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SUSTAINABLE LAND USE PLANNING BASED ON ECOLOGICAL HEALTH
—Case Study of Beiwenquan Town, Chongqing, China

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ABSTRACT: This paper, taking Beiwenquan Town of Beibei, Chongqing as an example, assessed the impacts of land use on ecological health by comprehensive index method, and discussed methodological system of sustainable land use planning based on ecological health. Results indicated that: 1) From 1992 to 2002, land use changes focused on 12 patterns with the total conversion area of 92.11%, which were related to cultivated land, residential and industrial-mining area, and orchard land. Urbanization and economic reconstruction were the leading driving forces. 2) There was obvious difference of the areas of ecotypes driven by land use change in wide valley and mild slope between 1992 and 2002, while there were little or no difference in steep slope and very steep slope. 3) Both of the conditions of ecological health in 1992 and 2002 were sound, and the ecotypes focused on the types of health and sub-health. But, health ecosystem in 1992, with an area of 764.64ha, accounting for 38.51% of the total evaluation area, was better than that in 2002, with an area of 636.10ha, accounting for 34.19% of the total evaluation area. 4) The ecotypes involved into different ranges have already degenerated, due to humankind's disturbance, while the conditions of ecological health in the same ranges in 1992, regardless of stability and reconstruction, were better than that in 2002. 5) The planning scenario based on ecological health was accorded with the practice condition of Beiwenquan Town: 388.29ha of cultivated land could meet the Beiwenquan demand of food and byproduct; 1045.26ha of forest land area, the Beiwenquan demand of ecological health; and 1004.73ha of the residential and industrial-mining area, the Beiwenquan building demand. 6) Sustainable land use planning based on ecological health had higher useful value, because it not only stood to ecological theory, but also satisfied the developmental demand of society and economy.

KEY WORDS: ecological health; land use ecological evaluation; land supply and demand; sustainable land use planning

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1 INTRODUCTION

Since the 20th century, ecosystem and even biosphere has been faced with threats under the impacts of climate and humankind together (ERICH and ULRIKE, 2002; GLADE, 2003; OLGERTS *et al*., 2005). Land is an important part of nature ecosystem. The different patterns of land utilization could directly influenced ecosystem health (THEOBALD and HOBBS, 2002; MARIO and JOAO, 2003). However, such impact threatened the existence and development of humankind itself in turn, especially in economically developed and densely populated areas. So, ecological health, one of the hot points for modern ecology research, faces severe challenges (COSTANZA *et al*., 1992; BURGER and GOCHFELD, 2001; LIANG *et al*., 2002; DANNENBERG *et al*., 2003; LI *et al*., 2003; JONES *et al*., 2004). The reasonable adjustment, planning, and construction of land ecosystems favorably accorded with the functions of natural, economic and social compound system, and promoted sustainable utilization of land resources and social and economic sustainable development. Therefore, land ecological planning was put forward (NAVEH and LIEBERMAN, 1984; ZHU, 1995; YANG, 2000). Though people have put forward the concept of ecological health for only 10 or more years, the time when

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people introduced it to land use could be backed to the 19th century in America and West Europe. MCHARGE (1969) established the planning framework and flow that emphasized fellowship between humankind and nature, and studied all-roundway by cases. FABOS (1981) presented a regional ecological land use optimization scenario of metropolises, based on ecological health principle and model. THEOBALD *et al*. (2000), and ODELL *et al*. (2003) integrated biological information into land use planning. In China, the land ecological planning originated earlier, but with the really modern implication, it has appeared since the late 1980s (Problem Group of Northeast Normal University, 1990; JING, 1991; YANG, 1996; WANG and LI, 2001). In short, single land ecological planning was less; it was generally taken as the professional planning of land use planning. Although it not only emphasized the cultivated land quantity, but also considered ecological demand to some extent, such as the limited slope farmland's de-farming, ecological planning still did not achieve ecological health under the impacts of humankind and climate together.

