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Analysis on sensitivity and landscape ecological spatial structure of site resources

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Abstract: This article establishes a set of indicators and standards for landscape ecological sensitivity analysis of site resources by using the theories and approaches of landscape ecology. It uses landscape diversity index(H), evenness(E), natural degree(N), contrast degree(C) to study spatial structure and landscape heterogeneity of site resources and thus provides a qualitative-quantitative evaluation method for land planning and management of small, medium scale areas. The analysis of Yantian District, Shenzhen of China showed that Wutong Mountain belonged to high landscape ecological sensitivity area, Sanzhoutian Reservoir and Shangping Reservoir were medium landscape sensitivity area and high ecological sensitivity area; Dameisha and Xiaomeisha belonged to medium sensitivity area caused by the decline of natural ecological areas. Shatoujiao, Yantian Pier belonged to low sensitivity area but urban landscape ecological development had reshaped and influenced their landscape ecological roles in a great extent. Suggestions on planning, protection goals and development intensity of each site or district were raised.

Keywords: sensitivity area; site resource; landscape heterogeneity; scale; landscape architecture

Natural resources(landform, geology, hydrology, creature, ecology etc.), human resources (culture, economy, location etc.) and landscape ecological spatial structure of a certain place can determine its development patterns and landscape architecture as well as its limitation of development intensity. In order to make the projects fit for the local natural characteristics so that the goals of both a harmonious, efficient landscape architecture and better environmental protection and sustainable development can be achieved, we undertook a landscape ecological analysis on Yantian District, Shenzhen of China after having referred to American View Resources Management System (VRM). This article has set up a set of indicators and standards for landscape ecological sensitivity analysis of site resources and provided scientific grounds for the development and management guideline, which is conductive to full utilization of characteristics and potential of site resources.

1 Research approach and evaluation standards

1.1 Brief introduction on researched area

Yantian District, located in east Shenzhen and facing Hong Kong and Dapeng Bay in its south direction, has a total area of 67.36 km^2 and 21.5 km coastal line. The geomorphologic framework of Yantian District is mainly composed of three mountains (west: Wutong, 943.7m a.s.l.; middle: Meishajian, 753m a.s.l.; east: Liantangshe, 503m a.s.l.) and 2 lower plains(Yantian fluvial plain and Dashuikeng valley). In Dashuikeng valley, there was a road leading to the northern Sanzhoutian Reservoir along the Meishajian hill foot; in Dapeng Bay coastal area in the south, there were 4 main stripes of town residential area: Shatoujiao Town and Yantian Pier in the west; Dameisha and Xiaomeisha coastal sand resort in the east. The total population of Yantian District is 120 thousand.

Yantian District lies in the area of southern subtropical moist monsoon climate, it has a mean annual temperature of 22℃ and mean annual precipitation of 1950 mm. Current vegetation is mainly composed of southern subtropical valley rain forests, southern subtropical monsoon broad-leaved forests, bushes, orchards and small area of mangroves.

Yantian District is divided into 7 site (regional) units which have formed 4 small drainage area: Wutong Mountain——Shatoujiao (drainage area 1, abbreviation DA 1); Yantianxu (DA 2); Meishajian——Sanzhoutian Reservoir(DA 3); Shangping Reservoir——Dameisha——Xiaomeisha(DA 4;

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Fig.1 and Table 2). 10 landscape element types were classified into 3 landscape sections: natural section (mountain, hill, river, coast, sea surface); semi-natural section(reservoir, crop field and its subclasses such as orchard, tea garden, village, mud road); and artificial section(town, road, pier).

