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Research Article

Comprehensive Evaluation of Population, Resource, Environment and Economy in Heilongjiang Province, Northeast China

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Abstract: This study established a comprehensive appraisement indicators system of population, resource, environment and economy in Heilongjiang Province of China suffering from depletion of resource and degradation of environment. This study evaluated the development index of each subsystem from 1997 to 2010 by using the method of principal component analysis. The results revealed that each subsystem has an increasing tendency in different degrees in general, while showed obvious fluctuant characteristic. Population subsystem and economy subsystem ascended obviously, especially the economy subsystem. Environment subsystem showed the characteristic of phase. Compared to other subsystems, resource subsystem changed slowly. The conclusion indicates that the population quality, environment protection and economy development have made remarkable progress, but the comprehensive utilization efficiency of resources still is very low, which has become the bottleneck for the harmonious development of between population, resource, environment and economy in Heilongjiang Province.

Keywords: Economy, environment, Heilongjiang province, population, principal component analysis, resource

INTRODUCTION

A series of acute contradiction among excessive population, scanty resource, destructible environment and unbalanced economic development has been the severe challenge for human subsistence and development. Harmonious development of population, resource and environment and economy is the inevitable way to achieve sustainable development, which would obtain the better economic development by less resources consumption and environmental cost. However, there is noticeable negative correlation between natural resource and economic development (Sachs and Warner, 2001). In the analysis the interaction between economy and environment, the idea of environmental carrying capacity (Sayre, 2008), the viewpoint of ecological economy (Berck *et al*., 2012) and the thought of sustainable development (Marsiglio, 2011; Veeravatnanond *et al*., 2012) are reflected and applied. In the background of rapid economic and social development in China, the interactions among population, resource, environment and economy are becoming much intense and complicated, which have aroused government's and people's particular attention (Zhang *et al*., 2008; Yue and Li, 2009; Hu and Zhu, 2009; Guan *et al*., 2011; He and Weng, 2012).

This study takes Heilongjiang Province in China as a case study. Affected by history, geography, nature and other factors, the development level of Heilongjiang Province's social economy is relatively backward compared to the central and eastern areas in China. A series of severe resource and environmental problems are restricting sustainable development of society-economy and ecological security in Heilongjiang Province (Li *et al*., 2006; Li, 2009; Tang, 2013). Therefore, it is meaningful to assess development state of population, resource and environment and economy system in Heilongjiang Province. Through the construction of the comprehensive appraisement indicators system of population, resource, environment and economy, this study evaluated the development index of each subsystem from 1997 to 2010 by using the method of principal component analysis. Based on the results, some development countermeasures are put forward in a scientific way. The research results can contribute to guide the construction of ecological province in Heilongjiang Province and to guide the healthy development of regional sustainable development.

Study area: Heilongjiang Province is located in northeast China, the location at latitude 43°25' to 53°33', longitude 121°11' to 135°05'. Heilongjiang Province covers a land area of 473,000 km^2. Accounting for 4.9% of entire land area in China (Fig. 1). The climate is the mid temperate continental monsoon climate. The mean annual temperature ranges from -4 to 5°C. The mean annual precipitation is

Fig. 1: The location of Heilongjiang province in China

400-650 mm, concentrated mostly in the summer season. The frost-free period is 100-160 days and accumulated temperature (≥10°C) is 2000-3000°C. The topography is higher in the northwestern, northern and southeastern hills and lower in the northeastern and southwestern plains. Plains areas account for 37% of the land. The population is 38,334,000 in 2010, accounting for the national total population 2.86%. Heilongjiang Province is rich in resources, where cultivated land, forest, oil and coal resources are tops in the forefront of the country. Due to the complexity of the province's geographical environment and natural conditions, some areas are facing challenges from resources and environment pressures.

METHODOLOGY

Establishment of index system: On the basis of the principles of typicality, integrality and feasibility, this study establishes the comprehensive appraisement indicators system of population, resource, environment and economy in Heilongjiang Province (Table 1). Finally, 35 factors are chosen to analyze the coupling status among population, resource, environment and economy in Heilongjiang Province (Table 1).