During the Chinese economic transformation, population growth, economy growth, urbanization and industrialization influenced deeply natural resources, for instance, biodiversity decline, soil and water loss, land desertification, water scarcity, acid rain and environmental pollution, etc. Therefore, it was crucial for us to further study the methods and frameworks of sustainable land use planning based on ecological health, so that land use, i.e., the most basic practice activities, could preserve favorably ecosystem health including structure and function. Beiwenquan Town of Beibei County, Chongqing with especial social and economic conditions was the representative region of local resources and environment research. This paper analyzed land use change and its impacts on ecological health in the past 10 years in Beiwenquan Town, and further discussed the framework of sustainable land use planning based on ecological health.

2 MATERIAL AND METHODS

2.1 Site Description

Beiwenquan Town (29°47′38"–29°52′10"N, 106°21′24"–06°25′21"E) is located in the northwest suburb of Chongqing, China, covering an area of 31.53km^2, with a population of 31 424. The area is the center of politics, economy and culture of Beibei County, as well as the most important tour town of Chongqing, with the national-level key protective zone—Jinyun Mountain and the famous scenic spots of Chongqing. Presently, with the development of urbanization and evolvement of economic structure in Beiwenquan Town, land resources were generally decreasing, and ecological environment was faced with hypersensitivity, low-risk and mid-vulnerability (SHAO and LIU, 2002; GAO *et al*., 2003). Beiwenquan Town is a representative of the zones with economy driving and dense population. In order to effectively harmony the interrelation among land use, ecological health and sustainable development, it was necessary to optimize land use based on diagnosing the situation of ecological health.

2.2 Data Collection

The data of land use were obtained from the land use survey maps of 1992 and 2002 at a scale of 1:10 000, the topographic maps of 1996 at a scale of 1:10 000, and the TM images of 1992 and 2002. Population records and socio-economic data were obtained from the *Chongqing Statistical Yearbook* (Chongqing Statistical Bureau, 2003), as well as unpublished statistical data from the Beiwenquan Town and the Management Association of Jinyun Mountain. To coordinate well the objectives for human welfare and objectives for landscape conservation, the interviews were carried out using quantitative and qualitative methods. All the families of Beiwenquan Town were interviewed from March to October 2002. The questions covered two issues: the basic statistics data, including the number of people in each household, their ages, educational achievement, current employment, family budget, standard of their habitation and land-use property, and the qualitative information on the attitudes of the people to land use and landscape conservation, especially their views about their current situation, and their aspirations for the future.

2.3 Data Analysis

Land use classification was carried out by means of a computer and human supported numerical analysis, and the classification system of Chinese Ministry of Land and Resources (MLR) (ZHOU *et al*., 2002; LOUISA and ANTONIO, 2003; DOUGLAS *et al*., 2004). The types of ecosystem were divided by dominant ecological factors, driving ecosystem towards heterogeneity, e.g., topography and vegetation (WILCOX, 2001; PARKES and PANELLI, 2001; TOEWS *et al*., 2003; SHRESTHA, 2004) (Table 1). The classification processing between land use types and ecotypes is allowed to overlay the data for each period, when land use types are not in correspondence with ecotypes, such as wide valley arbor ecosystem including forest land and orchard land, and unused land including lower cover grassland ecosystem, bare land ecosystem and bare rock ecosystem. Ecological health evaluation was carried out by comprehensive index method (FU *et al*., 2001; LIU *et al*., 2003). The indices of ecological health were chosen based on the regional disparity of ecotypes (CRAWFORD, 1994; FAIRWEATHER, 1999; NAVEH, 2001; XIAO and OUYANG, 2002; DIBARI, 2003; LIU *et al*., 2003), and the weights were endowed by the contribution rates of them to ecological health (Table 2). The scenario of land use planning was established by linear programming (ARBEL and KORHONEN, 1998; AERTS *et al*., 2003). Spatial data processing and analysis of the transformation of land-use types were carried out using ArcView GIS (ESRI GIS software), whilst statistical analysis of demographic and other data were carried out using Excel, Mathematica2. 2 for windows and ArcView GIS. The social data relating to the different farmers or landowners were also spatially referenced to individual farmsteads so that the presentation of spatial patterns of attitudinal data was possible.