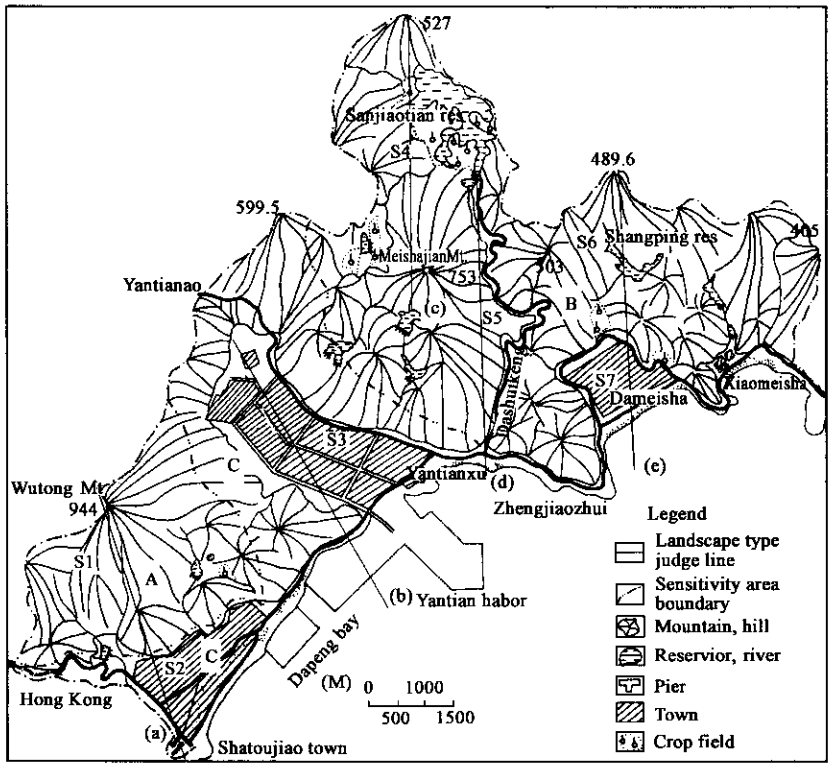

Fig.1 Analysis on landscape and ecology sensitivity in Yantian, Shenzhen

During 1999—2001, after field investigation on biodiversity of rocks, waters, vegetation etc. we drew up a 1:10000 plant distribution map and landscape ecological classification map.

1.2 Measurement of ecological spatial structure and landscape heterogeneity

(1) Landscape diversity and evenness were calculated to study the local landscape ecological spatial structure by drawing out 5 km^2 of each site unit in the core section in 1:10000 air photo (1998). Some indexes describing landscape heterogeneity were chosen:

Diversity index (H): It reflects the amounts of landscape elements and the variations of their proportions. When the landscape is composed of a single element, it is homogenous and its diversity index is 0.

$$H = -\sum_{i=1}^{m} P_i \cdot \log_2 P_i ,$$

where, P_i is the area proportion of each element type in the landscape while m is the number of the total landscape types.

Evenness(E): It describes the even degrees of distribution in different landscape types. The relationship between evenness and dominance is inverse.

$$E = H/H_{max} ,$$

where, $H_{max} = \log_2 m$, means when the proportions of each landscape type are equal; the area has the maximum diversity index.

(2) Using linear sampling to measure landscape heterogeneity and contrast degree. This approach is to set up one or some landscape parallel lines in each site unit of the landscape map, each line is 5 km(or 4 km) and is divided into 50 parts (or 40 parts), the real length of each part is 100m. The relative frequency of each landscape type can be deduced by calculating the number of each landscape type in each part.

Table 1 Indicators and ratings of landscape ecology sensitivity analysis

Evaluation indicators	Landscape quality		
	A(8 points)	B(5 points)	C(2 points)
Topography	Slope > 60, has cliffs, great fluctuation and ridges	Slope 30—60, surface fluctuation is not obvious	Slope 0—30, less surface fluctuation, poor scenery
Rock	Has peculiar rocks, cliffs and waterfalls	Ordinary rocks	Few or no rock landscapes
Plant	Has original or derivedaged forest, peculiar and abundant community types(9 points)	Less community types, ordinary forest composition	Few plant types, mainly unstable communities
Water(brook)	Has various, zigzag and peculiar flowing features, has waterfalls and great amount of water	Ordinary flowing features, roughly even and linear flowing tracks	Discontinuous or seasonal streams, few variability on flow and fall
(lake, reservoir)	Has great area, act as a dominated role in the whole landscape, has clear water quality and quiet surroundings	Act as a supporting role in the whole landscape	Unevident or lack of waters
Visual effect and singularity	High viewing site, view angle 60°—90°, from which can overlook the entire or most of the landscape region (9 points)	Medium viewing site, view angle 30°—60°, has its own notable features	Low viewing site, view angle < 30°, ordinary landscape, has minor attraction
Humanity impact and adjacent landscape	Has positive effect on landscape quality	Has a certain extend of impact but not harmonious	Has minor positive or even negative impact(minus 2 points)
Evaluation indicators	Ecological quality		
	A(8 points)	B(5 points)	C(2 points)
Topography	Has valleys and heavy forests, good-looking forest composition	Disturbed forests, main plant type is bush	Smooth surface and monotone plant types
Rock	Has plants growing on the rock wall and peculiar plant figure	Ordinary rock environment	Few or no plants
Plant	Has protected or rare species, wooden vines or tall trees; rich forest hierarchy diversity index (D) > 15	Less rich forest hierarchy, obvious trails of human disturbance, dominated man-planted forest D = 10 – 15	Few species or no forest, poor forest composition. D < 10
Water (brook)	Has affluent rocks, fishes, plants in or near waters	Clean waters, less creatures	Serious polluted waters bad water environment
(lake, reservoir)	Excellent water quality, good primitive plants (e.g. mangrove) in water bank.	Medium water quality, part of waters are accessible, no wetlands and humandisturbance	As the above
Visual effect and singularity	Primitive forests, spectacular water scenery, has rare species	Semi-artificial ecologicallandscape, dominated original and local species	Mainly artificial architecture and man-planted plants
Humanity impact and adjacent landscape	Natural degree (N) > 45%	N: 44%—30%	N < 30%

