Research and Prediction of Ecological Security in Jiangsu Province Based on the Ecological Footprint

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Abstract According to the 2000 –2010 *Jiangsu Statistical Yearbook*, per capita ecological footprint and per capita ecological carrying capacity in Jiangsu Province in the years 2001 –2009 are analyzed starting from the ecological footprint model. Per capita ecological deficit is measured, as well as the pressure index of ecological footprint in order to judge the grade of ecological security and to objectively evaluate the ecological security of Jiangsu Province. GM(1,1) grey forecasting model is used to forecast the ecological security of Jiangsu Province in the years 2010 –2014. Research shows that in the next 5 years, both the per capita ecological footprint and the pressure index of ecological footprint will increase by 4% and 3.7% each year, respectively. And the ecological status in Jiangsu Province will be extremely unsafe. To achieve the coordinated development of ecological security and economy of Jiangsu Province, we should strictly control the population growth, rationally utilize the land resources, and strengthen the ecological restoration and construction.

Key words Ecological footprint, Ecological security, Jiangsu Province, Forecast, GM(1,1), China

Since the industrial revolution, the extent of environmental damage is expanded by human activities with the sustainable development of modern civilization. Therefore, how to maintain the sustainable development has become one of the strategic emphases in China in recent years. As the prerequisite and basis for sustainable development, ecological security has received increasing attention. It is not only closely related to the survival safety of human in future, but also is as importance as the military security, economic security, political security, and national security. Thus, ecological security becomes a research hotspot in recent years at home and abroad.

Ecological security refers to a status of people with no threats of healthy, basic rights, necessary resources, social order, sources of livelihood security, and the ability of humans to adapt to environmental change. It includes three aspects of ecological security, economic and ecological security, and social and ecological security, which constitute a composite artificial ecological security system[1]. In the current evaluation method of ecological security, ecological economics method is the most popular method when analyzing the ecological carrying capacity, among which ecological footprint is the most representative one[2-3]. This research uses ecological footprint model to calculate the ecological footprint change of Jiangsu Province in the years 2001 –2009, evaluate the level of ecological security of Jiangsu Province by measuring the ecological deficit/surplus and the ecological footprint pressure index, forecast the status of ecological security of Jiangsu Province in the next five years by using grey model GM(1,1), and provide scientific basis for the sustainable development of ecology and society.

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1 Data source, research method and index selection

1.1 Data source Data are mainly from the 2000 –2010 *Jiangsu Statistical Yearbook.*

1.2 Research method Ecological footprint model is used to measure the per capita ecological footprint and per capita ecological carrying capacity. GM(1,1) grey forecasting model is used to forecast the ecological security of Jiangsu Province in the years 2010 –2014.

1.2.1 The basic theories of ecological footprint model. Ecological footprint analysis method evaluates the ecological security and sustainability of a region from the aspects of demand and supply. Ecological footprint is the demand party of this method and ecological carrying capacity is the supply party of this method. According to the productive land area, ecological footprint model measures the resource consumption and waste absorption levels of economic subject, which reflects the consumption and demand status of resources in a certain region[4].

1.2.1.1 Calculation of per capita ecological footprint. Calculation of ecological footprint consists of three parts, which are the consumption of biological resources, the consumption of energy, and the part of trade adjustment. Due to the lack of relevant trade data in statistical data, we can not calculate the part of trade adjustment. Therefore, this research divides the ecological footprint of Jiangsu Province into two parts, which are the consumption of biological resources and the consumption of energy. Among the 6 types of biological productive land of ecological footprint, consumption of biological resources mainly refers to the consumption of cultivated land, grassland, water area and woodland; and the consumption of energy mainly includes the consumption of fossil fuel land and construction land. In the account of cultivated land, accounting item has in all 6 products of cultivated land, including grain, wheat, peanut, corn, cotton, and vegetable. The accounting project of grassland has in all 6 products, such as pork, beef, mutton, egg, milk and honey. Forestland account considers the fruit and tea. The accounting project of fossil fuel land has 6 items of coke, crude oil, gasoline, kerosene, diesel fuel, and fuel oil. The account of water area only considers the output of aquatic products. And the account of construction land mainly considers the electric power. In order to make it more continent to compare the calculation results of regions and countries, production area conversion of biological resources adopts the world average production data of biological resources in the year 1993 provided by the Food and Agriculture Organization of the United Nations. Heat consumption by energy is converted into the fossil fuel land by taking the world average heat of per unit fossil fuel land as the standard[5-6].

