Suitability Evaluation and Empirical Study of Green-way Network Selection Based on GIS

Yuanrong He[1, 2], Jianan Li[3]*, Guihua Liao[1] and Jianzhi Chen[3]

[1]*School of Computer and Information Engineering, Xiamen University of Technology, Xiamen, P.R. China*

[2]*Institute of Urban Environment, CAS, Key Laboratory of Urban and Environment Health, Xiamen, P.R. China*

[3]*School of Engineering Management, Guizhou University of Finance and Economics, Guiyang, P.R. China*

Abstract: Based on the background of Gutian country-level green-way planning project, this essay carries out suitability evaluation and empirical study of green-way network selection based on GIS.The main study contents include: According to the green-way network selection principles and analysis of basic construction conditions,taking overlay analysis of GIS quantitative suitability , and putting forward a set of more universal green-way network selection factor evaluation system. Inviting experts to determine the score for each factor score by questionnaires and e-mails, and writing a AHP program for calculating factor weight of, then this essay uses the space analysis modeling module of GIS software to make weighted overlay analysis on evaluation factors layer data so to obtain suitability analysis results. Finally, superior planning, that is municipal planning routing and experts recommend points are taken as a suitability evaluation results graph to verify, and the verification are to confirm the applicability of this evaluation method and the rationality of the results.

Keywords: Green-way, gıs, suitability evaluation, empirical, ahp.

1. INTRODUCTION

Green-way, a borrowed word, represents those linear green open space which is constructed along the natural and artificial corridors, like rivers, valleys, ridges and scenery roads. The origin of Green-way can be traced back to that Frederick Law Olmsted completed the famous Boston Park system planning in 1867 [1]. The green-way system is of 25km length, connecting Boston, Brooklyn and Cambridge, and making them connected with Charles River. Then, Charles Eliot extended his ideas, by expanding the green-way network to the entire Boston metropolitan area to 6000km^2, and organically integrating the three major rivers and six almost connected large open space into the periphery of the region, which set a precedent for green-way system construction in USA.

Currently, the number of green-ways that the United States are annually planning and constructing is up to hundreds or even thousands. In the East coast of the US, for example, the total green-way construction of 4500km cost $300 million, and brought the states tourism revenue of $16.6 billion, while also bringing economic, social and ecological benefits for more than 38 million inhabitants. Overview of classic cases of domestic and international green-way construction, the comprehensive efficiency is significantly, reflected in following aspects:

(1) Economic benefits. Building roads is precondition of wealth, which is summed up the masses in the life practice experience. For green-way, as a result of chronic mode like cycling and walking associating residents and visitors with avariety of forest parks, nature reserves, scenic spots, country parks, waterfront parks and cultural sites, increasing in contact with tourism elements such as "eat, live, travel, shopping, entertainment", which promotes the vigorous development of the tertiary industry and brings incalculable economic benefits. Take Zengcheng City, the first domestic city in green-way construction, as an example, the amount of tourists was only 2.7 million in 2007, while the number of annual visitors exploded to 16.9 million in 2011 [3-5]. The green-way tourism brings Zengcheng explosive growth in tourists number. Green-way, therefore, is also known as the "fiscal-way". In addition, green-way not only functions as basic road infrastructure and ecological infrastructure, but also plays a role in optimizing regional spatial form, improving the quality of residential environment, so raising the value of the land and property. Ruhr industrial area in German, for example, has made the combination of green-way construction and industrial zones renovation since 1989, so to control the wanton expansion of the city, focus on settlements, improve air quality and provide recreational opportunities. The seven programs of "green-way" turn the centuries' filthy and inefficient industrial zone into a livable city of ecological security and beautiful scenery, which improves residents' quality of life, promotes urban renovation of old city, and enhances the value of the surrounding lands as well.

