

Sustainable Use of Regional Land Resources Trend Analysis Based on The Coordination ----A Case Study In Wuxi City

Juan Li, Hua Sun

Abstract—Degree of coordination is a measure of coordination between elements or systems. Based on the theory of sustainable development and the principles of system, sustainable land using is the coordination of resources, economy and society. This paper uses the coordination function to predict sustainable land use trends of Wuxi city and analyze of the results. And the study indicates that from 1996 to 2006, changes in the degree of coordination is a tortuous process, and there is still much room for improvement. This paper also put forwards some suggestions on how to constantly increase the level of the sustainable land use in Wuxi.

Index Terms—sustainable land use; coordination model; trend analysis; forecasting; Wuxi City

I. INTRODUCTION

Land is the important place where people live and carry out production activities. It is the most precious resources of mankind, and its valuable assets as well. However, with the development of economy and society, the acceleration of the urbanization process, and the increasing population growth, the contradiction between human and land is exceptionally tense. The experience of the western developed countries tells us: the traditional economic development model which is "at the expense of eco-environment to pursue economic growth" and "treatment after pollution" can't meet the current requirements of the sustainable development. Thus we must seek a way to achieve sustainable development with economy, society, resources and environment all in harmony and make full and rational use of the land. According to the coordination degree of the land use social system, land use economic system and land use eco-environment system, we can judge the coordinated development of land use, analyze the social and economic development level of land use and the eco-environment situation of land use. In this way, we can provide a scientific guidance to decide a rational land use way.

The sustainable land use is the material basis and

precondition of the sustainable social and economic development, and has a direct influence on sustainable development strategy. As a basis of sustainable development, sustainable land use is a key topic for researchers, policy-makers, and the public [1]. Evaluation of the sustainable land use sets the standard to measure whether land is properly used. It is the foundation for the evaluation and monitoring of the situation and degree of the sustainable land use, the foundation for the comprehensive policy-making and coordinated administration of the sustainable land use, the reference for the implementation of sustainable development administration. Nowadays, both local and overseas scholars have examined sustainable land use and the dynamic monitoring of its status [2-8]. Some studies have evaluated land use suitability for urban construction [9-11], where inappropriate land use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty, and other social problems [12].

This thesis carries out the evaluation study on the sustainable land use based in Wuxi City of Jiangsu Province. The aim is to objectively and accurately grasp the current land-use situation of this area, analyze the existing problems, put forward feasible countermeasures, therefore provide a scientific basis for the micro-policy-making of the government and increase the level of the sustainable land use. This thesis makes an analysis of the natural, social and economic conditions, and the current land-use situation and its characteristics of Wuxi City. Starting from the fundamentals of the sustainable land use, in line with the goals and principles of comprehensive evaluation, this thesis establishes the comprehensive evaluation system of the sustainable land use from three aspects—rationality of resources, economic feasibility and social acceptability. Used the analytic hierarchy process to determine the target weight. Membership function of fuzzy mathematics is adopted to nondimensionalize indexes of the system. Then the method of weighting is applied to grasp the level of the sustainable land use in Wuxi City from 1996-2006. And coordination model is used to get the coordination degree of the sustainable use of land in Wuxi.

Study indicates that from 1996-2006, after the initial period and the period in which the sustainable use land was largely achieved, Wuxi is approaching a full level of sustainable land use. Though minor fluctuation still exists, the overall tendency is rising while maintaining stability. Coordination degree is good. As for the problems emerged in the comprehensive evaluation, this thesis adopts the

Manuscript received February 10, 2011. The manuscript was sponsored by the humanities and social scientific research project in 2010 funded by Ministry of Education of the P.R.Chin, under Grant No. 10YJA630138-“environmental risk evaluation and adjustment mechanism research of typical brownfields on Taihu Lake Basin” and National Science Foundation of China, under Grant No. 61075031

Juan Li, Public Management College, Nanjing Agriculture University (phone: 13655172304; e-mail:lijan19861108@163.com).