Table 1 Classification of ecotypes

No.	Ecotype	Area (ha)		No.	Ecotype	Area (ha)	
		1992	2002			1992	2002
1	Wide valley arbor ecosystem	44.12	61.52	15	Steep slope shrubbery ecosystem	105.29	105.29
2	Wide valley sparse woods ecosystem	25.01	24.61	16	Steep slope degradation forestland ecosystem	83.68	83.68
3	Wide valley shrubbery ecosystem	14.82	13.57	17	Steep slope lower cover grassland ecosystem	23.00	22.50
4	Wide valley lower cover grassland ecosystem	54.48	34.89	18	Steep slope bare land ecosystem	5.21	5.21
5	Wide valley paddy field ecosystem	96.41	58.26	19	Steep slope bare rock ecosystem	7.83	7.83
6	Wide valley dryland ecosystem	101.28	71.06	20	Steep slope dryland ecosystem	57.40	33.74
7	Mild slope arbor ecosystem	292.25	328.90	21	Very steep slope arbor ecosystem	66.23	66.23
8	Mild slope sparse woods ecosystem	85.91	85.60	22	Very steep slope shrubbery ecosystem	12.80	12.80
9	Mild slope shrubbery ecosystem	49.66	48.91	23	Very steep slope degradation forestland ecosystem	10.37	10.37
10	Mild slope degradation forestland ecosystem	38.07	36.78	24	Very steep slope lower cover grassland ecosystem	15.16	15.16
11	Mild slope lower cover grassland ecosystem	77.95	58.71	25	Very steep slope bare land ecosystem	2.81	2.81
12	Mild slope paddy field ecosystem	190.75	162.81	26	Very steep slope bare rock ecosystem	3.59	3.59
13	Mild slope dryland ecosystem	125.17	86.20	27	Water ecosystem	245.86	233.91
14	Steep slope arbor ecosystem	396.18	419.26	28	Other ecosystem	921.29	1058.38

Table 2 Classification and evaluation of indexes

Grade	Erosion degree	Function lacking degree	Productivity level
Ⅰ (≥0.75)	Zero (≤2°)	Perfect (harmonious)	High (arbor, paddy field)
Ⅱ (0.75–0.60)	Slight degree (2°–6°)	Sub-perfect (sub-harmonious)	Sub-high (shrubbery, sparse woods and dryland)
Ⅲ (0.60–0.35)	Middle degree (6°–15°)	Less perfect (less harmonious)	Lower (degradation forestland, low cover grassland)
Ⅳ (0.35–0.10)	Serious degree (15°–25°)	Not-perfect (worst harmonious)	Lowest (bare rock, bare land)
Ⅴ (≤0.10)	Very serious degree (25°–35°)	–	–
Weight	0.205	0.423	0.372

3 RESULTS AND DISCUSSION

3.1 Land Use Change

From 1992 to 2002, changes in land use in Beiwenquan Town mainly occurred in the transformation of 12 land use types, accounting for 92.11% of the total change area, and relating with cultivated land, residential and industrial-mining land and orchard land (Table 3). That is, the key of changes in land use was cultivated land, residential and industrial-mining land and orchard land. They were a breakthrough point to analyze the driving mechanism of land use change. The transformation area of cultivated land into residential and industrial-mining land was 84.44ha or 31.85% of the total transformed area, and mostly in the southern and northern wide valley and mild slope area of Beiwenquan Town with the trend of expanding outwards. The transformation area of cultivated land into orchard land was 59.74ha, mostly in Beiwenquan-Chengjiang border narrow area. These land use changes were closely related to urbanization and agricultural reconstruction.