(2) Social benefits. in 2012 to During the meeting to improve the level of urbanization development in 2012, when the chairman of Guangdong Provincial Party Secretary Wang Yang, who was the Secretary of Guangdong Provincial Party Committee highly criticized the "three evils" in

Guangdong urban development: buildings were westernized while features were lost, city became bigger while space became smaller, population was raised while communication was reduced [6]. Green-way construction provides more space for residents and visitors, makes the traffic easier for visiting relatives and friends, offers a variety of leisure activities, and promotes people communication and society harmony. The green-way of Singapore, a multi-ethnic country, was founded in 1991 originally only for cascade planning of green space and water. The concept planning in 2001 put forward the goal to improve the accessibility of green space, and expand the coverage of cascade system to the parks, the new town center, sports facilities and public neighborhood. This smooth and seamless-connection cascaded green corridor connects the regional open case of urban periphery with the open green space inside the city, creates plenty of outdoor space for leisure and entertainment and communication, which not only allows residents to walk, jog and cycle, but also provides habitats for wild animals, not only creates a beautiful and pleasant "garden city", but also effectively promotes the harmonious integration of a multi-ethnic country.

(3) Ecological benefits. During the late 19^{th} century and the early 20^{th} century, London was famous for Fog, and poor environment caused many people's worry and concern. In order to combine the urban and the suburban and create comfortable space for leisure, London proposed the city-country combination model of garden city. By systematic planning of open space, sidewalks, bike paths and water space, the greenbelts and associated green-way network was formed. Today, nearly 300 green necklace -like open space has been constructed around London, and the square is as 7 times as that of the urban. The rule that the city development is limited within the Green-Chain makes the green ecological corridor become an inhibiting magic phrase to prevent the out-of-ordered extension [7]. London's greenbelts combining green-way construction and urban open space makes London a complete change from polluted city into garden city, becoming the most successful model to promote the urban greenbelt construction in the world.

With the construction of the green-way sweeping the world, Fujian Province has also set off a building boom. The government promulgated the "Fujian Green-way Network Planning Outline", planning to realize the construction of the green-way all over the province in 2020by dividing into the implementation of provincial, municipal and county level. Many factors influence every level, and it is of great theoretical and practical value for the costly people-benefit project by proposing a set of more universal green-way network selection factor evaluation and validation system according to the green-way network selection principles and basic construction conditions, which takes the overlay analysis of GIS quantitative suitability.

2. MATERIALS AND METHODOLOGY

Gutian County are of superior ecological environment and rich forest resources. In the large area position, Gutian County is located in the west side, between the two economic circles, Pearl River Delta and Yangtze River Delta. In the small area position, Gutian County is located in east-central northern Fujian, in the connecting part of Nanping City, Fuzhou City and Ningde City, belonging to Ningde City. It is 120 km away from Fuzhou City center, and 133km away from that of Ningde. It is located at longitude 118° 32'~ 119° 24', latitude 26° 16'~ 26° 53'.

Gutian County is rich in tourism resources, such as Ping Lake, Lake Bell, Waterfront Palace, Lam Tin College, Kek Lok Si homes. There are four provincial units and 14 county-level units. Gutian is known as cultural town, within beautiful scenery, numerous cultural relics , that auspicious Temple built in the Song Dynasty and secluded rock Temple , Master of Science Zhu Xi lecture Gutian Lantian College, president of the Chinese Buddhist Society first round Ying Master Memorial, the famous waterfront palace in Southeast Asia, the Millennium Kek Lok Si temple and other relics , there are large artificial lake formed Cuiping Lake Hydroelectric power plants (37.1 km^2) and Lake Bell (35.4 km^2) and other attractions, monuments and Silk Mountain melt as a whole, picturesque.

Gutian County green-way network selection mainly analyzes the resource factors, policy factors demands, local willingness and other aspects. As " mountain, lake (river), city," on the basis of the, By taking the overall urban pattern of mountain-river-city as the principles, it emphasizes the relationship among the urban and rural settlements, history, culture, landscape resources and the natural landscape of the city, and highlights its landscape and multicultural culture.

The article summarizes that the main influenced factors are ecological background elements, and facilities basic elements [8]. Green road line should be selected closed to ecological background like rivers, valleys and mountains of good connectivity, combining landscape resources, such as series of representative scenic spots, resorts, demonstration pilot project of historic settlement, tourism, cultural relics and beautiful countryside landscape resources and historical and cultural corridor, making good use of basic facilities which are close to residents.

