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Original Research Paper

# Grey Relationship Analysis on Ecological Footprint and Economic Growth in China: Based on Environmental Protection Perspective

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## ABSTRACT

Based on the perspective of environmental protection, this paper adopts the Grey relationship analysis method to measure the relationship between ecological footprint of different land types, ecological footprint and economic growth. It is shown that there is strongest consistency between the grassland ecological footprint and the total ecological footprint. Changing tendency consistency between biological resource landÕs ecological footprint and the total ecological footprint is higher than that of energy resource land, the influence of energy resource landÕs ecological footprint on economic growth is stronger than that of biological resource land, and the building landÕs ecological footprint influences economic growth the most strongly.

## THEORETICAL CONNOTATION OF ECOLOGICAL FOOTPRINT

The ecological footprint (EF) is the instrument to measure the human demand for earth renewable natural resources, which contrast the ecological footprint and the renewable ability of the earth (the biological capacity), to track the demand for biosphere. The human activities can not do without the usage of biological productive area. The ecological footprint is the summation of the usage of the biological productive area. The analysis of ecological footprint is benefit to prompt human to pay more attention to the effect of ecological environment to the economic growth. In our country, the longtime extensive economic development devastated the environment, which threat the human's survival and development. The ecological footprint reflects the efficiency of the usage of nature resources, a country's sustainability level, and it also conforms to the current situation of the ecological environment and economic growth in the usage of economic growth theory. It has the practical significance to the analysis of the present economic growth.

In the 1990's, Wackernagel et al. (1997) published the concept of ecological footprint, and our country's study beginning at 1999. As a measure method, which adapt to the modern development concept, has been used widely, although the study of this method has a short time in our country. With the publish of the concepts, sustainable development, green development, ecological security, the effect which ecological footprint developed is becoming more and more obviously in the process of economic development. The economic development is not only about the material development, but also includes the environment protection, the human's development and so on. The longtime extensive economic development brings havoc to the ecological environment, and it also bring the baptism to the new growth path.

According to Bai et al. (2009), besides the defect of trade-correct, the environmental liability of greenhouse gases was ignored when ecological footprint was applied in urban scale. They stated that the standard of urban sustainable development should be redefined based on its regional characteristics, where the city belongs to. Using the ecological footprint model, Zhang et al. (2014), calculated the ecological footprint of the development project on mild slope of low mountains and hills in Songzi City in 2012 and quantitatively reflected the impact of the development process on the ecological environment from all aspects. In Wu et al. (2013) paper, the lands were divided into six major categories based on their ecological footprints, namely, construction land, fishery land, grazing land, forest, cropland and carbon uptake land. Ecological footprint calculation models were used for the calculation of different types of land and the results were converted to normalized numerical calculation of carbon, to obtain a single evaluation indicator of the ecological environment evaluation data, to facilitate management of the ecological environment. Li Zexi et al. (2011) think that from the ecological symbiosis concept, the use of ecological footprint model to evaluate the macro-environment of a region's tourism carrying capacity is a new research method. In this way, they conducted tourism carrying capacity and ecological footprint calculation and analysis of Lhasa, Tibet in 2005-2010, and found that the whole Lhasa City tourism environment in an inconsistent state. The ecological footprint is an ecological method of ecological security assessment, environmental Kuznets curve reflects the law of development of the economic development and resources and environment from an economic point of view. Fu Wei et al. (2013) stated that with the ecological footprint of ten thousand yuan GDP, both of them can give the situation of ecological security of China's northwestern region a comprehensive analysis as Gansu for example. Based on the relative theories and methods of ecological footprint and ecological carrying capacity, and according to practical conditions of Guangdong Province, Liu Qiang et al. (2010) tried to put forward the determinant standard for ecological compensation through calculating the ecological footprint and ecological carrying capacity of every city in Guangdong Province. In Xu Su et al. (2010) paper, to estimate the situation of environment-friendly city of Fuzhou, consumption of residents was quantitatively analysed by the theory of ecological footprint from 2001 to 2006. According to Li Hongli et al. (2010), it is the popular measure to analyse sustainable development state by the way of ecological footprint and ecological capacity; it could be used to assess ecological deficit or ecological surplus of a region or a country, which is the base of ecological modernization. The key to improving overall levels of ecological modernization is improving the regional ecological environment carrying capacity of a system's key components. They used an ecoenvironmental quality index and ecological modernization index to measure the fragile ecological environment of western China's Xinjiang Uygur Autonomous Region, and assessed its ecological footprint and environmental pressure changes.