The transformation area of unused land into orchard land was 11.14% of the total transformed area, and mostly happened in mild slope and steep slope area around Jinyun Mountain. The mainly driving factors of this conversion were the improvement of "four kinds of barrens" (e.g., barren mountain, barren slope, barren gully and barren beach) and the offset of orchard land

Table 3 Land use change matrix from 1992 to 2002

1992		2002 Cultivated land	Orchard land	Forest-land	Residential and industrial-mining land	Transportation land	Water	Unused land	Total (ha) (Percent (%))
Cultivated land	A_{ij} (ha)	403.69	59.74	1.51	84.44	19.17	0.46	0.00	569.01
	B_{ij} (%)	70.95	10.50	0.27	14.84	3.37	0.08	0.00	(18.05)
	C_{ij} (%)	97.97	22.61	0.15	8.43	33.83	0.20	0.00	
Orchard land	A_{ij} (ha)	0.43	169.91	1.29	15.81	6.99	0.17	0.00	194.60
	B_{ij} (%)	0.22	87.31	0.66	8.12	3.59	0.09	0.00	(6.17)
	C_{ij} (%)	0.10	64.30	0.12	1.58	12.34	0.07	0.00	
Forestland	A_{ij} (ha)	0.25	1.75	1024.36	2.64	0.71	0.08	0.00	1029.79
	B_{ij} (%)	0.02	0.17	99.47	0.26	0.07	0.01	0.00	(32.66)
	C_{ij} (%)	0.06	0.66	99.14	0.26	1.25	0.03	0.00	
Residential and industrial-mining land	A_{ij} (ha)	5.67	2.71	3.58	887.58	1.65	0.05	0.00	901.24
	B_{ij} (%)	0.63	0.30	0.40	98.48	0.18	0.01	0.00	(28.59)
	C_{ij} (%)	1.38	1.03	0.35	88.61	2.91	0.02	0.00	
Transportation land	A_{ij} (ha)	0.45	0.37	0.12	0.45	19.66	0.00	0.00	21.05
	B_{ij} (%)	2.14	1.76	0.57	2.14	93.40	0.00	0.00	(0.67)
	C_{ij} (%)	0.11	0.14	0.01	0.04	34.70	0.00	0.00	
Water	A_{ij} (ha)	0.12	0.25	0.00	6.95	3.78	233.15	1.61	245.86
	B_{ij} (%)	0.05	0.10	0.00	2.83	1.54	94.83	0.65	(7.80)
	C_{ij} (%)	0.03	0.09	0.00	0.69	6.67	99.68	1.07	
Unused land	A_{ij} (ha)	1.46	29.53	2.40	3.85	4.70	0.00	149.09	191.03
	B_{ij} (%)	0.76	15.46	1.26	2.02	2.46	0.00	78.05	(6.06)
	C_{ij} (%)	0.35	11.17	0.23	0.38	8.30	0.00	98.93	
Total (ha) (Percent (%))		412.07 (13.07)	264.26 (8.38)	1033.26 (32.78)	1001.72 (31.77)	56.66 (1.80)	233.91 (7.42)	150.70 (4.78)	3152.58 (100.00)

Notes: Row means the ith land use types in the kth period, and line means the jth land use types in the $(k+1)$th period; A is the area of transformation of land use types in the kth period into land use types in the $(k+1)$th period, respectively, that is, the original matrix of land use change matrix A_{ij}. The transformation rate is $B_{ij}=A_{ij}\times 100/\sum_{j=1}^{7} A_{ij}$, meaning the rate of transformation of land use types in the kth period into land use types in the $(k+1)$th period, respectively. The contribution rate is $C_{ij}=A_{ij}\times 100/\sum_{i=1}^{7} A_{ij}$, meaning the rate of the jth land use types in the $(k+1)$th period transformed from the ith land use types in the kth period. The total area of row and line is the area of land use types in the kth and the $(k+1)$th period, and the number in the bracket is the proportion of their area to total area(%), respectively. The change rate is $\left(\sum_{i=1}^{7} A_{ij}-\sum_{j=1}^{7} A_{ij}\right)\Big/\sum_{j=1}^{7} A_{ij}$, meaning the change degree of the area of land use types in the $(k+1)$th period to the area of land use types in the kth period.