In order to compare the biological productive land, equivalence factor must be multiplied in order to turn it into a comparable biological productive area. The equivalence factor uses the results of World Wildlife Fund International. The equivalence factors values of cultivated land, grassland, woodland, water area, construction land and fossil fuel land are 2.17, 0.47, 1.35, 0.35, 2.17 and 1.35, respectively[7].

The calculation equation of ecological footprint demand is

$$EF = Nr_i\sum_{i=1}^{n}(aa_i) = N \cdot r_i\sum_{i=1}^{n}C_i/P_i \quad (1)$$

$$ef = \frac{EF}{N} \quad (2)$$

where EF is the overall ecological footprint, $i=1,2,\cdots n$, $j=1,2,\cdots 6$, N is the total population, ef is the per capita ecological footprint, aa_i is the per capita biological productive area converted from the ith trading commodity, C_i is the per capita consumption of the ith land type, P_i is the average production capacity of the ith material, i is the type of consumption commodity and input, j is the type of biological productive area, and r_j is equivalence factor.

1.2.1.2 Calculation of per capita ecological carrying capacity. According to the data of land use status of research region, the ecological productive area that the region can supply and the per capita ecological productive area are calculated. Due to the great differences in the ecological productivity, equivalence factor must be multiplied in order to make the calculation result more comparable and to turn into the biological productive area. Then, a yield factor is multiplied in order to obtain the per capita ecological carrying capacity in research region. Based on this, the deduction of 12% biodiversity protection area is carried out, in order to obtain the available per capita ecological carrying capacity. Among them, yield factor adopts the value of ecological footprint in Hengshui City by Liu Jianfeng. The values of cultivated land, grassland, woodland, water area, construction land, and fossil fuel land are 1.66, 0.19, 0.91, 1.00, 1.66 and 0, respectively[8].

The calculation equation of ecological carrying capacity is

$$EC = N\sum_{j=1}^{6}a_j r_j y_j \quad (3)$$

$$ec = \frac{EC}{N} \quad (4)$$

where EC is the overall ecological carrying capacity, $j=1,2,\cdots 6$, ec is the per capita ecological carrying capacity, N is the population, a_j is the jth ecological productive land area per capita, r_j is the equivalence factor, y_j is the output factor, j is the type of ecological productive land area.

1.2.2 Forecast method of GM(1,1) grey forecasting model[9]. Assuming that the original series arrange themselves into time series $X_t(t=0,1,2,\cdots,n)$. X_t is the original sequence of time period t. The specific steps are as follows:

(1) Generate sequence Y_t. Grey theory carries out accumulative generation of irregular original data according to equation (6). Thus, they are turned into relatively regular sequence Y_t.

$$Y_t = \sum_{i=0}^{t}X_i \quad (t=0,1,2,\cdots,n) \quad (5)$$

(2) Moving average of the accumulated generating data Y_t is conducted according to equation (7) in order to obtain Z_t:

$$Z_t = \frac{1}{2}(Y_t + Y_{t+1}) \quad (t=0,1,2,\cdots,n) \quad (6)$$

(3) Establish GM(1,1) model. The first order linear differential equation of y_t is:

$$\frac{Dy_t}{dt} + \alpha y_t = \mu \quad (7)$$

Equation (8) is the GM(1,1) model, where α and μ are specific coefficients. According to the solving method of differential equation, we have

$$y_T = (X_0 - \frac{\mu}{\alpha})e^{-\alpha t} + \frac{\mu}{\alpha} \quad (t=0,1,2,\cdots,n) \quad (8)$$

where X_0 is the original data at initial time.