Notes: * Simpson diversity index: $D = N(N-1)/n(n-1)$, N is the population of all species, n is the population of a certain species

Contrast degree indicates the divergent degree of the landscape types. Natural landscape is influenced greatly by human activities, as a result, some of the transitional belt become shorter or even disappeared so that the contrast degree become greater.

Natural degree (N) is the proportion of the natural landscape in a certain region

$$N = \sum_{i=1}^{n} (\sum F_{ij}) W_i ,$$

where, F_{ij} is the arisen frequency of j landscape type in i landscape section; W_i is the weight of i landscape section; suppose that the weights of natural section, semi-natural section, artificial section are 0.6, 0.3, 0.1 respectively; n is the total number of landscape sections.

1.3 Evaluation indicators and ratings of sensitivity analysis

Sensitivity analysis of landscape ecology is multidimensional, but material level and sensitivity are of the most significance. Material level is to use the view and ecosystem compared to environmental factors to reflect material conditions of a specific landscape; while sensitivity reflects the relation between scenery and viewers: the bigger heterogeneity of a scenery, the greater effect on viewers and the stronger responses. Sensitivity analysis of landscape ecology is devoted to reflect and assess the significance of scenery by using the perspective of harmonization of vision, aesthetics and environment. Considering the sites' small scale, we established a set of evaluation indicators and ratings after having referred to American (VRM) System(Table 1).

1.4 Sensitivity and the goals of planning and management

The higher sensitivity of landscape ecology, the better landscape ecological quality. There are 3 sensitivity classes: A is high, B is medium, and C is low. The combined full score of landscape quality and ecological quality is 100(each is 50). Landscape areas are classified into 4 levels: protection(R), partial protection(PR), changeable(M), largely changeable(MM) according to their permission of human disturbance.

Since the sensitivity of landscape ecology is inverse to the allowed development intensity (the higher sensitivity, the more protection and less development should be done), we set up a generally comprehensive evaluation standard(sensitivity-comprehensive score-goals of planning and management):

A——≥85 points——R/PR, B——84—60 points——PR/M, C—— < 60 points——PR/M/MM.

2 Outcome analysis and planning goals

2.1 Site landscape structure and sensitivity analysis

Table 2 and 3 are the outcome of sensitivity analysis of Yantian District.

2.2 Characteristics of landscape ecological spatial structure of site resources

The general characteristic of landscape ecological spatial structure of site resources in Yantian District was that mountains and sea distributed linearly along the coastal line. Although Yantian District had formed a mountain-town-reservoir-coastal line landscape that was of great diversity, high contrast degree and obvious heterogeneity due to urbanization, its affluent resource conditions still made it a good ecological function area of urban forest and coast tourism in Shenzhen.

According to Table 3, the orders of landscape diversity index and evenness of small valleys were the same, so their orders were DA4 > DA1 > DA3 > DA2, their characteristics are as follows:

Wutong Mountain-Shatoujiao Drainage area (DA1): its landscape ecological spatial structure was changing from dominated natural highland landscape to balanced natural highland and artificial coastal town landscape. The ratio of natural highland to artificial coastal town was 48% : 42% from the line connecting these 2 places(Fig.1). DA1 had great landscape ecological heterogeneity, medium natural degree, and relative high contrast degree. It was lack of bottomlands and river steps, the landscape diversity of

Shaotoujiao caused a high H value, also, the roughly equivalent proportion of urban landscape and mountain landscape in Wutong Mountain caused a great E value.