2.1. Ecological Background Analysis

(1) Rivers and water system. With much hydrometer and many rivers, the water system in Gutian County develops in arborization. Separated by Tuman Mountain, the west belongs to Min River system, while the east belongs to Ao River system. Besides the Min River, the water system includes Gutian River, Yuyuan River, Longyuan River, Cuiping Lake and some reservoirs.To highlight ecological characteristics, green-way network planning should take riverside waterfront location into consideration [9-11].

(2) Natural mountains. Gutian County is rich in forests and mountains, including Wuhua Mountain, Gao Hummock, Zhen mountain, West Mountain, Shita Mountain and Qilin Mountain, and so on. The central part of the county is mainly for mountain ecological conservation area, which is the cradle of main rivers and upstream, the concentrated area of ecological preservation area, rare biological reserve area and scenic spot as well. In order to increase the attraction of green-way, green-way network planning should take the natural mountains and scenic into consideration.

2.2. Landscape Resources Analysis

(1) Natural landscape resources. Gutian County is rich in natural tourism resources. There are famous Cuiping Lake and Kek Lok Si Temple in the eastern street, Yutian Park and Ganguobao's former residence in the western street. There are many famous landscapes in other towns.

(2) Cultural landscape resources. Gutian County, an ancient county with a history of more than 1,000 years, shows advantages in cultural landscape resources. Since Yin and Zhou Dynasties, people had ever lived here. There are three villages listed in the first batch of Chinese traditional villages, that are Fuda Village, Changyang Village and Shanyang Village.

(3) Beautiful rural resources. The construction of "Beautiful country" of Gutian county focus on four beauty-- "beautiful environment, beautiful villages, sweet life and social beauty". It plans to be completed in five years, so the green-way planning should take combination of beautiful country points and rural resources into consideration.

3.3. Transportation Infrastructure

Green-way construction should strengthen connection with the urban public traffic and make good use of the transportation infrastructure, by connecting the main public stations, bus stop, railway station and BRT stations, so to improve the service efficiency and accessibility of green-way and provide convenience for the citizens' travel. The planning of Jade Lake Area is located in the eastern suburbs of 3 km at Gutian county, the district is mainly relying on State Road 316 Contact Fuzhou, relying on Highway 202 and Highway 304 links Pingnan, Ningde; The region's major road by the lake, walking trails and water route composition, traffic location is good. Planning and construction of the Beijing-Fuzhou Expressway, Beijing high-speed railway and Nanping, Old Yang (Pingnan) cable, will increase future traffic conditions in the area of location.

Based on the overall analysis of resource elements and factor, Gutian County green-way selection reference model is shown in Fig. (**1**).

3.4. AHP Index Weight

According to the established evaluation factor system and the principle of AHP method to calculate, according to the principles of scientific, normative, timeliness and rationality, the hierarchy structure model is established. The target layer: A = line selection influence factors; Criterion layer: C1 = ecological background layer, C2 = landscape resource layer, C3 = facilities base layer.

Primary indicators layers: P1= terrain elements, P2 =ecological elements, P3 = natural nodes, P4 = humanities nodes, P5= slow system foundation, P6 = road infrastructure foundation, P7 = transport interchange foundation, P8 = service facilities foundation.

Secondary indicators layers: Q1 = slope, Q2 = river reservoirs, Q3= large green area and mountains, Q4= tourist scenic area and resorts, Q5 = forest parks and urban green area, Q6 = beautiful countryside, Q7 = characteristic nodes and security unit, Q8 = ancient villages and the other nodes, Q9= levees and tree-lined trails, Q10= non-high rapid road network, Q11= rail station sites, Q12 = passenger and bus stops, Q13 = various attractions and park service area.

For each factor in the calculation of the benchmark model, carried out arithmetic assignment in accordance with the rating, and determine the weight, to establish a complete evaluation system; Combined with green-way connection and functional requirement by population density and landscape resources concentration factor overlay analysis, establishing contact green-way of huge population density or rich landscape resources areas. Concrete are shown in Table **1** above.