(4) Measure the α and μ. Parameters are estimated according to the least square method:

$$\alpha = [(\sum_{t=1}^{n}X_t)(\sum_{t=1}^{n}Z_t) - n(\sum_{t=1}^{n}Z_t X_t)]/D \quad (9)$$

$$\mu = [(\sum_{t=1}^{n}Z_t^{\ 2})(\sum_{t=1}^{n}X_t) - (\sum_{t=1}^{n}Z_t)(\sum_{t=1}^{n}Z_t X_t)]/D \quad (10)$$

$$D = n(\sum_{t=1}^{n}Z_t^{\ 2}) - (\sum_{t=1}^{n}Z_t)^2 \quad (11)$$

(5) Calculate the predictive value.

$$\hat{X}_t = y_t - y_{t-1} \quad (12)$$

(6) Calculate the posterior error ratio C. C value is the statistics for forecasting the accuracy. $C<0.35$ indicates that the fitting accuracy of the model is good

$$C = S_1/S_2 \quad (13)$$

$$S_1 = \sqrt{\frac{\sum_{t=1}^{n}(\delta_{(t)} - \delta)^2}{n}} \quad (14)$$

$$\delta_{(t)} = X_t - \hat{X}_t \quad (15)$$

$$S_2 = \sqrt{\frac{\sum_{t=1}^{n}(X_t - \bar{X})^2}{n}} \quad (16)$$

1.3 Index selection In order to reasonably evaluate the status of ecological security, we select the per capita ecological deficit/surplus, and ecological pressure index as the indices to evaluate the ecological security and to further determine the ecological security level of research region.

1.3.1 The per capita ecological deficit/surplus. When the per capita ecological footprint is greater than the per capita ecological carrying capacity, the human complex in this region has exceeded the ecological capacity. Thus, per capita ecological deficit will occur and its value is equal to the difference between the per capita ecological footprint and the per capita ecological carrying capacity. It can be concluded that the ecological security of this region will be threatened in this region. When the demand for per capita ecological footprint is smaller than the per capita ecological carrying capacity, the ecological capacity of this region can maintain the human complex. Thus, the per capita ecological surplus will occur and its value is equal to the difference between the per capita ecological footprint and the per capita ecological carrying capacity. It can be concluded that the ecological security is safe in this region.

1.3.2 The pressure index of ecological footprint. The pressure index of ecological footprint refers to the ecological footprint of per unit carrying area. It is used to reflect the pressure on ecological environment. And its equation is

$$EFI=\frac{EF}{EC} \quad (17)$$

where *EFI* is the pressure index of ecological footprint, *EF* is ecological footprint, *EC* is ecological carrying capacity. When $0<EFI<1$, we have $EF<EC$, indicating that the ecological resources supply is greater than the demand and the region is at the status of ecological security. When $EFI=1$, we have $EF=EC$, indicating the balance between supply and demand of ecological resources and the ecological security is at the critical status. When $EFI>1$, we have $EF>EC$, showing that ecological demand is greater that the ecological supply and the region is at a status of insecurity.

1.3.3 The level of ecological security. According to the *Living Planet Report* in the year 2004 by the International Monetary Fund, calculation results of the ecological footprint in 147 regions or countries in the year 2001 are put forward; and the corresponding ecological security evaluation index and grading standard are made (Table 1)[10].

Table 1 Grading standards of ecological footprint pressure index

Grade	Ecological footprint pressure index	Characterization state
1	<0.50	Very safe
2	0.50 -0.80	Relatively safe
3	0.81 -1.00	A little unsafe
4	1.01 -1.50	Relatively unsafe
5	1.51 -2.00	Very unsafe
6	>2.00	Extremely unsafe

2 Result and analysis

2.1 Calculation results of the per capita ecological footprint and the per capita ecological carrying capacity in Jiangsu Province

2.1.1 Calculation results of the per capita ecological footprint in Jiangsu Province. According to the basic theories of ecological footprint and the equations (1) and (2), EXCEL is used to calculate the per capita ecological footprint in the years 2001 - 2009. Table 2 reports the calculation results.