Table 2 Comprehensive landscape ecological structure analysis on Yantian District

Relative frequency	Wutong Mountain S1	Shatoujiao S2	Yantianxu S3	Meishajian-Sanzhoutian S4	Sanzhoutian-Dashuikeng S5	Shangping Reservoir S6	Dameisha-Xiaomeisha S7
1. Mountain (≥500m)	37	0	0	12	2	10	0
2. Hill	45	15	20	46	64	45	45
3. River (brook)	(5)	(2.5)	0	(4)	(10)	(5)	(4)
4. Reservior (lake)	5	7.5	2	20	4	10	2
5. Crop field (orchard/tea garden)	(2.5)	0	(2)	(10)	0	(10)	0
6. Town (village)	(2.5)	52.5	44	(4)	0	10	22
7. Road (mud road)	(2.5)	7.5	10	(4)	12 (4)	2.5 (2.5)	4
8. Pier	0	0	18	0	0	0	0
9. Coast	0	2.5	0	0	2	5	10
10. Sea	0	12.5	4	0	2	0	18
Natural degree(N)	56.25	27.75	22.8	48.6	51.6	47	46.4
Natural degree of small valleys	42		22.8	50.1		46.7	
Indicators of landscape ecology (areas of each landscape are omitted)							
Diversity index(H)	1.0123	1.9616	1.9332 1.1705	1.4799	1.7682	1.4077	2.1387
Evenness (E)	0.4360	0.7588	0.6886 0.5041	0.5272	0.6298	0.5014	0.7618
Small valleys Diversity index (H)	2.0173		1.6959	1.7044		2.2153	
Small valleys Evenness (E)	0.6364		0.5653	0.6071		0.6988	

Table 3 Landscape and ecological sensitivity analysis on Yantian District in Shenzhen

Evaluation indicators	Wutong Mountain	Shatoujiao	Yantianxu	Meishajian-Sanzhoutian	Sanzhoutian-Dashuikeng	Shangping Reservoir	Dameisha-Xiaomeisha
Topography	8/8*	2/2	5/5	8/5	5/8	5/8	5/2
Rocks	2/2	2/2	2/2	2/2	5/5	5/5	2/2
Plants	9/8	2/2	5/5	5/5	9/5	5/5	2/5
Waters	8/9 (brook)	5/5 (sea)	2/2 (sea)	5/9 (reservoir)	5/5 (brook)	8/9 (reservoir)	8/5 (sea)
Visual effect and singularity	9/9	2/2	2/2	9/9	5/5	5/5	9/9
Humanity impact and adjacent landscape	8/5	5/2	2/2	8/8	5/8	5/8	8/5
Score of landscape quality	44	18	18	27	15	30	34
Score of ecological quality	41	15	18	21	15	36	28
Total score and class	85 A	33 C	36 C	75 B	70 B	73 B	62 B
Goals of planning and management	R/PR	MM	M/PR	PR/M	PR/M	PR	PR/M

Notes: * 8/8 means 8 points in landscape quality/ 8 points in ecological quality

Yantianxu(DA2): its landscape ecological spatial structure was high congregation of urbanization and industrialization. Since a new industrial area and the 2nd largest pier in China were constructed in DA2, the natural degree has lowered down from 37.2% in 1990 to current 22.8%. Enlarged contrast degree was caused by lack or rapid decline of fluvial plains (crop fields) and coastal wetlands. DA2 has changed from rural ecological type to urban ecological type and now tend to be an evenly hill-town ecological landscape.

Meishajian-Sanzhoutian valley(DA3): its landscape ecological spatial structure was dominated by congregation of hill forest-medium reservoir. It had the highest N and relative low contrast degree. Moderate H, E meant that there was dominated landscape type exists so that the evenness in this area was medium.

Shangping Reservoir-Dameisha and Xiaomeisha valley(DA4): its landscape ecological spatial structure was an even distribution of mountain-reservoir-town-coast along the gradient. It had the highest H and E and medium contrast degree value. Its natural degree was 2nd due to the expansion of artificial town landscape. DA4 was lack of coastal fluvial plain, coastal wetlands are threatened more and more by human disturbance and town expansion.