Hua Sun, Dr., Management College, Nanjing Agriculture University (phone: 13770676369; e-mail: sh@njau.edu.cn).

obstruction model to analyze the degree of obstruction of each index, and find the main factors that affect the sustainable land use.

This thesis also put forwards some suggestions on how to constantly increase the level of the sustainable land use in Wuxi.

II. GENERAL SITUATION OF THE STUDYING AREA

Wuxi City is located in the southeast of Jiangsu Province, the Yangtze River Delta hinterland (31° 07' to 32° 00'N, 119° 31' to 120° 36'E). It's eastern boundary is adjacent to Suzhou's western border; in the west, it is adjacent to Changzhou; in the south, it borders Taihu Lake; and the western boundary lies to Anhui and Zhejiang Provinces. It has a jurisdiction over 6 regions (Chongan, Nanchang, Beitang, Jiaoqu, Mashan and Xinqu) and 3 counties (Jiangyin, Xishan and Yixing), including 117 towns and 27 streets. By the end of 1996, it has a population of 4308.2 thousand and covers an area of 4908 square kilometers, among which the plain is 69.4% and the hilly of southwest is 12.61%. Wuxi is an important economic center and key tourist city. The economic grows steadily, various social undertakings have significant achievements, the comprehensive economic strength enhances persistently and people's living standards improves especially after 90's. The jurisdiction of Jiangyin, Xishan, Yixing three cities (counties) are ranked in the forefront of China's comprehensive strength of the hundred counties.

The total area of Wuxi city is 4908 square kilometers (7362 thousand hm), including 36.15% arable land, 33.26% water, 14.86% residential and industrial land, 8.6% forest land, 3.13% transportation land, 3% garden and 1.01% unused land.

With the character of high degree of land use, large area of water, potential for depth development in hilly areas and rich tourism resources, but there are still many problems in the use of land resource, such as dropping arable land, sharp contradiction between people and land, relatively extensive land use of small towns, large area of rural settlements, scarce land reserve resources, faster non-agricultural construction, and more prominent issue of conflicts between agriculture and non-agricultural land.

Therefore, it is a priority to use land resources rationally and achieve balanced and sustainable development of land.

III. DATA SOURCES AND RESEARCH METHODS

A. Data sources

In order to reflect Wuxi's coordinated development of land use, this paper selected Wuxi's social, economic and ecological aspects data of land use from 1996 to 2006, which comes from Statistical Yearbook of Jiangsu Province and Wuxi City, Wuxi economic and social development bulletin.

B. Research method

Degree of coordination is an important quantitative indicator to measure the good or bad condition between systems or elements of. According to the meaning of

sustainable land use, sustainable land use is the coordination between resource, economic and social, the degree of coordination is the coordination situation between the three subsystems. Scores and the rates of changes of the three should be mutually balanced, harmonious, and any one of the vulnerabilities would affect the comprehensive level of sustainable land use. Coordination Index (CI) is calculated as:

$$CI = \frac{x + y + z}{\sqrt{x^2 + y^2 + z^2}}$$

(X represents a resource changes, Y represents changes in the economy, Z represents that social change)

This paper will establish the evaluation index system of sustainable land use, then determine the weight of each index and calculate the value of the index over three, and then obtain the coordination index, the specific calculation process is following:

C. Establish evaluation index system and determine the index weight

According to principles of sustainable development and the actual situation in Wuxi City, and the reference index of sustainable land use at home and abroad, this paper selected 26 factors from three aspects, the rationality of resources, economic viability and social acceptability, as evaluation index system of sustainable land use [13-15], and used Delphi method to determine the weight (Table 1).

D. Calculate the index of reasonable resources, economic viability, social acceptability

Because different indicators have different dimension and units, in order to eliminate the dimension and the non-commensurability caused by different dimension units, index should be dimensionless. The standard formula is:

$$X_i = \frac{X_i - X_{\max}}{X_{\min} - X_{\max}}$$

(X is the positive effects index)

$$X_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

(X is the negative effects index)

Where X_i is the original value of the index, and X_{\max} and X_{\min} are the maximum and minimum indexes respectively.