Table 2 Summary of the per capita ecological footprint in Jiangsu Province hm^2/people

Year	Cultivated land	Woodland	Grassland	Water area	Fossil fuel land	Construction land	Per capita ecological footprint
2001	0.213 8	0.010 4	0.491 7	0.526 5	0.207 4	0.011 5	1.461 2
2002	0.490 2	0.010 5	0.499 2	0.546 8	0.231 5	0.013 2	1.791 4
2003	0.423 1	0.009 9	0.507 0	0.558 6	0.278 3	0.015 9	1.793 1
2004	0.476 9	0.010 8	0.499 8	0.594 5	0.352 6	0.019 1	1.953 7
2005	0.467 2	0.010 8	0.498 0	0.627 6	0.425 8	0.022 9	2.052 2
2006	0.502 7	0.011 4	0.493 8	0.647 5	0.453 8	0.026 6	2.135 7
2007	0.511 2	0.011 9	0.395 3	0.647 4	0.498 5	0.030 3	2.094 5
2008	0.538 6	0.012 7	0.431 0	0.694 2	0.503 3	0.033 0	2.212 9
2009	0.547 2	0.012 7	0.450 2	0.721 0	0.549 9	0.034 9	2.315 9

Table 2 indicates that the per capita ecological footprint in Jiangsu Province shows an upward trend in general in the years 2001 -2009, increased from 1.461 2 hectares per capita in the year 2001 to 2.315 9 hectares per capita in the year 2009, up by 0.854 7 hectare per capita with the annual average increasing rate being 6.14%. In the year 2007, per capita ecological footprint shows a downward trend and decreases by 0.041 2 hectare per capita compared with the year 2006. This is mainly because that Jiangsu Province carried out excessive land reclamation in the year 2007 and destroyed the vegetation. Thus, the per capita ecological footprint of grassland is reduced by 0.1 hectare per capita compared with the year 2006. After implementing the *Notice of the Village Afforestation and Other Project Funds of Jiangsu Province* in the year 2007[11], biological productive area of grassland is improved. According to the components of per capita ecological footprint, cultivated land and water area account for the greatest proportion, reaching 55%. This is because Jiangsu Province has been the land of fish and rice since ancient times and its agriculture and aquaculture are both relatively developed.

2.1.2 Calculation results of the per capita ecological carrying capacity in Jiangsu Province. According to the basic theories of ecological footprint and the equations (3) and (4), EXCEL is used to calculate the per capita ecological carrying capacity in the years 2001 -2009. Table 3 reports the calculation results.

Table 3 indicates that in the years 2001 -2009, the per capita ecological carrying capacity in Jiangsu Province shows a downward trend, decreased from 0.240 5 hectare per capita in the year 2001 to 0.235 9 hectare per capita in the year 2009, a reduction of 0.004 6 hectare per capita. Except cultivated land and water area, the rest three land use types show an upward in general. Woodland increases from 0.003 0 hectare per capita in the year 2001 to 0.003 7 hectare per capita in the year 2009, an annual average increasing rate of 2.7%; and grassland increases from 0.000 1 hectare per capita in the year 2001 to 0.000 3 hectare per capita in the year 2009, an annual average increasing rate 13.8%, indicating that Jiangsu Province pays attention to the construction of woodland and grassland, as well as the construction of Urban environment greening. The per capita ecological carrying capacity of construction increases from 0.023 0 hectare per capita in the year 2001 to 0.033 0 hectare per capita in the year 2009, an annual average growth rate of 4.6%. Change of construction land is mainly due to the governments' investment in infrastructure and the exploitation of real estate. The reduction of usable per capita ecological carrying capacity is mainly caused by the reduction of cultivated land from 0.243 6 hectare per capita in the year 2001 to the 0.227 6 hectare per capita in the year 2009, a decrease of 0.016 hectare per capita. Per capita ecological carrying capacity of cultivated land accounts for 87% of the overall per capita ecological carrying capacity. Therefore, the reduction of per capita ecological carrying capacity of cultivated land directly causes the fall of per capita ecological carrying capacity.