When we study objective things, there always exists a wide range of gray, which is the information's incompleteness and indetermination. The reason is that the grey system is by the form of objective things, which means, part of the information is known, and part is unknown, for example, the social system, the economic system, the ecological system. When it comes to the object of the comprehensive assessment, we mean, the understanding of the evaluated things, there also exist the grey, so we can take advantage of the theories of the grey system to study the synthetic evaluation problem. The advantage of the GRA is clearness, and to a large extent, it can cut the loss which the information asymmetry brings. Beyond that, the calculation is simple, and the requirement of data is not so strict. In this aspect, the method of GRA has a wide use. Vishnu & Syamala (2012) used the grey system theory and GM model to predict the mid and long-term stream flow. Grey system is applicable in the case of unclear interrelationship, uncertain mechanisms and insufficient information and requires only small samples for parameter estimation. Ali Mohammadi et al. (2011) consider the complexity and uncertainty of the influencing factors on traffic accident, they think the traffic accident forecasting can be regarded as a grey system with unknown and known information, so be analysed by grey system theory. Then use the GM model and the grey system to predict the road traffic accident in Pars province. Fu Yan (2014) used the GRA to analyse the correlation of the economic growth and energy consumption in china, and put forward the development strategy to promote the economic development and energy conservation by two analyses, one is the GRA of economic growth and energy consumption of the industrial structure, and the other is the GRA of economic growth and varieties of energy consumption structure. Chen Youyu (2013) used the GRA to analyse the factor of the economic growth, design the grey correlation sorting table. The result shows that the consumption habit, industrial structure and domestic trade development level have the strong influence to the economic growth, and the sanitary level, the quantity of labour force and urban and rural structure have the weak influence. Ma Qimao & Yan Lidong (2013) analysed the GRA between the production value of the agriculture, forest, fishery, animal husbandry and the gross output in 11 years, then come to the association of the agriculture, forest, fishery, animal husbandry and the gross output, and published a series of policy recommendations. Thus, it can be seen that there are a lot of studies which used the GRA to analyse the economic growth factors. But as a new measuring standard, there are few studies which were based on the ecological footprint to analyse the economic growth. So, in this paper, from the angle of the ecological footprint, combine the GRA, to analyse the relationship of the ecological footprint and the different land structures of ecological footprint, the relationship of the ecological footprint and the GDP, then, analyse that how the different land structures of ecological footprint influenced the total ecological footprint, and the influence between the change of ecological footprint and the economic growth.

## GRA METHOD AND DATA PREPROCESSING

The association is the measurement of the correlation which the factors changed with time or the different objects between two different systems. In the process of system development, if the variation trend of the two factors is consensus, the synchronization of variations is high, this means, that the degree of association is high. On the contrary, the degree of association is low. So, the GRA is the method to measure the association of the factors, which is based on the similar or diversity level of the development tendency between the factors.

We usually follow the following steps to conduct Grey Relationship Analysis.

**Determine the analysis sequence:** Based on the qualitative analysis of the research question, determine one dependent variable factors and multiple independent variable factors. Then the dependent variable data constitute the reference sequence $X_0^{'}$, the independent variable factors constitute the comparative sequence, $n+1$ data sequences constitute the matrix as follows:

$$\left(X_0^{'}, X_1^{'}, \cdots, X_n^{'}\right) = \begin{pmatrix} x_0^{'}(1) & x_1^{'}(1) & \cdots & x_n^{'}(1) \\ x_0^{'}(2) & x_1^{'}(2) & \cdots & x_n^{'}(2) \\ \vdots & \vdots & & \vdots \\ x_0^{'}(N) & x_1^{'}(N) & \cdots & x_n^{'}(N) \end{pmatrix}_{N\times(n+1)} \quad ...(1)$$

Where, $\left(x_i^{'}(1), x_i^{'}(2), \cdots, x_i^{'}(N)\right)^T, i = 0,1,2,\cdots,n$, $N$ is the length of the random variable.