Data source: According to the indicators system shown in Table 1, the original data utilized in the analyzing process from 1997 to 2010 are derived from the corresponding Heilongjiang Statistics Yearbook (1998-2011) (Statistics Bureau of Heilongjiang Province, 1998-2011). There are 490 samples. All the statistical analyses are performed using SPSS statistical software, version 20.

Data standardization: In order to eliminate the noise interference caused by different dimensions of the indicators, the original data need to be dealt with. This study standardizes the original data with the following method (Z-score) (Tang, 2013):

$$ZX_{ij} = \frac{X_{ij} - \overline{X_{ij}}}{S_{ij}} \quad (1)$$

where,

ZX_{ij} = The non dimensional value processed by standardization
X_{ij} = The value of raw data
$\overline{X}_{ij}$ = The average value of raw data
S_{ij} = The standard deviation value of raw data

Table 1: The comprehensive appraisement indicators system of population, resource, environment and economy in Heilongjiang province

System	Index	Factor
Population (Z_1)	Scale (Y_1)	Total population (10000 persons, X_1), density of population (person/km^2, X_2), natural growth rate (%, X_3)
	Structure (Y_2)	Proportion of urban population (%, X_4), Proportion of employed persons (%, X_5), dependency rate (%, X_6)
	Quality (Y_3)	University and college students per 10000 population (person, X_7), number of health institutions beds per 10000 persons (unit, X_8)
Resource (Z_2)	Total and per capita data (Y_4)	Total energy production (10000 tons of SCE, X_9), per capita energy production (tons of SCE, X_{10}), per capita water volume (cu.m, X_{11}), per capita cultivated area (ha, X_{12}), per capita stock volume of the forest (cu.m, X_{13})
	Efficiency (Y_5)	Elasticity ratio of energy consumption (X_{14}), clean energy composition (%, X_{15}), energy consumption unit GDP (tons of SCE/10000 Yuan, X_{16})
Environment (Z_3)	Ecological condition (Y_6)	Forest-coverage rate (%, X_{17}), per capita public green areas (m^2, X_{18})
	Pollution discharge (Y_7)	Volume of industrial waste water discharged (10000 tons, X_{19}), volume of waste gas emission (100 million cu.m, X_{20}), volume of industrial solid wastes produced (10000 tons, X_{21})
	Pollution treatment (Y_8)	Percentage of industrial waste water up to the discharge standards (%, X_{22}), volume of industrial solid wastes utilized (10000 tons, X_{23}), total funds of pollution treatment (10000 Yuan, X_{24})
Economy (Z_4)	Level (Y_9)	Gross domestic product (100 million Yuan, X_{25}), per capita GDP (Yuan, X_{26}), per capita retail sales of consumer goods (Yuan, X_{27}), per capital annual net income of rural residents (Yuan, X_{28}), per capital annual disposable income of urban residents (Yuan, X_{29})
	Structure (Y_{10})	Proportion of primary industry (%, X_{30}), proportion of secondary industry (%, X_{31}), proportion of tertiary industry (%, X_{32})
	Benefit (Y_{11})	Overall labor productivity (Yuan/person, X_{33})
	Impetus (Y_{12})	Proportion of investment in fixed assets in GDP (%, X_{34}), per capita foreign capital actually used (USD, X_{35})

i = 1997, 1998, …, 2010
j = 1, 2, …, 35

Principle component analysis: Principal Component Analysis (PCA) is a multivariate analysis method that can reduce data dimensionality. Compared with other methods, the PCA method is objectively reasonable and widely applicable. The steps of PCA: standard the raw data and then calculate the correlation matrix of the sample data, next calculate it's the eigenvectors, eigenvalues and the contribution rate, at last select the principal components. Be noted that, the first few principal components can more fully explain the information of raw data that the eigenvalues are greater than 1 or close to 1 and the cumulative contribution rate of variances reach to over 85%. The purpose of the rotation is to transform the initial matrix into one that is easier to interpret, which attempts to minimize the number of subsystems that have high loadings on a factor (Guan and Tang, 2005).