Table 3 Summary of per capita ecological carrying capacity in Jiangsu Province hm^2/people

Year	Cultivated land	Woodland	Grassland	Water area	Fossil fuel land	Construction land	Per capita ecological carrying capacity	Available per capita ecological carrying capacity (deducing 12% biodiversity protection area)
2001	0.243 6	0.003 0	0.000 1	0.003 5	0	0.023 0	0.273 3	0.240 5
2002	0.239 4	0.003 4	0.000 2	0.003 6	0	0.023 5	0.270 1	0.237 7
2003	0.236 3	0.003 3	0.000 2	0.003 7	0	0.024 2	0.267 8	0.235 6
2004	0.232 4	0.003 4	0.000 2	0.003 8	0	0.025 0	0.264 9	0.233 1
2005	0.230 4	0.003 6	0.000 2	0.003 8	0	0.026 8	0.264 8	0.233 0
2006	0.226 3	0.003 5	0.000 2	0.003 2	0	0.028 4	0.261 6	0.230 2
2007	0.223 5	0.003 3	0.000 2	0.003 2	0	0.030 4	0.260 5	0.229 3
2008	0.230 1	0.003 5	0.000 2	0.003 3	0	0.032 1	0.269 1	0.236 9
2009	0.227 6	0.003 7	0.000 3	0.003 4	0	0.033 0	0.268 0	0.235 9

2.2 Evaluation result of the ecological security in Jiangsu Province based on ecological footprint According to the ecological footprint model, the per capita ecological footprint and per capita ecological carrying capacity in Jiangsu Province are calculated. Equation (17) and EXCEL are used to obtain the corresponding ecological security evaluation indices in the years 2001 – 2009, the results of which are shown in Table 4.

Table 4 Calculation results of ecological security evaluation index in Jiangsu Province in the years 2001 – 2009

Year	Per capita ecological deficit // hm^2/people	Ecological footprint pressure index
2001	1.220 7	6.075 8
2002	1.553 7	7.536 4
2003	1.557 4	7.609 9
2004	1.720 6	8.382 0
2005	1.819 2	8.808 6
2006	1.905 5	9.276 7
2007	1.865 2	9.136 1
2008	1.976 0	9.342 9
2009	2.080 0	9.819 1

Table 4 indicates that in the years 2001 – 2005, the per capita ecological deficit of Jiangsu Province shows an upward trend and the ecological footprint pressure index increases rapidly with the annual growth rate of 6.4%. Among them, ecological footprint pressure in the year 2009 is the maximum, which reaches as high as 9.819 1 and is 3.743 3 greater than the year 2001. According to the ecological security level, the ecological pressure index of Jiangsu Province is greater than 2 in the nine years, which is at an extremely unsafe status and needs to carry out corresponding measures to maintain the ecological security in Jiangsu Province. However, in the years 2006 and 2007, both per capita ecological deficit and ecological footprint pressure index show a downward trend, because of the implementation of the *Notice of the Village Afforestation and Other Project Funds of Jiangsu Province* in the year 2007. Biological productive area of grassland has been improved, which reduces the demand for per capita ecological footprint. Thus, the ecological coordination is improved and the ecological pressure is reduced. In general, the calculation results show that there are prominent contradictions between the ecological footprint and the ecological carrying capacity with harsh ecological environment and extremely unsafe ecological system.

2.3 Forecast results of the ecological security in Jiangsu Province

2.3.1 Forecast of the per capita ecological deficit of Jiangsu Province. According to the per capita ecological deficit in the years 2001 – 2009, GM(1,1) grey forecasting value of per capita ecological deficit in Jiangsu Province in the years 2001 – 2014 is obtained by using EXCEL and equations (5) – (16). Table 5 reports the result.