**Non-dimensionalization of the random variable:** Normally, the original variable sequence has different dimension or orders of magnitude. In order to ensure the reliability of the analysis results, we need to nondimensionalize the random variable. After the nondimensionalization, the factor variables formation the matrix as follows:

$$\left(X_0, \mathrm{X}_1, \cdots, X_n\right) = \begin{pmatrix} x_0(1) & x_1(1) & \cdots & x_n(1) \\ x_0(2) & x_1(2) & \cdots & x_n(2) \\ \vdots & \vdots & & \vdots \\ x_0(N) & x_1(N) & \cdots & x_n(N) \end{pmatrix}_{N\times(n+1)} \quad ...(2)$$

The common nondimensionalization methods are equalization method (3) and initialization method (4).

$$x_i(k) = \frac{x_i^{'}(k)}{\frac{1}{N}\sum_{k=1}^{N} x_i^{'}(k)} \quad i = 0,1,\cdots,n; k = 1,2,\cdots,N \quad ...(3)$$

$$x_i(k) = \frac{x_i^{'}(k)}{x_i^{'}(1)} \quad i = 0,1,\cdots,n; k = 1,2,\cdots,N \quad ...(4)$$

**Calculate the difference sequence, max difference and min difference:** Calculate (2) the absolute difference between the first column (reference sequence) and the rest corresponding of the columns (comparative sequence), the difference between these two format the absolute difference matrix:

$$\begin{pmatrix} \Delta_{01}(1) & \Delta_{02}(1) & \cdots & \Delta_{0n}(1) \\ \Delta_{01}(2) & \Delta_{02}(2) & \cdots & \Delta_{0n}(2) \\ \vdots & \vdots & & \vdots \\ \Delta_{01}(N) & \Delta_{02}(N) & \cdots & \Delta_{0n}(N) \end{pmatrix}_{N\times n}$$

Where, $\Delta_{0i}(k) = \left|x_0(k) - x_i(k)\right|$

$$i = 0,1,\cdots,n; k = 1,2,\cdots,N \quad ...(5)$$

In the absolute difference matrix, the maximum number and the minimum number is max difference and the min difference:

$$\max_{\substack{1\le i\le n \\ 1\le k\le N}} \left\{\Delta_{oi}(k)\right\} = \Delta(\max) \quad ...(6)$$

$$\min_{\substack{1\le i\le n \\ 1\le k\le N}} \left\{\Delta_{oi}(k)\right\} = \Delta(\min) \quad ...(7)$$

**Calculate the correlation coefficient:** Change the data in the absolute difference matrix as follows:

$$\xi_{oi}(k) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_{oi}(k) + \rho\Delta(\max)} \quad ...(8)$$

Then we get the matrix of the correlation coefficient:

$$\begin{pmatrix} \xi_{01}(1) & \xi_{02}(1) & \cdots & \xi_{0n}(1) \\ \xi_{01}(2) & \xi_{02}(2) & \cdots & \xi_{0n}(2) \\ \vdots & \vdots & & \vdots \\ \xi_{01}(N) & \xi_{02}(N) & \cdots & \xi_{0n}(N) \end{pmatrix}_{N\times n} \quad ...(9)$$

In this equation, resolution ratio $\rho$ values from 0 to 1, and in general condition, we value from 0.1 to 0.5 in accordance to the data information in (9). The smaller the $\rho$, the higher the difference between the correlation coefficient. The correlation coefficient $\xi_{0i}(k)$ is positive number less than 1, and it reflects the interdependence degree of the comparative sequence $X_i$ and the reference sequence $X_0$ in the $k$ times.

**Calculate the association degree:** The association degree of the comparative sequence $X_i$ and the reference sequence is $X_0$ reflected by the correlation coefficients. Then, calculate the average value to get the association degree of $X_i$ and $X_0$.