In this study, PCA is presented to reduce dimension of population subsystem (Z_1), resource subsystem (Z_2), environment subsystem (Z_3) and economy subsystem (Z_4). Varimax orthogonal rotation (Varimax) is selected, then rotated component matrix, eigenvalues, contribution rate of variance, cumulative contribution rate of variance and component score coefficient matrix are obtained. Then inserting the standardization data of various subsystems in component score coefficient matrix to carry on the calculation, the study works out the synthesized score ($\sum F$) and $\sum F$ is taken as the comprehensive assessment value of the four groups and also is the index of integrated development of population, resource, environment and economy.

RESULTS

The comprehensive scores of each subsystem: Taking population subsystem as an example, PCA is used to draw the variance contribution and score coefficient matrix by virtue of SPSS statistical software (Table 2-3). The results from PCA show that when the number of principal components is 3, the cumulative variance explained is 95.590%, which means 3 principal components can explain 95.590% of the total information reflected by the 8 population parameters. Then the population comprehensive score equation ($\sum FZ_{i1}$) is built up with the score coefficient matrix and variance contribution. Standardizing data of population subsystem are substituted in this equation to calculate the comprehensive scores of population subsystem for all years 1997-2010. The higher the value, it is shown that the system integration condition is the better. In a similar way, this study calculates the variance contribution, the score coefficient matrix and the comprehensive scores of resource, environment and economy subsystem. The calculated results Table 4-10 and Fig. 2:

The comprehensive scores of population subsystem: $\sum FZ_{i1} = 0.440\ (0.301\ ZX_{i1} + 0.301\ ZX_{i2} - 0.324\ ZX_{i3} - 0.141\ ZX_{i4} - 0.030\ ZX_{i5} + 0.042\ ZX_{i6} + 0.154\ ZX_{i7} - 0.043\ ZX_{i8}) + 0.381\ (-0.060\ ZX_{i1} - 0.059\ ZX_{i2} + 0.115\ ZX_{i3} + 0.403\ ZX_{i4} + 0.294\ ZX_{i5} + 0.164\ ZX_{i6} + 0.122\ ZX_{i7} + 0.363\ ZX_{i8}) + 0.135\ (0.022\ ZX_{i1} + 0.025\ ZX_{i2} -$

Table 2: Total variance explained of population subsystem

Component	1	2	3
ZX_{i1}	0.974	0.177	-0.053
ZX_{i2}	0.974	0.179	-0.051
ZX_{i3}	-0.983	-0.030	0.007
ZX_{i4}	-0.036	0.966	-0.117
ZX_{i5}	0.285	0.897	-0.261
ZX_{i6}	-0.062	-0.209	0.972
ZX_{i7}	0.720	0.609	-0.216
ZX_{i8}	0.226	0.910	-0.044
Eigen values	3.521	3.045	1.081
% of variance	44.010	38.064	13.515
Cumulative %	44.010	82.075	95.590

Table 3: Component score coefficient matrix of population subsystem

Component	1	2	3
ZX_{i1}	0.301	-0.060	0.022
ZX_{i2}	0.301	-0.059	0.025
ZX_{i3}	-0.324	0.115	-0.036
ZX_{i4}	-0.141	0.403	0.116
ZX_{i5}	-0.030	0.294	-0.051
ZX_{i6}	0.042	0.164	1.027
ZX_{i7}	0.154	0.122	-0.059
ZX_{i8}	-0.043	0.363	0.192

Table 4: Total variance explained of resource subsystem

Component	1	2	3	4
ZX_{i9}	0.153	0.945	0.249	0.119
ZX_{i10}	0.183	0.941	0.199	0.141
ZX_{i11}	-0.034	0.177	-0.006	0.969
ZX_{i12}	0.911	0.348	0.105	0.009
ZX_{i13}	0.890	0.142	-0.046	-0.010
ZX_{i14}	0.217	0.134	0.901	0.184
ZX_{i15}	0.022	-0.368	-0.815	0.243
ZX_{i16}	-0.934	0.043	-0.225	0.024
Eigen values	2.598	2.106	1.641	1.066
% of variance	32.471	26.319	20.516	13.330
Cumulative %	32.471	58.790	79.307	92.637