Determine the weight of each criterion: the use of on-site survey questionnaires and mail, to invite a number of experts in scoring more than 20 years of economics, landscape ecology, urban planning, landscape design and other fields, to

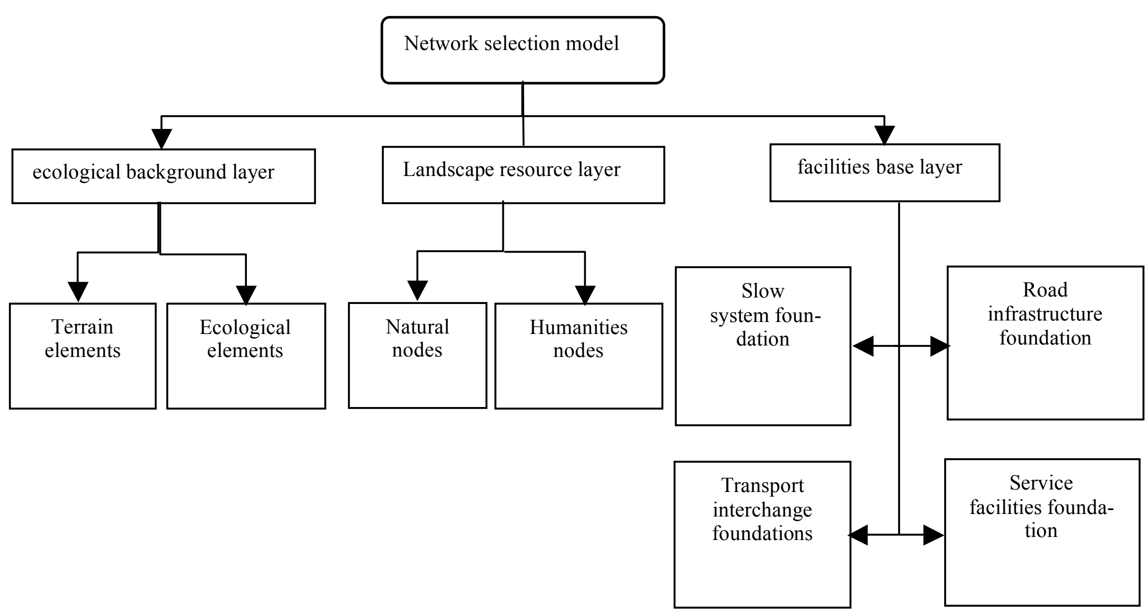

Fig. (1). Gutian County green-way selection reference model.

Table 1. Weight value of impact green-way network selection of each criterion.

Criterion Number	1	2	3	4	5	6	7	8	Weight Value ω
1	1	1	1/4	1/5	2	4	3	1/5	0.075
2	1	1	1/4	1/5	4	6	5	1/6	0.089
3	4	4	1	1	5	6	4	1	0.229
4	5	5	1	1	4	6	5	1/3	0.211
5	1/2	1/4	1/5	1/4	1	1	1	1/6	0.038
6	1/4	1/6	1/6	1/6	1	1	1	1/4	0.032
7	1/3	1/5	1/4	1/5	1	1	1	1/6	0.035
8	5	6	1	3	6	4	6	1	0.291

determine the relative importance of each two criteria then use AHP computing and power factor criteria layer weight value.

It can obtain the maximum eigenvalue лmax = 8.69414 , a one-time index CI = 0.09916. Because n=8, RI=1.41, so the one-time ratio $CR = CI/RI = 0.07033 < 0.1$, comply with the requirement of consistency.

Similarly we can obtain the secondary layer weights: slope 0.075, river reservoirs 0.049, large green area 0.04, tourist scenic area and resorts 0.14, forest parks and urban green area 0.089, beautiful countryside 0.072, characteristic nodes and security unit 0.069, ancient villages and other nodes 0.07, slow road network 0.038, non-high rapid road network 0.032, rail station sites 0.017, passenger and bus stops 0.018, various attractions and park service area 0.0291. Based on above calculations, reorganizing can be obtained green-way network selection factor evaluation system in the following Table **2**.

3. RESULTS

3.1. Slope Analysis

Multi-use green-way crowd for walkers, cyclists, wheelchair users. As an important impact factor of people walking or cycling physically output and ability to moving freely, the slope becomes the key of green-way planning considerations. Refers to the ratio of the slope of the slope in the horizontal direction perpendicular to the length of the projection length of the projection direction.

Table 2. Green-way network selection factor evaluation system.