Calculates the level of sustainable land use in Wuxi City, and in order to be more intuitive, multiplies 100 to each score value to get the level of sustainable land use of Wuxi City (1996 -2006). (Table 2)

E. Calculate the degree of coordination

Calculated in accordance with the formula of coordination, coordination must have:

$$-1.732 \leq CI \leq 1.732$$

Calculates the coordination index of sustainable land use of Wuxi City by the values in Table 2 (Table 3)

F. Calculate comprehensive level of sustainable land use

Reference to different scholars on the division of

sustainable land use evaluation criteria, this paper classifies the level of sustainable land use as four stages, non-sustainable use, initial sustainable use, basic sustainable use and sustainable use. [16-17](Table5)

IV. ANALYZE THE CHANGES OF THE DEGREE OF COORDINATION OF WUXI

A. Analysis of the degree of coordination of sustainable land use

From Table 3, the degree of coordination of sustainable land use of Wuxi City has increased annually during the latest ten years, and the three aspects (reasonable resources, economic viability and social acceptability) are towards the sustainable direction, with a good momentum of development.

From 1996 to 1999, the degree of coordination of sustainable land use was up and down. Because social acceptability had little increase even down, which was lower than the other two aspects, and as a result, the degree of coordination had turned down. Subsequently, the coordination of the three aspects was strengthened day after day, and the degree of coordination of sustainable land use improved steadily year by year. But in 2006, due to a wide gap between social acceptability and the other two aspects, the degree of coordination of sustainable land use fell.

Through the data and charts, we can see that after the coordinated degree of sustainable land use decreased substantially, it will be a corresponding rise again, then continued to decline. This shows that, there are still many shortages in improving the coordinated degree of sustainable land use of Wuxi City, it is not very accurate to control the level of coordination for the three, each room for growth and the degree of mutual influence. So management and skills training in this regard should be strengthened to keep the economy growing, at the same time, we should strengthen the management and protection of resources and emphasis on the use of social benefits, in order to make the indexes of resources of rationality and social acceptability growing synchronization, and become coordinated gradually.

B. Analysis of comprehensive level of sustainable land use

Through the calculation and Table 2, Table5 and Figure 1, we can see that Wuxi City was in unsustainable land use stage before 2000, in the initial stage of the sustainable land use from 2001 to 2003, in the basic sustainable land use stage from 2004 to 2005 and has reached the sustainable land use stage until 2006. Generally speaking, in the decade, land use of Wuxi City gradually evolved to the high stage and sustainability was growing.

From 1996 to 2000, the level of sustainable land use of Wuxi City had a slight decrease, but the change was not significant. The scores of all three aspects, resources reasonability, economic viability and social acceptability, decreased, except the indexes of GDP per person, the number of undergraduates, the disposable income of urban residents and a few other indicators. Resources reasonability has improved since 2001, but the other two are still on the decline. However, the decrease was significantly lower than the

increase range, so the level of sustainable land use improved. Resources reasonability, economic viability and social acceptability was beginning to significantly improve since 2002, the level of sustainable land use of Wuxi City improved steadily.

V. FORECAST

This paper predict the trend of coordinated degree of sustainable land use of Wuxi City using prediction of time series, and the results is obtained in Figure 2.

In Figure 2, we can see that the development of coordinated degree of sustainable land use of Wuxi will be in very steady in the coming years, resources reasonability, economic viability and social acceptability are coordinated, and hope to be stable and continue to improve.

VI. SUGGESTION

A. Deal with the relations of resource rationality, social and economic benefits

By calculating, we can see that the coordination of the resources rationality, economic viability and social acceptability in Wuxi City improved year by year, and there is still room for improvement. But there is still a gap among the three. So it is particularly important to deal with relations of resources reasonability and economy and society. We should guide land use with the system overall theory. It is necessary not only to avoid the pursuit of economic development and inconsideration of resource protection, but also to avoid emphasizing on resource protection but not allowing any scientific and rational use and development. That means that using land with protection, protecting land with using and promoting the sustainable use of land to prevent the two extremes resolutely.

