function, and advantages and/or disadvantages of resources, population, and environment. So, urban niche determines the attractiveness as well as centrifugal force of different economic activities and different people to the city (Hai, 2005). Urban niche is calculated by urban ecological suitability.

Ecological civilization, a kind of human civilization, is on the premise of respecting and maintaining the nature, for the purpose of person, natural and social harmony, and for the essence of establishment of sustainable production and consumption patterns. Ecological civilization can guide people onto the road of sustainable development. The level of ecological civilization was calculated by ecological efficiency (EEI) (Yang, 2009).

EEI=GDP/ecological footprint……………………………(1)

The term of ecological construction was brought up by Chinese scientists in 1980s, of which the theory and methodology continues to be explored. Although the term is used broadly in research field, government, and public media, the exact meaning is still lack of standardized definition (Lv *et al.,* 2006). It has the similar meaning as ecological restoration in this study and involved in natural, economic, social and cultural activities. The formula of showing the level of ecological construction was proposed in this study.

the level= a* ecological suitability + b*EEI' …………………(2)
EEI' is the standardized value of EEI.

Ecological suitability calculation: The formula of ecological suitability was identified as followed (Liang, 2005; Tan *et al.* 2007; Li *et al.*, 2004; Lin and Li 1998; Shi *et al.,* 2011; Liao *et al.,* 2003).

$$F_i = \frac{1}{n}\sum_{j=1}^{n}\frac{\min\{x_{ij}-x_{aj}|\}+\frac{1}{2}\max\{x_{ij}-x_{aj}|\}}{|x_{ij}-x_{aj}|+\frac{1}{2}\max\{x_{ij}-x_{aj}|\}} \quad \cdots\cdots(3)$$

F_i denotes the ecological suitability in the year of i. n denotes the number of index. X_{ij} denotes the standardized value of niche of index j in the year of i. X_{aj} denotes the standardized value of optimum niche, which is often the maximum value. Equalization was used for standardization of the original data.

Grey relation analysis: The grey relation coefficient essentially indicates the approaching degree of two geometric curves: the larger the relational coefficient is the nearer the geometry curves are. When the structure is damaged, the geometric shape of the structure will change. Especially, the geometric shape of the damaged elements changes more largely than that of the other undamaged elements. According to the grey system theory, the changes of the geometric shape can be evaluated by the grey relation coefficient which can, thus, be expected to identify the damaged elements.

Now, we write the reference sequence X_0 and test sequence X_i in the form $X_0=(x_0(1), x_0(2)\ldots x_0(k)$, $X_i=(x_i(1), x_i(2)\ldots x_i(k))$, where x_i is the standardized value. The initial value method is often used for standardization here. The essential expression of the grey relation coefficient (GRC) $\xi_i(k)$ is given in Deng (1982).

$$\xi_i(k) = \frac{\min\limits_i\min\limits_k \Delta_i(k) + \alpha\max\limits_i\max\limits_k \Delta_i(k)}{\Delta_i(k) + \alpha\max\limits_i\max\limits_k \Delta_i(k)} \quad \cdots\cdots(4)$$

where $\Delta_i(k)=|x_0(k)-x_i(k)|$; $\alpha\in[0, 1]$ is the distinguishable coefficient used to adjust the range of the comparison environment, and to control level of differences of the relation coefficients. When α=1, the comparison environment is unaltered; When α=0, the comparison environment disappears. In cases where data variation is large, α usually ranges from 0.1 to 0.5 for reducing the influence of extremely large $\max\limits_i\max\limits_k \Delta_i(k)$

The grey relation coefficient $\xi_i(k)$, usually ranges from 0 to 1, evaluates the point-relation degree at the *i*th point of the test sequence $X_i(k)$ and reference sequence $X_0(k)$. Generally, when $\xi i(k)$ is more large, it indicates that the reference point and the test point are related more closely; when $\xi i(k)$ is small, the relation is poor. Gray Correlation Degree r_i was identified as followed.

$$r_i = r(x_0, x_i) = \frac{1}{n}\sum_{k=1}^{n}(\xi_i(k)) \quad i=1,2,\cdots,m \quad \cdots\cdots(5)$$

Formula to measure the level of ecological construction proposed in this study was based on other scientists' research, from which the level of ecological construction of Sichuan province was calculated. The driving force on ecological construction of Sichuan province was analyzed from four aspects of nature, economy, society and culture through grey relation theory. Experts were consulted in the course of index screening and data processing, at the same time, many references were studied carefully so that the indices screening were scientific and objective and the results could reflect the fact of ecological construction of Sichuan province to the largest extent.