sharp decreasing reduced by urbanization. Furthermore, it was very evident that cultivated land, orchard land, unused land and water were transformed into transportation land, mostly along the Chongqing–Hechuan highway. The transformed area was 7.23%, 2.64%, 1.77% and 1.43% of the total transformed area, respectively. The orchard land, water and unused land were increasingly transformed into residential and industrial-mining land, due to urbanization. The transformation of residential and industrial-mining land into cultivated land and forestland was mainly related to vacant village consolidation.

3.2 Ecological Health Evaluation

From 1992 to 2002, changes in ecological health in Beiwenquan Town were obvious (Table 4). Firstly, in terms of evaluation area, although the identical classification of ecotypes, the areas of ecotypes droved by land use change were obviously different in wide valley and mild slope in the two periods, there were little or no difference in steep slope and very steep slope. For instance, the area of wide valley paddy field ecosystem was 96.41ha in 1992, while it was 58.26ha in 2002. At the same time, this paper did not evaluate water ecosystem and other ecosystem (e.g., residential and industrial-mining land, transportation land, etc.). Therefore, the total areas of evaluation in the two periods were distinctly different, with 1985.43ha in 1992 and 1860.29ha in 2002, respectively. The reasons for this difference were urbanization and the development of transportation that transformed

Table 4 Health scales of ecotypes and its ranges

Grade	Range	Type		Area (ha)		State	Feature
		1992	2002	1992	2002		
Ⅰ	≥0.73	1, 2, 3, 5, 6, 7, 12	1, 2, 5, 7, 12	764.64	636.10	Health	Strong stability, sound sustainable
Ⅱ	0.73–0.65	8, 9, 10, 13, 14	3, 6, 8, 9, 13, 14	694.99	724.60	Sub-health	Easier damaged, easier reconstructed
Ⅲ	0.65–0.55	4, 11, 15, 21, 22	4, 10, 15, 21	316.75	243.19	Less health	Low stability, easier damaged, harder reconstructed
Ⅳ	≤0.55	16, 17, 18, 19, 20, 23, 24, 25, 26	11, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26	209.05	256.40	Non-health	Worst stability, easiest damaged, hardest reconstructed

cultivated land, orchard land and forestland into residential and industrial-mining land and transportation land, respectively. Secondly, as for the conditions of ecological health, they were both sound in 1992 and 2002, with an area of 73.52% and 73.15% of the total evaluation area, respectively, and the ecotypes focused on the types of health and sub-health. But, health ecosystem in 1992 with an area of 764.64ha, accounting for 38.51% of the total evaluation area, was better than that in 2002 with an area of 636.10ha, accounting for 34.19% of the total evaluation area. The area of non-health ecosystem was 209.05ha in 1992, while it added to 256.40ha in 2002. Thirdly, in terms of the health ecosystems, they consisted of wide valley arbor, shrubbery and cropland with mild slope, perfect function and high productivity in both 1992 and 2002. However, wide valley shrubbery and dryland ecosystems were in health in 1992, while they generally degenerated to the sub-health ecosystems in 2002, due to the humankind's disturbance, such as the exploitation of tour resources and building. At the same time, sub-health mild slope degradation forestland ecosystem in 1992 degenerated to less health ecosystem in 2002; less health mild slope lower cover grassland ecosystem and less health steep slope shrubbery ecosystem in 1992 degenerated to non-health ecosystem. In addition, the investigations found that in the same ranges for two periods, the ecological health conditions in 1992, no matter stability or reconstruction, were better than that in 2002. Finally, as for the spatial distribution of ecosystem health conditions, they were mainly accordant in the two dates. Health ecosystem was mostly distributed in the southern wide valley, western mild slope and lower mountainous area of Beiwenquan Town. Sub-health ecosystem was mostly distributed in the western mild slope, lower mountainous area and the southern wide valley area of Beiwenquan Town. Less health ecosystem was mostly distributed around Jinyun Mountain and North Hot Spring (*Beiwenquan* in Chinese) where the humankind has disturbed frequently. Non-health ecosystem was mostly distributed in the western lower mountain suburban of Beibei County. In short, both of the conditions of ecological health in 1992 and 2002 were sound. But, the ecotypes involved into difference ranges have already degenerated, due to humankind' disturbance, while in the same ranges for two periods, the ecological health conditions of stability or reconstruction in 1992 were better than that in 2002.