B. Combination of use and raise land to increase yield

The data from 1996 to 2006 shows that Wuxi's arable land per person is decreasing annually and the loss of arable land area increased year by year. The unit yield of grain cultivated area is also reduced, the situation of land use is grim, so we should be dug in to increase yields potential.

For the region of high-yield fields, we could increase production through the measures of improving varieties and field management techniques. For the region of low-yielding fields, we should increase technical input and transform to increase production. On the other hand, combine using and raising land, protect the potential of the land and maintain and enhance the land productivity function of land. On the aspect of fertilization technology, we should improve the efficiency of fertilizer use to reduce soil pollution. In addition, we should control industrial and domestic wastewater and sewage discharge directly to the farmland by economic and legal ways.

C. Intensive and economical use of urban land

Construction land area of Wuxi City was increasing in recent yeas, especially in 2001, more than doubled over the previous year. Construction land planning should take full

account of foundation conditions, choose high-rise buildings as far as possible to improve the building floor area ratio. Macroeconomic regulate the land structure of residential and commercial land, change the inefficient type of high input but low output and develop the efficient model of low input but high output and to improve the density of the urban economy and save urban land.

D. Handle the relationship between land use and scientific management

First, enhance extensive public education of the concept of territory and legal education, strengthen legal awareness, establish the per capita awareness and improve the awareness of protecting arable land and reasonable land use. If people's actions are consistent with the requirements of the negative feedback mechanism, the whole system of sustainable land use will be stable. Second, we must resolutely implement the existing laws and regulations. When it meets local protectionism and the recent interests, the law will be weak. So law enforcement must be strict to awaken people's legal awareness, self-discipline misconduct and protect resources and environment. Third, law enforcement should be further enhanced to enable law enforcement officers to take effective means to investigate and punish the illegal land use, in order to ensure the sustainable land use.

E. Focus on protecting environment

Outbreak of blue algae in Taihu Lake in Wuxi reminds us that we can't ignore the tremendous costs of pollution of the environment during economic development, it is equally important to protect the ecological environment.

REFERENCES

- [1] J. Peng, Y.L. Wang, J.S. Wu, Q. Chang, Y. Zhang. 2007. Evaluation for sustainable land use in mountain areas of Northwestern Yunnan Province in China. *Environ Monit Assess.* 133:407-415.
- [2] F.R. Zhang. 2000. Land resource and sustainable land use. China Agricultural University Press.
- [3] H. Hurni. 2000. Environmental Impact Assessment Review. *Agricultural Ecosystem Environment.* 81:83-92.
- [4] N.X. Thinh, G. Arlt, B. Heber, J. Hennetsdorf, I. Lehann. 2002. Evaluation of urban land use structures with a view to sustainable development. *Agric Environ Impact Assess Review.* 22:475-492.
- [5] I. Garay, R. Pellens, A. Kindel, E. Barros, A.A. Franco. 2004. Evaluation of soil conditions in fast-growing plantations of *Eucalyptus grandis* and *Acacia mangium* in Brazil: a contribution to the study of sustainable land use. *Appl Soil Ecol.* 27:177-187.
- [6] X.L. Chen, S.J. Li, Z.X. Guo. 2009. Analysis on the harmonious degree between land use and ecological environment in Yanbian Korean Autonomous Prefecture, Jilin Province. *China Land Science.* 22(1):66-69.
- [7] L.M. Dai, X.F. Zhao, H.S. He, H.B. Deng, D.P. Yu, L. Zhou, S.N. Wu. 2008. Evaluating land use suitability of an industrial city in northeast China. *Int J Sus Dev World Ecol.* 15:378-382.
- [8] Q.P. Shen, Q. Chen, B.S. Tang, Y. Stanley, Y.C. Hu, C. Gordon. 2009. A system dynamics model for sustainable land use planning and development. *Habitat Int.* 33:15-25.
- [9] F.C. Dai, C.F. Lee, X.H. Zhang. 2001. GIS-based geo-environmental evaluation for urban land-use planning: a case study. *Eng Geol.* 61(4):257-271.
- [10] T. Svoray, P.B. Kutiel, T. Bannet. 2005. Urban land use allocation in a Mediterranean ecotone: habitat heterogeneity model incorporated in GIS using a multi-criteria mechanism. *Landsc Urban Plan.* 72(4):337-351.
- [11] J.F. Zhou, G.M. Zeng, G.H. Huang, A.W. Li, S. Jiao, L. Tang. 2007. Ecological suitability evaluation on urban expansion land based on uncertainties. *Acta Ecologica Sinica.* 27(2): 774-783.
- [12] D.G. Rossiter. 1996. A theoretical framework for land evaluation. *Geoderma.* 72:165-190
- [13] B.J. Fu, L.X. Chen, C. Ma. 1997. The evaluation index system and method of sustainable land use. *Natural Resource Transaction.* 12(2).
- [14] B.M. Chen. 2001. The evaluation index system theory and method of sustainable land use in China. *Natural Resource Transaction.* 16(3):197-203.
- [15] X.S. Zhang. 2004. Population, resource and environment economic. Chemistry Industry Press.
- [16] F.R. Zhang. 2003. The evaluation index system and method of sustainable land use. China Agricultural University Press.
- [17] X.Q. Xu, J.J. Zhang. 2001. The comprehensive evaluation of sustainable land use of Guangzhou city. *Geography Transaction.* 56(1):54-63.