2.3 Sensitivity and planning

Based on "sites determine their best planning patterns which can make the full use of their potential", the basic principle of site planning, we used sensitivity analysis to inspire and support our conceptual planning which aims to benefit the sustainable development of regional ecology and economy in Yantian District. According to natural conditions, topography, creature community resources and humanity landscape, Yantian District was divided into 5 resorts and 11 landscape subareas.

2.3.1 Wutong Mountain fell into high sensitivity area (A class), the goal of planning and management is mainly protection

Wutong Mountain site unit(S1) was mainly of forest landscape. Although it showed low diversity and contrast degree in medium scale(0.1—10 km^2), it had the highest comprehensive score in sensitivity when using fine scale(0.1—10 hm^2). It was the most important ecological function area of urban forest in Shenzhen and should be protected carefully. Wutong Mountain was divided into 3 subareas: I1 protection subarea of forest creatures; I2 Zhengkeng protection subarea of valley rain forest and water-origined forest; I3 ecological resort subarea of Enshang Village. Only outside the core area of S1 can reasonable forest-village tourism projects be developed.

2.3.2 Meishajian, Sanzhoutian Reservoir, Shangping Reservoir, Dameisha and Xiaomeisha fell into medium sensitivity area(B class), it allowed reasonable development besides protection

Meishajian-Sanzhoutian Reservoir(S4) had the 2nd highest landscape ecological sensitivity, it had a landscape ecological system of valley rain forest——*Schifflera octphylla* evergreen forest-reservoir-tea garden. Site design should focus on small but scattered and hidden patterns. The construction of road made the valley more accessible and unharmonious with the mountain landscape, it can be remedied by silvicuture along the road. S4 was divided into 3 subareas: II1 Meishajian protection subarea of *Artocarpus hypargyrus* evergreen broad-leaved forest; II2 Dashuikeng subarea of *Schifflera octphylla* scenery forest; II3 Sanzhoutian Reservoir subarea of wetland and tea garden.

As the ecological area of wetlands and water-origined forest, S4 had excellent view and superb environmental conditions and thus acted as the habitat of some rare species such as *Alcedo*, *Pycnontus*, *Ardeola* and *Accipiter* etc. Minor development is allowed in the outskirts of reservoirs, but development of water tourism should be strictly prohibited.

Shangping Reservoir(S6) had both valley rain forest and wetlands, it had the highest score in ecological quality. Some rare species such as *Manis pentadactyla*, *Viverricula indica*, *Accipitridae*,

Phasianus colchicus, *Pycnonotidae*, *Rana*, *Rhacophorus* should be protected in this area. The forest is accessible via the path along the water and prone to human disturbance. It was divided into 2 subareas: Ⅲ1 Xikeng subarea of monsoon evergreen broad-leaved water-origined forest; Ⅲ2 Xiaodongkeng subarea of valley rain forest and wetland.

Dameisha, Xiaomeisha(S7) had become local coastal resort because of its good sand shore. It was divided into 2 subareas: Ⅳ1 Dameisha protection subarea of coastal wetland; Ⅳ2 Xiaomeisha subarea of coastal resort. The ecological quality of S7 was lowered down due to the sharp decline of bird population, so the goal of landscape ecological construction is not only to protect current vegetation but also to restore mangrove wetland so that it can serve as a new resort of bird habitat by attracting more rare species such as *Ardeloa* sp. *Egretta* sp. Also the construction of town gardens near coast should be coordinate with shore landscapes.

2.3.3 Shatoujiao, Yantianxu fell into low sensitivity area(C class)

Its goals of planning and management is to construct an urban tourism ecological area, it allows great development intensity. Meanwhile, more harmonious humanity landscape should be added to benefit the sustainable development of urban ecology.

Shatoujiao(S2) used the former Soviet marine carrier "Minsk" to spark tourism. How to construct the corresponding landscape architecture of coastal urban ecological tourism has become the key issue to make full use of the potential of natural and humanity resources and improve economic profit of tourism industry of the area.

Yantianxu(S3) is the 2nd largest container-loading pier in China, its landscape architecture and development of container-loading pier tourism projects are still under consideration.

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