In the course of calculation of ecological suitability, weighted method was not used because of the small number of indices and screening carefully. The maximum method was used in the course of EEI standardization according to the aim of addition with ecological suitability which belonged to 0 to 1.

Results and Discussion

Case study on Sichuan province

Ecological suitability calculation of Sichuan province: The level of ecological construction in Sichuan from 1997 to 2005 was analyzed considering the availability of original data which was acquired from Sichuan statistical yearbook and China city statistical yearbook. According to (Wang, 2007; Xia *et al.*, 2008; Liao *et al.*, 2003; Ma *et al.*, 2011; Tan, 2006; Liang, 2005; Shi *et al.*, 2011), and *Criteria of Construction of Ecological County, Ecological City and Ecological Province*, 10 indices were identified for the ecological construction level calculation. They are per capita GDP (Yuan), GDP growth rate (%), tertiary industry proportion (%), city housing area per capita (m^2), city Engel's coefficient, medical personnel per 10 thousand persons (person), city built-up area green rate (%), qualified industrial wastewater rate (%), afforestation area (10000 hectares) and investment in pollution control projects (10000 Yuan), denoted orderly by X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}. The data was in the followed table 1.

The data was standardized by equalization, which means that the new index is the ratio of original index to average value. Ecological suitability of Sichuan was calculated from formula 3. And the results were showed in table 2.

Calculation of the level of ecological civilization: Sichuan GDP data was acquired from Sichuan statistical yearbook and footprint data from (He *et al.*, 2008). Maximum method was used for the standardization of EEI, which means EEI2 was the ratio of EEI to maximum EEI. EEI was calculated from formula 1 and the results were showed in table 3.

Calculation of the level of ecological construction: It was calculated from formula 2, where a =0.6, b=0.4. The results were showed in table 4.

Table 1. Indices of ecological suitability calculation

Index	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1997	4032	10.2	33.81	8.32	49.10	30.35	23.40	50.17	28.15	28162.0
1998	4294	9.1	35.63	9.40	44.90	30.21	21.90	49.10	38.51	25419.1
1999	4540	5.6	37.64	9.90	43.88	30.43	21.40	49.39	40.46	37398.0
2000	4956	9.0	39.45	10.42	41.48	30.13	22.00	59.49	48.91	84115.9
2001	5376	9.2	40.52	11.58	40.23	29.56	21.10	72.38	51.66	35397.8
2002	5890	10.6	41.14	19.60	39.83	28.83	24.25	79.09	69.46	67892.3
2003	6623	11.8	41.06	20.06	38.91	28.24	26.87	81.82	72.32	99053.5
2004	7895	12.6	39.35	21.16	40.19	27.46	30.11	86.43	37.01	221560.2
2005	9060	13.3	38.41	22.18	39.32	27.31	31.00	88.26	24.19	200385.6

Table 2. Ecological suitability of Sichuan from 1997 to 2005

year	1997	1998	1999	2000	2001	2002	2003	2004	2005
ecological suitability	0.4262	0.4346	0.4522	0.5096	0.5347	0.6487	0.7131	0.7384	0.7988

Table 3. Level of ecological civilization of Sichuan

year	1997	1998	1999	2000	2001	2002	2003	2004	2005
EEI	2851.10	3036.18	3120.57	3276.50	3566.33	4006.84	4448.33	5302.07	5925.63
EEI'	0.4811	0.5124	0.5266	0.5529	0.6018	0.6762	0.7507	0.8948	1.0000

Table 4. Level of ecological construction of Sichuan

year	1997	1998	1999	2000	2001	2002	2003	2004	2005
ecological construction	0.4482	0.4657	0.4820	0.5270	0.5616	0.6597	0.7281	0.8010	0.8793

Grey relation analysis:

24 test indices were identified from natural, economic, social and cultural aspects according to Zhao (2010); Zhu *et al.* (2010) and experts suggestion. All test indices and ecological construction levels from 1997 to 2005 formed a matrix. Grey correlation degree was calculated from formula 4 and 5, where α =0.3.