Table 5: Component score coefficient matrix of resource subsystem

Component	1	2	3	4
ZX_{i9}	-0.068	0.524	-0.102	-0.059
ZX_{i10}	-0.051	0.528	-0.140	-0.040
ZX_{i11}	-0.008	-0.085	0.035	0.937
ZX_{i12}	0.344	0.087	-0.090	-0.030
ZX_{i13}	0.371	0.000	-0.145	-0.019
ZX_{i14}	0.020	-0.263	0.678	0.249
ZX_{i15}	0.121	-0.050	-0.511	0.248
ZX_{i16}	-0.395	0.215	-0.126	-0.035

Table 6: Total variance explained of environment subsystem

Component	1	2	3
ZX_{i17}	0.881	0.296	-0.084
ZX_{i18}	0.964	0.198	-0.078
ZX_{i19}	-0.629	-0.728	-0.133
ZX_{i20}	0.957	0.258	0.058
ZX_{i21}	0.982	0.088	-0.001
ZX_{i22}	0.169	0.964	0.112
ZX_{i23}	0.946	0.283	-0.014
ZX_{i24}	-0.046	0.133	0.989
Eigenvalues	4.907	1.759	1.026
% of variance	61.341	21.987	12.820
Cumulative %	61.341	83.327	96.147

$0.036 ZX_{i3} + 0.116\, ZX_{i4} - 0.051\, ZX_{i5} + 1.027\, ZX_{i6} - 0.059\, ZX_{i7} + 0.192\, ZX_{i8})$.

The comprehensive scores of resource subsystem: $\sum FZ_{i2} = 0.325\,(-0.068\, ZX_{i9} - 0.051\, ZX_{i10} - 0.008\, ZX_{i11} + 0.344\, ZX_{i12} + 0.371\, ZX_{i13} + 0.020\, ZX_{i14} + 0.121\, ZX_{i15} - 0.395\, ZX_{i16}) + 0.263\,(0.524\, ZX_{i9} + 0.528\, ZX_{i10} - 0.085\, ZX_{i11} + 0.087\, ZX_{i12} + 0.000\, ZX_{i13} - 0.263\, ZX_{i14} - 0.050\, ZX_{i15} + 0.215\, ZX_{i16}) + 0.205\,(-0.102\, ZX_{i9} - 0.140\, ZX_{i10} + 0.035\, ZX_{i11} - 0.090\, ZX_{i12} - 0.145\, ZX_{i13} + 0.678\, ZX_{i14} - 0.511\, ZX_{i15} - 0.126\, ZX_{i16}) + 0.133\,(-0.059\, ZX_{i9} - 0.040\, ZX_{i10} + 0.937\, ZX_{i11} - 0.030\, ZX_{i12} - 0.019\, ZX_{i13} + 0.249\, ZX_{i14} + 0.248\, ZX_{i15} - 0.035\, ZX_{i16})$.

Table 7: Component score coefficient matrix of environment subsystem

Component	1	2	3
ZX_{i17}	0.172	0.019	-0.079
ZX_{i18}	0.230	-0.099	-0.035
ZX_{i19}	0.018	-0.431	0.000
ZX_{i20}	0.223	-0.081	0.092
ZX_{i21}	0.278	-0.228	0.082
ZX_{i22}	-0.239	0.800	-0.142
ZX_{i23}	0.205	-0.035	0.007
ZX_{i24}	0.053	-0.151	1.012

Table 8: Total variance explained of economy subsystem

Component	1	2
ZX_{i25}	0.959	0.245
ZX_{i26}	0.960	0.240
ZX_{i27}	0.968	0.231
ZX_{i28}	0.985	0.143
ZX_{i29}	0.942	0.308
ZX_{i30}	-0.078	-0.944
ZX_{i31}	-0.655	-0.280
ZX_{i32}	0.556	0.745
ZX_{i33}	0.935	0.306
ZX_{i34}	0.955	0.168
ZX_{i35}	0.954	0.212
Eigenvalues	8.078	1.976
% of variance	73.438	17.965
Cumulative %	73.438	91.403