Table 1: The selection of the ecological footprint index.

| Account | The ecological footprint index | Consume resources |
|---|---|---|
| Biological resources account | Cultivated land | Cereal, beans, potato, cotton, oil plants, fibre crops, basudin, beet, tobacco, co coon, tea, eggs |
| | Forest land | Wood, bancoul nut, tea seed, walnut, fruit |
| | Water area | Sea food |
| | Grassland | Pork, beef, mutton, milk, wool, honey |
| Energy resources account | Fossil fuel land | Coal, crude oil, natural gas |
| | Building land | Electric power |

Note: the information was gathered from the WWF classification standards.

Table 2: The ecological footprint of all land types from 2001 to 2012; Unit: tenthousand $hm^2$.

| Year | Total | Cultivated land | Forest land | Grassland | Water area | Fossil energy land | Building land |
|---|---|---|---|---|---|---|---|
| 2001 | 25220977.0 | 20805.6 | 2688384.6 | 22320811.4 | 130893.9 | 59947.9 | 133.6 |
| 2002 | 25884211.0 | 21369.1 | 2634585.5 | 23027911.1 | 136374.4 | 63833.0 | 137.8 |
| 2003 | 28149729.1 | 20176.4 | 2767643.5 | 25147450.0 | 140587.0 | 73730.7 | 141.5 |
| 2004 | 30887486.0 | 22020.4 | 3021796.2 | 27611553.7 | 146433.4 | 85513.0 | 169.3 |
| 2005 | 32317827.1 | 22451.9 | 3199325.7 | 28849728.0 | 152409.1 | 93722.4 | 190.0 |
| 2006 | 32831006.8 | 23286.2 | 3745087.6 | 28801785.8 | 158055.2 | 102586.9 | 205.2 |
| 2007 | 31189589.6 | 23526.0 | 3926966.7 | 26964275.2 | 163707.6 | 110888.3 | 225.8 |
| 2008 | 32479140.1 | 25172.7 | 4513271.1 | 27657662.0 | 168813.7 | 113954.9 | 265.7 |
| 2009 | 32130989.3 | 24964.7 | 4052164.9 | 27757600.7 | 176427.7 | 119548.1 | 283.2 |
| 2010 | 33729541.1 | 25377.0 | 4559537.0 | 28832520.4 | 185275.9 | 126499.8 | 330.9 |
| 2011 | 34416138.7 | 26483.6 | 4718715.2 | 29341333.8 | 193214.1 | 136062.4 | 329.6 |
| 2012 | 34992054.5 | 27329.0 | 4812559.3 | 29808368.4 | 203713.0 | 139682.1 | 402.6 |

Table 3: The result of the non-dimensionalize.

| Year | $X_0$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|---|
| 2001 | 0.809 | 0.882 | 0.723 | 0.821 | 0.803 | 0.587 | 0.569 |
| 2002 | 0.830 | 0.906 | 0.708 | 0.847 | 0.837 | 0.625 | 0.587 |
| 2003 | 0.903 | 0.856 | 0.744 | 0.925 | 0.863 | 0.722 | 0.603 |
| 2004 | 0.990 | 0.934 | 0.812 | 1.016 | 0.898 | 0.837 | 0.722 |
| 2005 | 1.036 | 0.952 | 0.860 | 1.062 | 0.935 | 0.917 | 0.810 |
| 2006 | 1.053 | 0.988 | 1.007 | 1.060 | 0.970 | 1.004 | 0.875 |
| 2007 | 1.000 | 0.998 | 1.056 | 0.992 | 1.004 | 1.085 | 0.963 |
| 2008 | 1.041 | 1.068 | 1.213 | 1.018 | 1.036 | 1.115 | 1.133 |
| 2009 | 1.030 | 1.059 | 1.089 | 1.021 | 1.082 | 1.170 | 1.207 |
| 2010 | 1.082 | 1.076 | 1.226 | 1.061 | 1.137 | 1.238 | 1.410 |
| 2011 | 1.104 | 1.123 | 1.268 | 1.080 | 1.185 | 1.332 | 1.405 |
| 2012 | 1.122 | 1.159 | 1.294 | 1.097 | 1.250 | 1.367 | 1.716 |

$$\gamma_{0i} = \frac{1}{N}\sum_{k=1}^{N}\xi_{0i}(k) \qquad \text{...(10)}$$

**Rank by the association degree:** Rank the association degree of the comparative sequence and the reference sequence lowest to sort. The association degree is bigger, the change trend of the comparative sequence and the reference sequence is more consensus.