TABLE 1 : INDEX SYSTEM AND WEIGHT

Aim	First index	Weight	Second index	Weight
icevaluation index system of sustainable land use	rationality of resources A1	0.412	B1: Cultivated land per person	0.096
			B2: Area of public greenfield	0.175
			B3:Area of public installation	0.082
			B4: Decrement of cultivated land per year	0.146
			B5:Area of Construction area	0.160
			B6: The standard rate of drinking water	0.084
			B7:The proportion of effective irrigation area	0.099
			B8: Output of industrial waste water per unit	0.158
			B9: GDP per person	0.129
	economic viability A2	0.328	B10: Land productivity	0.147
			B11: Output of foods each unit	0.088
			B12:Output of industry per unit	0.091
			B13:Net income of famers	0.062
			B14: Engers coefficient	0.089
			B15: The proportion of agriculture	0.095
			B16: The proportion of industry	0.110
			B17: The proportion of tertiary-industry	0.086
	social A3	0.260	B18: The investment of social permanent	0.103
			B19: Population density	0.134

B20: Natural rate of increase of population	0.154
B21: Living area per urban person	0.083
B22: Urbanization level	0.121
B23: The number of the undergraduates	0.234
B24: The proportion of technologic investment	0.118
B25: Urban per capita disposable income	0.082
B26: Educational expenditure per person	0.074

TABLE 2 : THE LEVEL OF SUSTAINABLE LAND USE OF WUXI(1996—2006)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
resources (x)	52.70	48.83	48.40	48.05	48.40	68.49	79.43	76.76	90.12	85.69	93.43
economic (y)	68.06	67.89	68.09	68.18	67.44	64.60	67.18	70.59	77.25	80.54	87.43
social (z)	53.01	43.65	47.76	44.14	48.45	47.86	56.73	59.28	75.32	75.17	78.66

TABLE3 COORDINATION INDEX OF SUSTAINABLE LAND USE OF WUXI(1996—2006)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Degree	1.7141	1.7025	1.6808	1.7042	1.6979	1.6483	1.7239	1.7272	1.7198	1.7185	1.7083

TABLE 4 : COMPREHENSIVE LEVEL OF SUSTAINABLE LAND USE OF WUXI(1996—2006)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Level	57.82	53.73	54.69	53.63	54.66	61.85	69.51	70.19	82.05	81.27	87.62