In the equation, $D = 1\,108.247$, $\alpha = -0.041\,1$, $\mu = 1.478\,0$, $S_1 = 0.044\,5$, $S_2 = 0.176\,8$, and $C = S_1/S_2 = 0.251\,7$.

Calculation results show that the forecasting model is $Y_t = 37.181\,1e^{0.041\,1t} + 35.961\,1$. The C value is $0.251\,7 < 0.350\,0$, indicating that the fitting accuracy of the model is good. Table 5 shows that the predicted value and actual value of per capita ecological deficit are close in the years 2001 – 2009, reflecting the good reliability of the model. In the GM(1,1) grey model, α represents the average development speed. If α is negative, there is a growing trend of the per capita ecological deficit; if α is positive, there is a decreasing trend of the per capita ecological deficit. Data in Table 5 also indicates that in the years 2001 – 2014, there will be more serious per capita ecological deficit. If not controlled, the deficit will grow at the speed of 4.11% each year. And the per capita ecological deficit in the year 2014 will reach 2.554 6 hectares per capita.

2.3.2 Forecast of the ecological footprint pressure index of Jiangsu Province. According to the data of ecological footprint pressure index in the years 2001 – 2009, Table 6 reports the predictive values of the ecological footprint pressure index in Jiangsu Province from the year 2001 to 2014.

Table 5 Predictive values of the per capita ecological deficit in GM(1,1) grey model in Jiangsu Province from the year 2001 to 2014

Year	t	Per capita ecological deficit // X_t	Y_t	Z_t	Z_t^2	Z_tX_t	y_t	$\hat{x}_t$	Posterior-variance test
2001	0	1.220 7	1.220 7				1.220 7		Residual error(δ)
2002	1	1.553 7	2.774 4	1.997 6	3.990 3	3.103 7	2.780 7	1.560 0	−0.006 3
2003	2	1.557 4	4.331 9	3.553 2	12.625 0	5.533 9	4.406 2	1.625 5	−0.068 1
2004	3	1.720 6	6.052 6	5.192 2	26.959 0	8.934 0	6.099 8	1.693 6	0.027 0
2005	4	1.819 3	7.871 8	6.962 2	48.471 7	12.666 0	7.864 5	1.764 7	0.054 6
2006	5	1.905 5	9.777 3	8.824 5	77.872 6	16.815 2	9.703 3	1.838 8	0.066 7
2007	6	1.865 2	11.642 5	10.709 9	114.702 1	19.976 4	11.619 2	1.915 9	−0.050 7
2008	7	1.976 0	13.618 5	12.630 5	159.530 2	24.958 0	13.615 5	1.996 3	−0.020 3
2009	8	2.080 0	15.698 6	14.658 5	214.872 8	30.490 1	15.695 6	2.080 1	−7.5E-05
2010	9						17.862 9	2.167 3	
2011	10						20.121 1	2.258 2	
2012	11						22.474 1	2.353 0	
2013	12						24.925 9	2.451 8	
2014	13						27.480 5	2.554 6	

Table 6 Predictive values of the ecological footprint pressure index in GM(1,1) grey model in Jiangsu Province from the year 2001 to 2014

Year	t	Ecological footprint pressure index(X_t)	Y_t	Z_t	Z_t^2	Z_tX_t	y_t	$\hat{x}_t$	Posterior-variance test
2001	0	6.075 8	6.075 8				6.075 79		Residual error(δ)
2002	1	7.536 4	13.612 2	9.844 0	96.904 6	74.188 9	13.732 1	7.656 3	−0.119 9
2003	2	7.610 0	21.222 1	17.417 2	303.358 5	132.543 2	21.675 4	7.943 3	−0.333 4
2004	3	8.382 0	29.604 1	25.413 1	6 45.827 5	213.012 5	29.916 5	8.241 1	0.140 9
2005	4	8.808 6	38.412 7	34.008 4	1 156.573 0	299.566 0	38.466 4	8.549 9	0.258 7
2006	5	9.276 7	47.689 4	43.051 1	1 853.393 0	399.370 6	47.336 9	8.870 5	0.406 2
2007	6	9.136 1	56.825 5	52.257 4	2 730.840 0	477.430 1	56.539 9	9.203 0	−0.066 9
2008	7	9.342 9	66.168 4	61.496 9	3 781.872 0	574.556 8	66.087 9	9.548 0	−0.205 2
2009	8	9.819 1	75.987 5	71.077 9	5 052.070 0	697.922 4	75.993 8	9.905 9	−0.086 8
2010	9						86.271 0	10.277 2	
2011	10						96.933 4	10.662 4	
2012	11						107.995 6	11.062 2	
2013	12						119.472 4	11.476 8	
2014	13						131.379 4	11.907 0	