The 24 test indices were cultivated land area (10000 hectares), extent of natural disaster damage (%), forest coverage (%), sulfur dioxide content in air (mg/m^3), nature reserve area (10000 hectares), forest pests and diseases area (hectare), GDP (Yuan), disposable income per capita (Yuan/person), consumption per capital (Yuan/person), labour productivity (Yuan/person), ordinary budget financial revenue of the local government (100 million Yuan), investment in capital construction (100 million Yuan), natural growth rate of population (%), divorce number (couple), Gini coefficient, ratio of endowment insurance population to employed population (%), insurance and welfare funds of retired personnel (Yuan/person), number of beds in health care institutions (10000), number of cultural centers per million people, number of college students per 10000 people, annual number of newspapers per capita, number of colleges and universities, number of approved patents and number of art performance associations. All the indices were denoted orderly by Q_i, i=1, 2, 3.......24, while ecological construction was symbolized by Y. Grey correlation degree of test indices and ecological construction level was calculated from formula 4 and 5. The results were showed in table 5.

It was seen from table 6 that there were 5 economic indices, 4 social indices and 3 cultural indices, of which the proportion to total indices was respectively 20.8%, 16.7% and 12.5% in the top 12 indices of having influence and driving force on ecological construction.

Conclusion

Thus analysis reveals that economic indices had the strongest driving force on ecological construction and the secondary strongest driving forces were from social factors. So, the economic and social factors should be paid more attention for making ecological policy and management.

Table 5. Grey correlation sequence

Index	Index code	Grey correlation degree	Grey correlation sequence
consumption per capital	Q_9	0.9457	1
GDP	Q_7	0.9429	2
labor productivity	Q_{10}	0.9386	3
disposable income per capita	Q_8	0.9156	4
insurance and welfare funds of retired personnel	Q_{17}	0.9134	5
number of colleges and universities	Q_{22}	0.9077	6
ratio of endowment insurance population to employed population	Q_{16}	0.8661	7
divorce number	Q_{14}	0.8126	8
ordinary budget financial revenue of the local government	Q_{11}	0.8007	9
Gini coefficient	Q_{15}	0.7978	10
annual number of newspapers per capita	Q_{21}	0.7877	11
number of cultural centers per million people	Q_{19}	0.7772	12
number of beds in health care institutions	Q_{18}	0.7644	13
cultivated land area	Q_1	0.7398	14
forest coverage	Q_3	0.7344	15
number of art performance associations	Q_{24}	0.7338	16
extent of natural disaster damage	Q_2	0.7185	17
investment in capital construction	Q_{12}	0.6887	18
nature reserve area	Q_5	0.6297	18
natural growth rate of population	Q_{13}	0.6153	20
sulfur dioxide content in air	Q_4	0.6047	21
number of approved patents	Q_{23}	0.5904	22
number of college students per 10000 people	Q_{20}	0.5850	23
forest pests and diseases area	Q_6	0.5388	24

Table 6. The top twelve indices

Index	Code	Degree	Sequence	Category	Proportion
consumption per capital	Q_9	0.9457	1	economic	20.8%
GDP	Q_7	0.9429	2	economic	
labour productivity	Q_{10}	0.9386	3	economic	
disposable income per capita	Q_8	0.9156	4	economic	
ordinary budget financial revenue of the local government	Q_{11}	0.8007	9	economic	
insurance and welfare funds of retired personnel	Q_{17}	0.9134	5	social	16.7%
ratio of endowment insurance population to employed population	Q_{16}	0.8661	7	social	
divorce number	Q_{14}	0.8126	8	social	
Gini coefficient	Q_{15}	0.7978	10	social	
number of colleges and universities	Q_{22}	0.9077	6	cultural	12.5%
annual number of newspapers per capita	Q_{21}	0.7877	11	cultural	
number of cultural centers per million people	Q_{19}	0.7772	12	cultural	

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