In this paper, the selections of the specific ecological footprint index are choosing from the classification standard in WWF (Table 1).

The data are collected from the China Statistical Yearbook 2013, and use the computational formulate of the ecological footprint:

$$EF = N \cdot ef = N\sum(\alpha a_i) = N\sum\left(\alpha \frac{c_i}{p_i}\right)$$

Where,

*EF* is the whole ecological footprint; *N* is the population; *ef* is the per ecological footprint ($hm^2.cap^{-1}$); α is proportional factor; *i* is the type of consumption goods and input; $a_i$ is the per ecological productive area that the I consumer good need to occupied; $c_i$ is the per annual consumption of *i* consumption good ($kg.cap^{-1}$); $p_i$ is the annual average productivity ($kg.hm^{-2}$) of the I consumption good by the relevant ecological productive area produced.

The calculated results of the ecological footprint are given in Table 2

## GRA OF LAND TYPES AND THE TOTAL OF THE ECOLOGICAL FOOTPRINT

When analyse the GRA of the land types and the total of the ecological footprint, we take the total ecological footprint as the dependent variable factor, and the land types ecological footprint as the independent variable factors. And then, take the total ecological footprint as the reference sequence $X'_0$, the land types ecological footprint as the comparative sequence $X'_i$, thereinto, the ecological footprint of the cultivated land is $X'_1$, the ecological footprint of the forest land is $X'_2$, the ecological footprint of the grassland is $X'_3$, the ecological footprint of the water area is $X'_4$, the ecological footprint of the fossil energy land is $X'_5$, and the ecological footprint of the building land is $X'_6$.

In this part, we use the equalization method (3) to dimensionless the variables sequence. The characteristic of this method is eliminating the influence of the extreme values, as use the original data divided the average value. The result is shown in Table 3.

Calculate the absolute difference of the first list ($X_0$) and the corresponding rest list ($X_i$) in the Table 3. The computation is shown in Table 4.

In this paper, we choose the resolution ratio $\rho = 0.4$. The relationship coefficient is shown in Table 5. The Table 5 indicates that the correlation coefficient of the biological land is relatively high and overall, the correlation coefficient of the energy land is generally low.

Calculate the degree of the association. Rank the association degree by the data in the Table 6. The result is $\gamma_{06} \prec \gamma_{05} \prec \gamma_{02} \prec \gamma_{04} \prec \gamma_{01} \prec \gamma_{03}$. In this case, $\gamma_{03}$ is the biggest one, it means that the association degree of the change of the grassland's ecological footprint and the change of the total's is biggest, the change trend of the two is more consensus. $\gamma_{06}$ is the smallest one, it means that the association d egree of the change of the building land's ecological footprint and the change of the total's is smallest, the change trend of the two is weaker. On the whole, the association degree of the change of the biological land's ecological footprint and the total's ecological footprint is higher than the association degree of the energy land's and the total's ecological footprint.

## GRA OF THE ECOLOGICAL FOOTPRINT AND THE ECONOMIC GROWTH

What the ecological footprint reflects is the occupation of natural resources. It is an analysis method to measure the demand of the earth's ecosystems and the natural resources. Under the condition of the existing technology, within the specified population units, how much land and water which have the biological productivity we need, to produce the required resources and absorb the derived waste. So, when the value of the ecological footprint is smaller, the occupation of the natural resource is less. When it comes to the GRA of the ecological footprint and the economic growth, we must take the actual change into consideration.

When analyse the grey relational degree of the ecological footprint and the economic growth, we take GDP as the independent variable factor, that is reference sequence $X'_0$, take the land types' ecological footprint as the independent variable factors, that is comparative sequence $X'_i$; in this case, the ecological footprint of the cultivated land is $X'_1$, the ecological footprint of the forest land is $X'_2$, the ecological footprint of the grass land is $X'_3$, the ecological footprint of the water area is $X'_4$, the ecological footprint of the fossil energy land is $X'_5$, the ecological footprint of the building land is $X'_6$.