In the equation, $D = 26\,014.88$, $\alpha = -0.036\,8$, $\mu = 7.292\,7$, $S_1 = 0.232\,2$, $S_2 = 1.112\,3$, and $C = S_1/S_2 = 0.208\,8$.

Calculation results show that the forecasting model is $Y_t = 204.247e^{0.036\,8t} + 198.171$. C value is $0.208\,8 < 0.350\,0$, indicating that the fitting accuracy of the model is good. Table 6 reports that the predicted value and actual value of per capita ecological deficit are close in the years 2001 – 2009, reflecting the good reliability of the model. The forecasting results show that $\alpha = -0.036\,8$, indicating that ecological footprint pressure index will grow at the speed of 3.68% each year in Jiangsu Province and it will reach 11.907 0 hectares per capita in the year 2014. Thus, the ecological system is at an extremely unsafe status.

3 Conclusion

Starting from the ecological footprint model, this research measures the per capita ecological footprint and per capita ecological carrying capacity in Jiangsu Province in the years 2001 – 2009, and overcomes the shortcomings of interconnection model in traditional ecological footprint model. Research results show that the per capita ecological footprint in the nine years is far greater than the per capita ecological carrying capacity in Jiangsu Province. Based on this, we select per capita ecological deficit and ecological footprint pressure index as the indices to evaluate the ecological security in Jiangsu Province. Calculation results show that there are serious per capita ecological deficit, great ecological pressure, and extremely unsafe status within the nine years. In order to find out the development trend of ecological security in Jiangsu Province, GM(1,1) grey forecasting model is used to forecast the changes of per capita ecological deficit and the ecological footprint pressure index of Jiangsu Province in the next five years, showing that the per capita ecological deficit and the ecological footprint pressure index will grow at the speed of 4.11% and 3.68% each year, respectively, and their ecological statuses are extremely unsafe. Since ecological security affects the development of economy, corresponding measures should be adopted in order to achieve the coordinated development of ecological security and economy of Jiangsu Province. Firstly, strictly control the population growth, and reduce the consumption of energy and natural resources by population growth. Secondly, rationally utilize the land resources, effectively protect and manage the use of cultivated land, grassland and woodland, and reduce ecological footprint. Thirdly, strengthen the ecological restoration and construction and improve the ecological carrying capacity. Fourthly, intensify propaganda of ecological and environmental protection and enhance the awareness of ecological protection of citizens.

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to promote the standard cultivation techniques, one-step production techniques of water and fertilizer, techniques defending pests, fertilizer techniques and economical irrigation and so on. The last is to improve the technique levels in production of banana managers and help to solve technical difficulties and finally break bottleneck of development.

3.8 Developing deeper procession of banana, extending industrial chains and weakening industrial risks All measures, such as refreshing thoughts methods, breaking traditional concepts, with markets guided and additional values as goals, transferring the traditional marketing mode which is dominated with sales of fresh fruits to marketing mode which is dominated both by fresh fruits and processed products, accelerating the construction of important projects of banana industry, cultivating leading enterprises, spinal enterprises, promoting further process of banana and extending lifetime of sales, contribute to better interaction between production and sales. Based on the guidance and leading of enterprises, the upgrading of industrialization would be realized and industrial risks could be weakened.

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