Table 9: Component score coefficient matrix of economy subsystem

Component	1	2
ZX_{i25}	0.130	-0.036
ZX_{i26}	0.131	-0.040
ZX_{i27}	0.135	-0.050
ZX_{i28}	0.160	-0.125
ZX_{i29}	0.111	0.019
ZX_{i30}	0.215	-0.742
ZX_{i31}	-0.061	-0.067
ZX_{i32}	-0.072	0.465
ZX_{i33}	0.110	0.019
ZX_{i34}	0.148	-0.097
ZX_{i35}	0.137	-0.062

Table 10: The integrated development index of population, resource, environment and economy in Heilongjiang province from 1997 to 2010

Year	Population	Resource	Environment	Economy
1997	-0.964	-0.140	-0.718	-0.724
1998	-0.704	-0.092	-0.667	-0.702
1999	-0.460	-0.665	-0.606	-0.711
2000	-0.519	-0.832	-0.353	-0.697
2001	-0.400	-0.606	-0.314	-0.502
2002	0.486	-0.494	-0.144	-0.353
2003	-0.298	-0.058	-0.515	-0.294
2004	-0.111	0.234	-0.228	-0.167
2005	0.016	0.322	-0.216	-0.081
2006	0.186	0.404	0.074	0.107
2007	0.310	0.436	0.467	0.483
2008	0.618	0.341	0.789	0.843
2009	0.796	0.594	1.251	1.235
2010	1.045	0.514	1.178	1.563

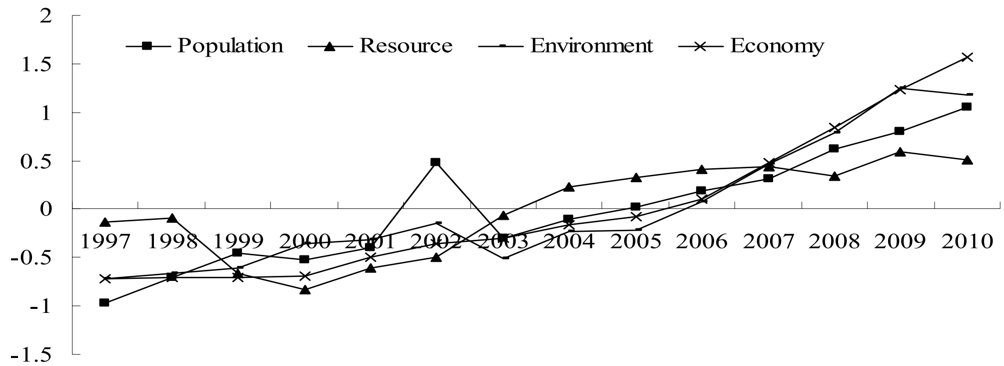

Fig. 2: The integrated development index of population, resource, environment and economy in Heilongjiang province from 1997 to 2010

The comprehensive scores of environment subsystem: $\sum FZ_{i3} = 0.613\ (0.172\ ZX_{i17} + 0.230\ ZX_{i18} + 0.018\ ZX_{i19} + 0.223\ ZX_{i20} + 0.278\ ZX_{i21} - 0.239\ ZX_{i22} + 0.205\ ZX_{i23} + 0.053\ ZX_{i24}) + 0.220\ (0.019\ ZX_{i17} - 0.099\ ZX_{i18} - 0.431\ ZX_{i19} - 0.081\ ZX_{i20} - 0.228\ ZX_{i21} + 0.800\ ZX_{i22} - 0.035\ ZX_{i23} - 0.151\ ZX_{i24}) + 0.128\ (-0.079\ ZX_{i17} - 0.035\ ZX_{i18} + 0.000\ ZX_{i19} + 0.092\ ZX_{i20} + 0.082\ ZX_{i21} - 0.142\ ZX_{i22} + 0.007\ ZX_{i23} + 1.012\ ZX_{i24})$.