3.3 Land Use Optimization

Applying Mathematica2.2 for windows, the optimization scenario that satisfied constraint equation, and preserved benign development of ecological health as well, was obtained (Table 5). As shown in Table 5, the biggest transformation area was orchard land, increasing 1.25%, the next were cultivated land, unused land, water and forest land, while residential and industrial-mining land and transportation land had not further adjusted. This optimization scenario rather accorded to the practices of nature, economy and society in Beiwenquan Town. Firstly, it was necessary to adjust agricultural structure to satisfy the change of food quantity and variety brought by the improvement of standard of living. Unused land

Table 5 Optimization of land use structure

Type	Existing area		Optimization area		Change
	(ha)	(%)	(ha)	(%)	(%)
Cultivated land	412.07	13.07	388.29	12.95	−0.75
Orchard land	264.26	8.38	303.75	9.06	+1.25
Forestland	1033.26	32.78	1045.26	32.84	+0.38
Residential and industrial-mining land	1001.72	31.77	1004.73	32.19	+0.10
Transportation land	56.66	1.80	57.41	1.76	+0.02
Water	233.91	7.42	222.83	7.07	−0.35
Unused land	150.70	4.78	130.31	4.13	−0.65
Total	3152.58	100.00	3152.58	100.00	0.00

was cultivated as orchard land and forestland to some extent, resulting from the property right adjustment of "four kinds of barrens" (e.g., barren mountain, barren slope, barren gully and barren beach). In Beiwenquan region with lower mountain and mild slope, the double effects were produced by transforming cultivated land into orchard land, and reclaiming unused land into orchard land and forest land, i.e., meeting the demand of people's living and improving ecological environment as well, especially for such non-health unused land. Secondly, the adjustment of water stemmed primarily from the reconstruction of flood control works in the bottomland of the Jialingjiang River. Presently, the water conservancy facilities were favored to reduce the flood damage, and to increase land for urban construction. For instance, the residential area along riverbank was built beside the first flood control project. Thirdly, forest land ecosystem was the main body of health ecosystem. This paper did not further adjust forestland area comparing to its existing area, but optimized forestland structure through rebuilding degradated forestland, sparse woods and lower cover shrubbery. Finally, although urbanization was one of the mainly driving factors of land use change, the expansion of residential and industrial-mining land was not at the expense of cultivated land, orchard land and forestland. It was the main objective to increase land intensive degree and utilization efficiency. At the same time, there were not the bigger items of transportation in the near future, in view of the construction of Chongqing–Beibei highway. Therefore, residential and industrial-mining land and transportation land were not further adjusted.