Criterion layer		Primary indicators layers		Secondary indicators layers	
content	**Weight**	**content**	**Weight**	**content**	**Weight**
ecological background layer	0.164	Terrain elements	0.075	slope	0.075
		Ecological elements	0.089	river reservoirs	0.049
				large green area	0.040
Landscape resource layer	0.440	Natural nodes	0.229	tourist scenic area and resorts	0.140
				forest parks, urban green area	0.089
		Humanities nodes	0.211	beautiful countryside	0.072
				characteristic nodes and security unit	0.069
				ancient villages and the other nodes	0.070
Facilities base layer	0.386	Slow system foundation	0.038	levees and tree-lined trails	0.038
		Road infrastructure foundation	0.032	non-high rapid road network	0.032
		Transport interchange foundations	0.035	rail station sites	0.017
				passenger and bus stops	0.018
		Service facilities foundation	0.291	various attractions and park service area	0.291

Combining with Flink and Liu Yue's research, the slope of the study area is divided into 5 levels: slope in the most suitable region for below 3°, anyone can freely in any way, four points; 3° ~ 5° is suitable, ordinary people can travel freely, special populations, such as the disabled people in wheelchairs can travel with the help of a normal person, 3 points; 5° ~ 10° to compare the most suitable, more exhausting, special groups can't travel, 2 points; 10° ~ 15° is not suitable, very exhausting, people need to use tools to travel, +1; More than 15° is not suitable, 0 points, but for the very famous scenery area, can be set up step ladder or covered round hill road to walk.

3.2. Accessibility analysis

Accessibility analysis is one of the important areas of geography research, it is the study of the people from any point in the space to the destination, to the difficulty of the process reflects the people to arrive the resistance to overcome space size, general use such as indicators to measure distance, time, cost, has been widely used in urban public service facilities distribution rationality and fairness.

According to the landscape architect portable manual, accessibility of walking distance criterion buffer distance can be set to: within 500 m very good scope for accessibility, score of 4; 500 m ~ 1000 m good scope for accessibility, score 3; 1000 m ~ 1500 m for the scope of the accessibility of general score of 2; 1500 m ~ 2000 m for the range of poor accessibility, score of 1; More than 2000 m for the range of poor accessibility, score of 0.

3.3. GIS Modeling Process

(1) Open the Arc Map, add all the required data into it.

(2) Open the "Arc Toolbox→New Toolbox" to create a "Green-way" tool, then create a new model in the Tools.

(3) set properties of the model. Open the Overlay Model Properties window, select Environments TAB, select "General Settings→ among" to set the value of it, choose "Same as variable slope". The purpose of this step is to set the size of the generated grid figure and slope figure size is consistent. Also, set the Raster Analysis Settings properties: the Cell Size is set to the "Same as variable slope", the Mask is set to gddem. The purpose of this step is to set the output size of the grid figure like yuan RMB and the gradient image size is consistent, and elevation figure as mask tool, cut out of the output raster map.

(4) The source data modeling are separately pulled to the model construction of the window, and alignment find Spstial Analyst Tools in

ArcToolbox→Distance→Euclidean Distance, the Euclidean Distance are drawn into the model editor window, the output path, and the output of the pixel size and set the distance grid is 90. Among them, Euclidean Distance refers to the straight line distance is calculated for each pixel center and the source pixel center.

(5) Found Spstial Analyst Tools in ArcToolbox→ Map Algebra→Single Output Map Algebra, the Single Output

Map Algebra in turn into model editor window.

(6) The factor of Single Output Map Algebra formula (for instance) :

1) Slope: Con (slope <3,4, Con (slope> = 3 and slope <5, 3, Con (slope> = 5 and slope <= 10,2, Con (slope> = 10 and slope <15,1, 0))))

2) Lake: Con (Lakes <500, 4, Con (Lakes> = 500 and Lakes <1000, 3, Con (Lakes> = 1000 and Lakes <= 1500,2, Con (Lakes> = 1500 and Lakes <= 2000, 1,0))))

(7) Finally, the weighting factor multiplied by the corresponding output results Single Output Map Algebra formula: slopeout * 0.075 + (river + lake) * 0.049 + park * 0.04 + holiday * 0.14 + (forest + city) * 0.089 + beauty * 0.072 + cultural * 0.069 + old * 0.070 + slow * 0.038 + uroad * 0.032 + track * 0.017 + pstation * 0.018 + sight * 0.291. Model as shown in Fig. (**2**).