In this part, we choose the initialization method to analyse the grey relational degree of the ecological footprint and the economic growth. The characteristic of this method is unity, as take the data of the first year as the base period data, then use the every period data divide the base period data. The result are given in Table 7.

Calculate the absolute difference of the first list ($X'_0$) and the corresponding rest list ($X'_i$) in the Table 3. The computation is given in Table 8. In this paper, we choose the resolution ratio $\rho = 0.4$. The relationship coefficient is as given in Table 9. In this Table, it is indicate that the downtrend is obvious for the grey relational coefficient of the land types ecological footprint and the economic growth, and the downtrend speed of the building land is slow, while the others are quick.

On the base of the Table 10, we rank the grey relational degree of the ecological footprint and the economic growth, the result is $\gamma_{01} \prec \gamma_{04} \prec \gamma_{03} \prec \gamma_{02} \prec \gamma_{05} \prec \gamma_{06}$. This result indicates that the grey relational degree of the building land's ecological footprint and the economic growth is the biggest, the energy land's is less than it, and the grey relational degree of the forest land, grassland, water land's ecological

Table 4: The difference sequences.

| Year | $\Delta_{01}$ | $\Delta_{02}$ | $\Delta_{03}$ | $\Delta_{04}$ | $\Delta_{05}$ | $\Delta_{06}$ |
|---|---|---|---|---|---|---|
| 2001 | 0.0736 | 0.0861 | 0.0126 | 0.0057 | 0.2220 | 0.2394 |
| 2002 | 0.0762 | 0.1218 | 0.0173 | 0.0067 | 0.2052 | 0.2426 |
| 2003 | 0.0470 | 0.1587 | 0.0227 | 0.0401 | 0.1810 | 0.2997 |
| 2004 | 0.0566 | 0.1781 | 0.0256 | 0.0920 | 0.1534 | 0.2686 |
| 2005 | 0.0842 | 0.1763 | 0.0253 | 0.1012 | 0.1189 | 0.2264 |
| 2006 | 0.0652 | 0.0460 | 0.0070 | 0.0830 | 0.0486 | 0.1781 |
| 2007 | 0.0024 | 0.0555 | 0.0079 | 0.0043 | 0.0853 | 0.0375 |
| 2008 | 0.0261 | 0.1718 | 0.0238 | 0.0058 | 0.0739 | 0.0911 |
| 2009 | 0.0284 | 0.0590 | 0.0089 | 0.0521 | 0.1398 | 0.1768 |
| 2010 | 0.0054 | 0.1441 | 0.0206 | 0.0551 | 0.1566 | 0.3288 |
| 2011 | 0.0195 | 0.1649 | 0.0239 | 0.0818 | 0.2282 | 0.3015 |
| 2012 | 0.0369 | 0.1716 | 0.0252 | 0.1278 | 0.2452 | 0.5940 |

In this table, the maximum difference Δ (max)= 0.5940; The minimum difference (min) = 0.0024

Table 5: Correlation coefficient.

| Year | $\xi_{01}$ | $\xi_{02}$ | $\xi_{03}$ | $\xi_{04}$ | $\xi_{05}$ | $\xi_{06}$ |
|---|---|---|---|---|---|---|
| 2001 | 0.7713 | 0.7416 | 0.9594 | 0.9867 | 0.5223 | 0.5032 |
| 2002 | 0.7648 | 0.6679 | 0.9415 | 0.9825 | 0.5421 | 0.4998 |
| 2003 | 0.8434 | 0.6057 | 0.9222 | 0.8643 | 0.5735 | 0.4467 |
| 2004 | 0.8159 | 0.5774 | 0.9121 | 0.7282 | 0.6139 | 0.4741 |
| 2005 | 0.7460 | 0.5800 | 0.9131 | 0.7084 | 0.6732 | 0.5173 |
| 2006 | 0.7926 | 0.8463 | 0.9811 | 0.7486 | 0.8386 | 0.5774 |
| 2007 | 1.0000 | 0.8189 | 0.9775 | 0.9924 | 0.7434 | 0.8726 |
| 2008 | 0.9104 | 0.5863 | 0.9183 | 0.9863 | 0.7705 | 0.7301 |
| 2009 | 0.9023 | 0.8093 | 0.9736 | 0.8285 | 0.6359 | 0.5792 |
| 2010 | 0.9879 | 0.6288 | 0.9294 | 0.8199 | 0.6089 | 0.4238 |
| 2011 | 0.9334 | 0.5964 | 0.9177 | 0.7514 | 0.5153 | 0.4452 |
| 2012 | 0.8743 | 0.5865 | 0.9133 | 0.6569 | 0.4972 | 0.2886 |