TABLE5 : EVALUATION CRITERIA OF SUSTAINABLE LAND USE

Total score	<60	60-75	75-85	>85
Standard	non-sustainable	initial sustainable	basic sustainable	sustainable

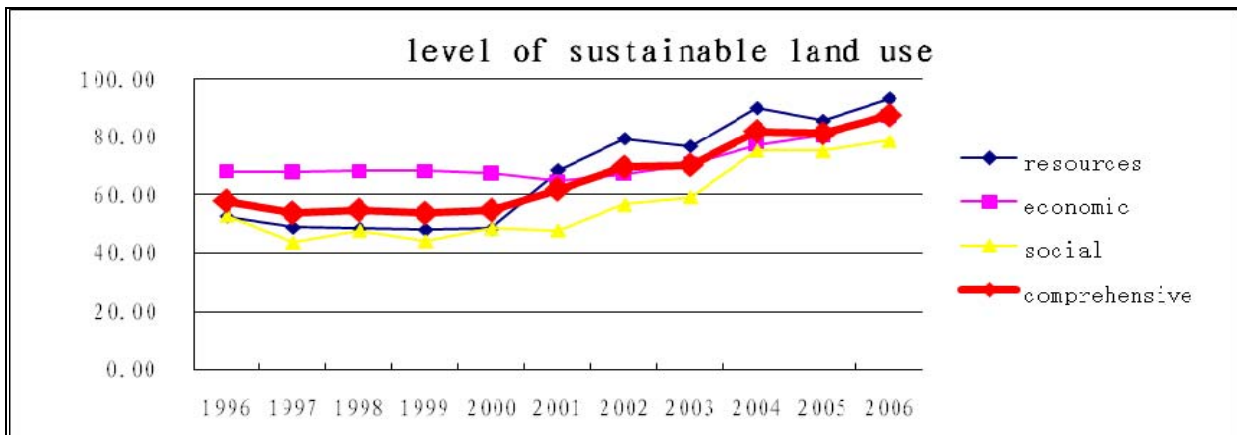


Figure 1 level of sustainable land use of Wuxi

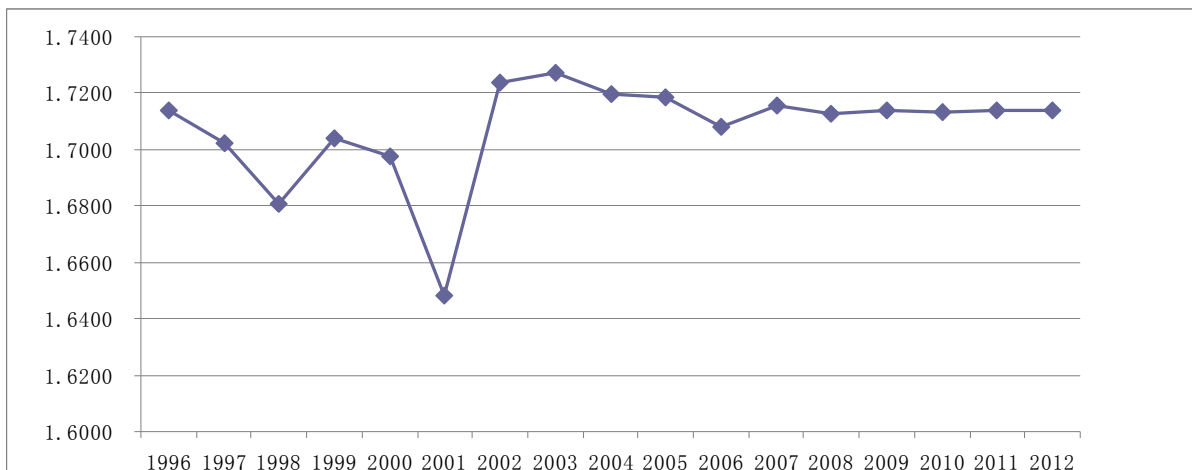


Figure 2 prediction of coordinated degree of sustainable land use