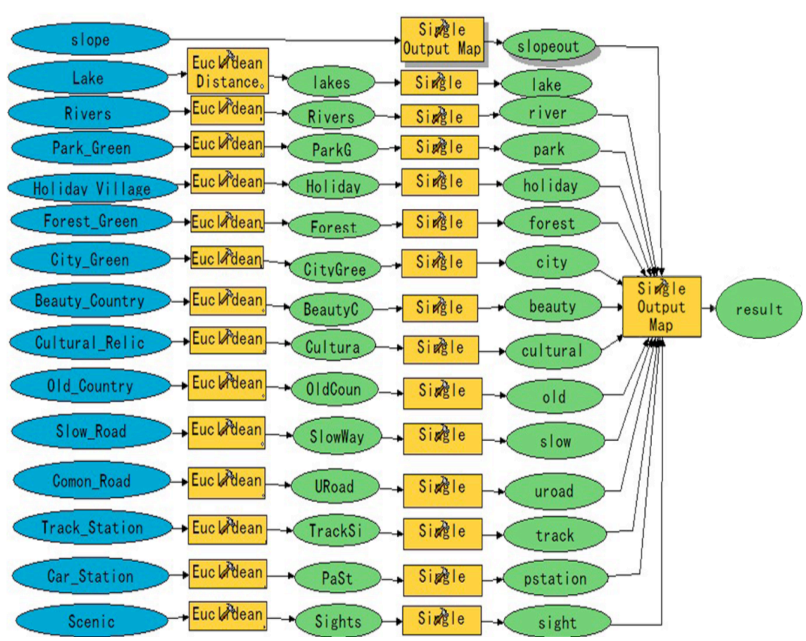

Fig. (2). Overall layout of buffer analysis model.

(8) According to the model constructed above, the results of the final output is shown below in Fig. (**3**).

4. CONCLUSIONS

4.1. Research 1: Verification with the Superior Planning and Municipal Planning Wiring

To 2020, Fujian province green-way network planning will built six provincial green-way mainlines (2727 km), two green-way branches (187 km) and twenty green-way interfaces , the total length of about 2914 km. Ningde City actively responds to the requirements of the provincial government, carries out the green-way planning. was completed in 2012 the The Ningde City Green-WAY Network Planning (2012-2020) has been finished in 2012, and some projects are under construction [12]. The Gutian County cope takes axis of Municipal 3 and Municipal 4 green-way, connecting Provincial 3 in the south and Provincial 2 in the north, with the total length of about 143.0km, as follows Fig. (**4**) shows.

(1) Provincial No.3 green-way is along the Minjiang River from east to west, reflecting the mountain, river, lake , sea , and other characteristics of the city. Starting in Minjiang River Estuary and connecting the coastal green-way, it passes through cities and counties like Fuzhou, Minqing, Furuta, Nanping, Jian'ou, Jianyang and Wuyishan, connecting about 31 nodes in a total length of 381 km, passing through a node in Shuikou Town. The length inside Gutian