Table 6: The association degree.

| $\gamma_{01}$ | $\gamma_{02}$ | $\gamma_{03}$ | $\gamma_{04}$ | $\gamma_{05}$ | $\gamma_{06}$ |
|---|---|---|---|---|---|
| 0.8619 | 0.6704 | 0.9383 | 0.8378 | 0.6279 | 0.5299 |

Table 7: The result of the non-dimensionalize.

| Year | $X_0$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|---|
| 2001 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2002 | 1.0479 | 1.0271 | 0.9800 | 1.0317 | 1.0419 | 1.0648 | 1.0317 |
| 2003 | 1.1014 | 0.9698 | 1.0295 | 1.1266 | 1.0741 | 1.2299 | 1.0591 |
| 2004 | 1.3568 | 1.0584 | 1.1240 | 1.2370 | 1.1187 | 1.4265 | 1.2678 |
| 2005 | 1.4207 | 1.0791 | 1.1901 | 1.2925 | 1.1644 | 1.5634 | 1.4227 |
| 2006 | 1.5233 | 1.1192 | 1.3931 | 1.2904 | 1.2075 | 1.7113 | 1.5364 |
| 2007 | 1.8140 | 1.1308 | 1.4607 | 1.2080 | 1.2507 | 1.8497 | 1.6909 |
| 2008 | 2.1356 | 1.2099 | 1.6788 | 1.2391 | 1.2897 | 1.9009 | 1.9894 |
| 2009 | 2.2321 | 1.1999 | 1.5073 | 1.2436 | 1.3479 | 1.9942 | 2.1203 |
| 2010 | 2.5685 | 1.2197 | 1.6960 | 1.2917 | 1.4155 | 2.1102 | 2.4773 |
| 2011 | 3.0090 | 1.2729 | 1.7552 | 1.3145 | 1.4761 | 2.2697 | 2.4680 |
| 2012 | 3.3187 | 1.3135 | 1.7901 | 1.3355 | 1.5563 | 2.3301 | 3.0143 |

Table 8: The difference sequence.

| Year | $\Delta_{01}$ | $\Delta_{02}$ | $\Delta_{03}$ | $\Delta_{04}$ | $\Delta_{05}$ | $\Delta_{06}$ |
|---|---|---|---|---|---|---|
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 0.0208 | 0.0679 | 0.0162 | 0.0060 | 0.0169 | 0.0161 |
| 2003 | 0.1317 | 0.0719 | 0.0252 | 0.0274 | 0.1285 | 0.0423 |
| 2004 | 0.2985 | 0.2328 | 0.1198 | 0.2381 | 0.0696 | 0.0890 |
| 2005 | 0.3415 | 0.2306 | 0.1282 | 0.2563 | 0.1427 | 0.0020 |
| 2006 | 0.4041 | 0.1303 | 0.2330 | 0.3158 | 0.1879 | 0.0131 |
| 2007 | 0.6832 | 0.3533 | 0.6060 | 0.5633 | 0.0358 | 0.1231 |
| 2008 | 0.9257 | 0.4568 | 0.8965 | 0.8459 | 0.2347 | 0.1461 |
| 2009 | 1.0322 | 0.7249 | 0.9886 | 0.8843 | 0.2379 | 0.1118 |
| 2010 | 1.3487 | 0.8724 | 1.2767 | 1.1530 | 0.4583 | 0.0911 |
| 2011 | 1.7361 | 1.2538 | 1.6945 | 1.5329 | 0.7393 | 0.5410 |
| 2012 | 2.0052 | 1.5286 | 1.9833 | 1.7624 | 0.9887 | 0.3044 |