The comprehensive scores of economy subsystem: $\sum FZ_{i4} = 0.734\ (0.130\ ZX_{i25} + 0.131\ ZX_{i26} + 0.135\ ZX_{i27} + 0.160\ ZX_{i28} + 0.111\ ZX_{i29} + 0.215\ ZX_{i30} - 0.061\ ZX_{i31} - 0.072\ ZX_{i32} + 0.110\ ZX_{i33} + 0.148\ ZX_{i34} + 0.137\ ZX_{i35}) + 0.180\ (-0.036\ ZX_{i25} - 0.040\ ZX_{i26} - 0.050\ ZX_{i27} - 0.125\ ZX_{i28} + 0.019\ ZX_{i29} - 0.742\ ZX_{i30} - 0.067\ ZX_{i31} + 0.465\ ZX_{i32} + 0.019\ ZX_{i33} - 0.097\ ZX_{i34} - 0.062\ ZX_{i35})$.

Analysis of integrated development index: The comprehensive score reflects the development level of each subsystem. It can be seen in Table 10 and Fig. 2, from 1997 to 2010, each subsystem generally showed an upward tendency in different degrees, but with volatility and stage. The integrated development index of each subsystem was all under 0 before 2001 and all above 0 after 2006, which showed that the comprehensive development level has a significant improvement from 1997 to 2010.

The integrated development index of population subsystem was negative before 2001, positive in 2002, negative in 2003 and 2004, positive after 2005 with rapidly ascending speed, from -0.964 in 1997 to 1.045 in 2010. The main factors influencing population subsystem are the continuing increase in population numbers, the greatly enhanced medical treatment level and the advantage of age structure.

Compared to other subsystems, resource subsystem changed slowly. The integrated development index of resource subsystem was negative before 2003 and positive after 2004. Due to the change of total energy production, energy consumption per unit GDP and clean energy composition, resource subsystem inclined to fluctuation. Heilongjiang Province occupies an important place in resource and energy reserves even in China, but per capita rate still be very low.

Environment subsystem showed the characteristic of phase. The integrated development index of environment subsystem was negative before 2005 and positive after 2006. The large-scale forestation and returning more farmland to forests had raised the forest coverage rate and per capita public greenbelt area, which made an improvement in Heilongjiang Province's environmental condition. However, the environmental situation is not so optimistic because the number of industrial wastes increases constantly and the total investment in environmental protection increased slowly compared with other regions.

Economy subsystem showed a steadily upward tendency. The integrated development index of economy subsystem was negative and relatively low before 2005, but was positive and obviously ascending after 2006, which was increased from -0.72 in 1997 to 1.56 in 2010. This is primarily caused by the growth of economy, adjustment in economic structure, increase of per capita income and enhancement of overall labor productivity.

CONCLUSION

It can be concluded from above results that each subsystem had an increasing tendency in different degrees in general from 1997 to 2010, while showed obvious stage and fluctuant characteristic. Economy subsystem showed a steadily upward tendency. In the future, Heilongjiang Province should continue to improve the internal structure of industry, increase the investment in the fixed assets proportion and raise the quality and level of foreign capital utilization, so as to promote economic development better and faster. Population subsystem developed in good conditions. Hence, Heilongjiang Province should take appropriate measures to promote the sustainable development of population subsystem, such as controlling the population size, improving health conditions, enhancing life quality and increasing investment in education. The score of environment subsystem rose with fluctuation. Therefore, to control the pollution emissions, readjust the distribution of industries, improve the technical transformation, recover waste gas, waste water and industrial residue for multipurpose use and introduce and put more funds in environmental protection, so that the economic development in Heilongjiang Province keeps within environmental bearing capacity. Compared to other subsystems, resource subsystem changed slowly. Heilongjiang Province is rich in resources. Some measures are being taken to promote the sustained yield of resources by rationally utilizing resources, introducing and developing new energy sources, optimizing energy structure by the use of cleaner high-quality energy and gradually reducing energy consumption for unit GDP production.

The conclusions indicated that the development level of overall system will be influenced with the constraints of resource and environment subsystem, although the economy and population subsystem develop in good conditions. The resource of Heilongjiang Province hasn't form the advantage, which has become the bottleneck for the harmonious development of between population, resource, environment and economy. In summary, the degradation of resource and environment system is closely related to economic development and other human activities. If the resource and environment system are beyond theirs capacity, it would inevitably restrict the economic development, which must be paid enough attention to the non-coordinated development of each subsystem.

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