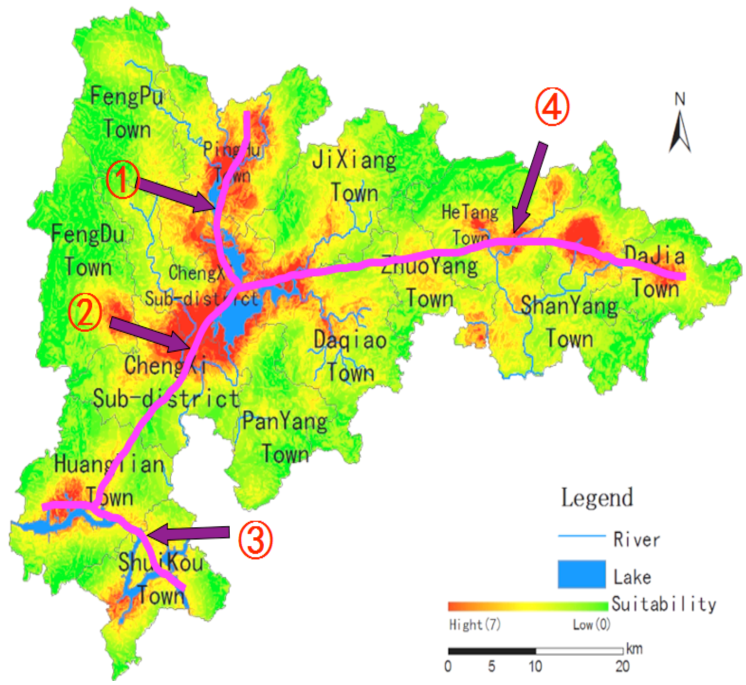

Fig. (3). The output results of buffer analysis model.

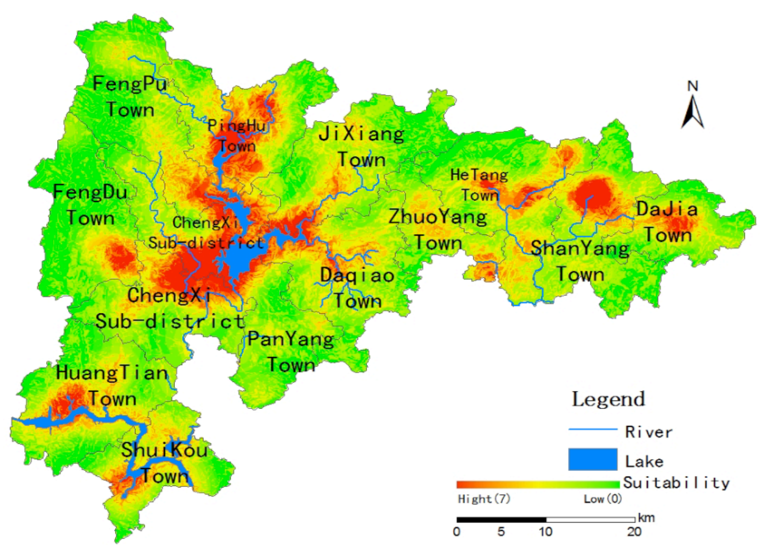

Fig. (4). Gutian country green-way network selection suitability evaluation results.

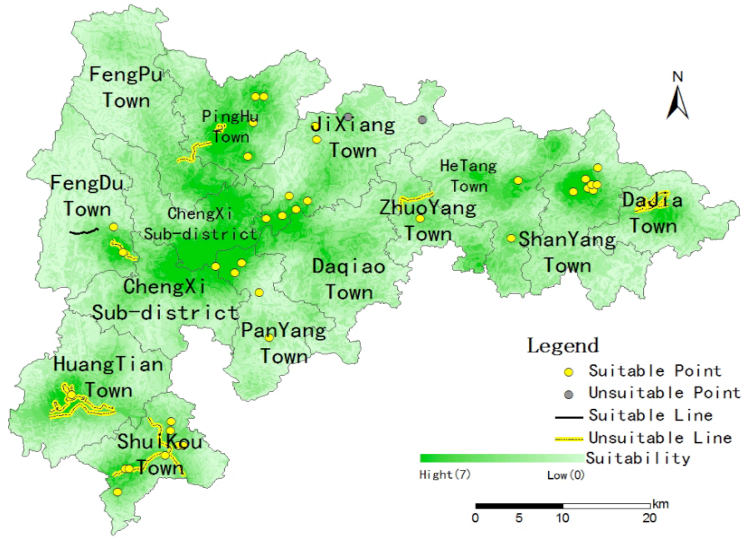

Fig. (5). Gutian country green-way network selection willingness investigate conditions.

County is about 13 km, starting from State Road 316 to Gutian through the Xiongjiang Town, and entering Nanping City on the east of Shuikou Town.

(2) The length of Municipal No.3 inside Gutian County is about 62.4km, starting from Shuikou Town, passing the urban and Fengpu, entering Pingnan County on the north of Pinghu Town, connecting Provincial 2 and Provincial 3.

(3) The length of Municipal No.4 inside Gutian County is about 62.6km, starting from the urban, passing Cuiping Lake, Daqiao Town, Hetang Town and Shanyang Village, entering Ningde City on the east of Dajia Village, and connecting Provincial 2 and Municipal 3. It constructs a county green-way network by taking the waterfront green-way of Cuiping Lake as the core.