In this table, the maximum difference Δ (max)= 2.0052; The minimum difference (min) = 0

Table 9: The correlation coefficient.

| Year | $\xi_{01}$ | $\xi_{02}$ | $\xi_{03}$ | $\xi_{04}$ | $\xi_{05}$ | $\xi_{06}$ |
|---|---|---|---|---|---|---|
| 2001 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2002 | 0.9747 | 0.9220 | 0.9802 | 0.9926 | 0.9793 | 0.9803 |
| 2003 | 0.8590 | 0.9177 | 0.9695 | 0.9670 | 0.8619 | 0.9499 |
| 2004 | 0.7288 | 0.7750 | 0.8700 | 0.7711 | 0.9201 | 0.9001 |
| 2005 | 0.7013 | 0.7767 | 0.8622 | 0.7578 | 0.8489 | 0.9975 |
| 2006 | 0.6650 | 0.8603 | 0.7749 | 0.7175 | 0.8102 | 0.9840 |
| 2007 | 0.5400 | 0.6942 | 0.5696 | 0.5874 | 0.9573 | 0.8670 |
| 2008 | 0.4642 | 0.6372 | 0.4722 | 0.4867 | 0.7736 | 0.8459 |
| 2009 | 0.4373 | 0.5253 | 0.4479 | 0.4756 | 0.7712 | 0.8776 |
| 2010 | 0.3729 | 0.4790 | 0.3858 | 0.4103 | 0.6364 | 0.8980 |
| 2011 | 0.3160 | 0.3901 | 0.3213 | 0.3435 | 0.5203 | 0.5972 |
| 2012 | 0.2857 | 0.3441 | 0.2880 | 0.3128 | 0.4479 | 0.7249 |

Table 10: The association degree.

| $\gamma_{01}$ | $\gamma_{02}$ | $\gamma_{03}$ | $\gamma_{04}$ | $\gamma_{05}$ | $\gamma_{06}$ |
|---|---|---|---|---|---|
| 0.6121 | 0.6935 | 0.6618 | 0.6519 | 0.7939 | 0.8852 |

footprint and the economic growth are at the same level, and occupy the middle level. The grey relational degree of the cultivated land's ecological footprint and the economic growth is the lowest.

## CONCLUSION

Based on the perspective of environmental protection, this paper adopts the Grey Relationship Analysis (GRA) method to measure the relationship between ecological footprint of different land types, ecological footprint and economic growth. Through the above analysis, we can draw the following conclusions:

Different land type's ecological footprint have different influence on the total ecological footprint and hence to our environment. The grey relational degree of the grass land's ecological footprint and the total ecological footprint, the change trend of the two is stronger. The reason is that in the six land types, the use ratio of the grassland is highest, and the biological growth cycle is shorter. The consistency of the change trend of the biological resources' ecological footprint and the total ecological footprint is higher than the energy resources', the reason is the cover area of the biological resources is larger, its proportion in the ecological footprint is also large. And the energy resources for a small proportion and there is the problem of non-human resources wastage, so this type lands' ecological footprint has weaker influence on the total ecological footprint.

Through its influence on our environment, different type land's ecological footprint have different influences on the economic growth. The study shows that, the grey relational degree of the building land's ecological footprint and the economic growth is the largest, and the fossil energy land's is little than it, and the grey relational degree of the forest land, grassland, water land's ecological footprint and the economic growth are at the same level and occupy the middle level. The grey relational degree of the cultivated land's ecological footprint and the economic growth is the lowest. The bigger grey relational degree of the ecological footprint and the economic growth means the greater influence on the economic growth.

The reason for this result is that in the process of the production and usage, the economic benefit, which is produced by energy resources, is higher than the biological resources. And with the improving science and technology level, the utilization of the new energy resources is becoming more common, so its influence on the economic growth is higher than the biological resources.

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