The planning scenario could quantitatively meet the optimization of ecological health and the rational utilization of land resources, but the benefit of land utilization depended on the spatial distribution of land resources to some extent. So, based on ecological health evaluation and the development trend of Beiwenquan Town, the distribution of land use structure was represented. Wide valley and mild slope intensive land use region was located in the southern Beiwenquan Town and urban-rural inter-distributed region. The former was in sound health, while the latter was represented as a sub-health, due to the slight disturbance of humankind. In these regions, topography was mild, and soil development was normal and fertile. Therefore, there was cropland rotation under the premise of soil and water conservation. However, to avoid soil degradation, shrub population and grass cover should be allocated around cultivated land near the slope break line, while water and soil conversation forest could be planted in periphery of cultivated land. They became the grid compound ecosystem with forest, shrub and cropland.

Urban industrial development area was distributed in the southern, northeastern, and outskirts narrow zone of Beiwenquan Town, including the central built-up area and outskirts integrated agriculture area. The built-up area was an essential part of the town, with dense population and categories of industry. To avoid ecosystem deterioration, land structure in this region should be harmonized under the condition that greenbelt area accounted for 25% of the total built-up area. Facing the threat of constructive occupation and the severity disturbance of built-up area, outskirts integrated agriculture area was in no-health. To inhibit constructive spread and outskirts pollution, it was planned as a basic farmland area. At the same time, it was suitable for the production of vegetable, fruit, aqua-product and flower, due to its better economic location. To stabilize farmland ecosystem, it should be linked with stable arbor and shrub ecosystem together.

Lower mountain ecological landscape area was located in the western Beiwenquan and Beiwenquan-Chengjiang contiguous belt. Its ecological health state was complex, with four types at the ranges from health to no-health. We should strongly protect the health area of mild slope and lower mountain in the western Beiwenquan Town, where arbor and shrubbery were major vegetation types, to reduce holiday economic disturbance, and to adjust ecosystem to the stereo-structure with arbor, shrubbery and grass. However, sparse woods and shrubbery ecosystem in this region was in sub-health, due to humankind slight disturbance. To protect slope land, one of the best ways was planting forest and grass, that is, optimizing forestland structure through planting the mixed forests of needle-broad leaved trees and the protection forest of arbor and shrubbery. Anti-slope terraced field was a good way as well. The reason was that it is possible to form compound ecosystem of forest, shrub and cropland through planting shrubbery population around a terraced field with slope, or planting forest, shrub and crop in mild slope. Less health ecosystem was mostly distributed around Jinyun Mountain and North Hot Spring (*Beiwenquan* in Chinese) holiday village where humankind's frequent disturbance has resulted in sparse vegetation and severe gully erosion. So we should pay attention to moderate exploitation of tour resources in this region. To protect landscape from being damaged, we could plant protective timber-forest along perpendicular strike of slope, and strengthen management. Non-health bare land and rock ecosystem were in bad site condition, hard reconstruction vegetation and high erosion degree. It was suitable to pla nt pioneer leguminous brush firstly, so as to accumulate soil organic matter. While in steep or broken slope, trees can be planted in fish-scale pits and horizontal furrow combined with general pits. To avoid the great damage, in the area not suitable for exploitation, pioneer plants should be preserved.

4 CONCLUSIONS

Land use was a complex, dynamic and controllable system. Land use patterns have direct impacts on ecosystem health. Especially, these impacts were greatly obvious in economically dynamic and densely populated areas. However, the key of land use was how to preserve favorably biodiversity and ecosystems function. Ecological health emphasized the dynamic harmony of different factors, and land use was coupling among many factors. Ecological health could be taken as the theoretical basis of sustainable land use and planning, in reverse, the sustainable land use and planning was the valid means to realize ecological health, due to both of them emphasizing the coordination of factors. From this study it could be seen that it is possible to put forward the macro-strategy optimization of land use through analyzing regional land use change and the land ecological states. The objectives to harmonize humankind's activities with ecological state at spatial-temporal scale could be realized. Therefore, sustainable land use planning based on ecological health at typical regional scale had main function to realize the intergrowth of human and land. Such planning framework has higher useful value, because it not only accords to ecology principle, but also satisfies the development demand of society and economy.

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