According to the chart of superior planning of Ningde city green-way network planning (2012-2020) and suitability analysis results, it shows that: the passing areas of Municipal No. 3 ecological green-way, green-way connecting line, Provincial No. 3 Minjiang green-way and Municipal No. 4 Gutian green-way are of high suitability, verifying the reasonable of suitability evaluation results.

4.2. Research 2: Verification with Recommends of Experts

During the green-way network selection process in Gutian County, questionnaires were designed to ask the selections of construction station masters from 7 towns, 5 townships and 2 sub-district office construction bureau staff. By on-spot survey and qualitative and quantitative analysis, the intention implementation tables were made. On the basis of station masters' recommend, and selected by the leaders of Municipal Construction Bureau, planning personnels and evaluation experts, the intention investigation and implementation about the green-way is finally made.

According to the Gutian County Green-way network selection intention investigation and implementation of the description and on the Gutian County Green-way network selection suitability analysis results of Fig. (**4**), the investigation is as following.

The Fig. (**5**) clearly shows that the adopted points or lines are distributed in the area of high suitability, while the unaccepted points or lines are distributed in the area of low suitability. In conclusion, the green-way selection suitability results in this essay are mostly in accordance to the people's selection intention, to further verify the scientifically of suitability selection results based on GIS, providing important references for the recent planning and detailed planning of green-way.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Funded projects: The fourth sub-topics of National Key Technology Research and Development Program of the Ministry of Science and Technology of China (number: 2012BAC16B00); One hundred billion yuan in Guangxi major scientific and technological projects (number: Guikegong 1218017-9D).

REFERENCES

[1] M. J. Teng, C. G. Wu, Z. X. Wu, E. Lord, and Z. M. Zheng, "Multipurpose Green-way Planning for Changing Cities: A Framework Integrating Priorities and a Least-cost Path Model", *Landscape and Urban Planning*, pp. 1-14, 2011.

[2] Y. Cai and F. He, "Greenway Site Choice With Urban Rural Integration", London: PLANNERS, pp. 35-37, 2011.

[3] Y. B. Zhang and R.W. Wu, "The Theory and Practice of Greenway Construction in Europe", *Chinese Landscape Architecture*, 2007.

[4] W. Wu and X. Fu, "The Concepet of Greenway Infrastructure and Review of Its Reseach Development", *Urban Planning International*, vol. 24, no. 5, 2009 .

[5] P. Basirat and H. Fazlollahtabar, "Modelling and Controlling Reliability of a Maintenance System using Casual Loop", *Advances in Industrial Engineering and Management*, vol. 3, no. 2, pp. 47-58, 2014. doi:10.7508/AIEM-V3-N2-47-58
[6] K. J. Yu, "Ecological Security Patterns in Landscape and GIS Application", *Geographic Information Sciences,* vol. 22, pp. 1-12, 1995.
[7] V. Ferretti and S. Pomarico, "Ecological land suitability analysis through spatial indicators: An application of the Analytic Network Process technique and Ordered Weighted Average approach", *Ecological Indicators*, vol. 34, pp. 507-519, 2013.
[8] N. A. Maleka, M. Mariapan, and M. K. M. Shariff, "The Making of a Quality Neighborhood Park: A Path Model Approach", *Social and Behavior Sciences,* vol. 49, pp. 202-214, 2012.
[9] M. Cabeza, "Ecological and Social Connectivity", *TRENDS in Ecology and Evolution,* vol. 20, no. 2, February 2005.
[10] M. Poff, "Navigating US green-ways: US political reflections in An Inconvenient Truth", *Journal of Integrative Environmental Sciences*, vol. 10, January 2014.
[11] W. Miller, M. G. Collins, F. R. Steiner, and E. Cook, "An Approach for Green-way Suitability Analysis", *Landscape and Urban Planning*, vol. 42, pp. 91-105, 1998.
[12] K. W. Tan, "A Green-way Network for Singapore", *Landscape and Urban Planning*, vol. 76, pp. 45-66, 2006.

Received: September 18, 2014 Revised: December 22, 2014 Accepted: December 31, 2014