# A Model for the Evaluation of Urban Green Spaces' System Using RS and GIS Methods

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***Abstract*-The availability of attractive green spaces is an integral part of urban quality of life. But the traditional methods of evaluating the level of green spaces shared by urban dwellers have some disadvantages. They are as follows: (1) Area of green spaces is always taken as an only indicator so that the importance of green gross inside the green space is ignored. (2) The spatial scale of the indicators is so macro that the micro-spatial pattern of the green spaces can't be reflected. (3) Evaluation of green spaces' system generally depends on the total area of green spaces. But other constraint factors are not taken into account. Keeping the limitation above in mind, this paper adopts a new approach for calculating the green spaces' qualities then tries to design a new model as to how green spaces attract citizens in the neighborhood with the help of RS&GIS technology.**

**The green gross is equal to the sum of vegetation fractions derived from Thematic Mapper images of the green space. The model is based on the theory of spatial interaction. The meanings of all the parameters are as follows: The attractiveness is in direct ratio with the green spaces' qualities while in inverse ratio with the exponential distance. Furthermore, the model also considers several restriction factors such as the accessibility, entrance fees, quietness, spaciousness and so on. The weights are given by simulation of Hopfield neuron network.**

**At last the approaches and model above are applied into the city of Shanghai in China. Taking the green spaces of parks inside the outer ring road as the study sample, the results are in accord with the actual spatial characteristic satisfactorily. The model is made operational easily, which can not only monitor space-time variety of urban green space, but also provide a new indicator for urban green space system planning.**

## I. INTRODUCTION

Green space is an important self-decontaminating system among urban ecological systems and often regarded as the lung of the city. It can beautify the landscape, ease the environment pressure, keep the ecosystem balance and so on [1]. As we know land source is limited. In order to make green space fulfill its ecological functions efficiently, then how to optimize the space patterns becomes more and more important. So urban green space system planning has recently been paid more attention by many specialists and scholars. But choosing appropriate indicators for evaluating green space system still remains a problem for the moment [2]. At present the indicators of urban green space in China mainly include green coverage per people, area of public green space per people, ratio of green space and percentage of greenery coverage [3]. These four traditional indicators above for evaluating green space system shared actually by urban dwellers have some disadvantages which are as follows: (1) Area of green spaces has always been taken as an indicator so that the importance of green gross inside the green space is ignored. (2) The spatial scale of the indicators is so macro that the micro-spatial pattern of the green spaces can't be reflected. Space dimensions' variety is also not considered. (3) Evaluation of green spaces' system generally depends on the total area of green spaces. But other constraint factors are not taken into account. So this article adopts a new approach based on the technology of GIS & RS for calculating the green spaces' qualities then according to quantitative and qualitative targets tries to design a new model as to how green spaces attract citizens in the neighborhood actually.

## II. STUDY AREA & DATA

### A. Study Area

This study was carried out in the city of Shanghai, the largest and a rapid developing city in the east of China, which lies between 30° 23′ ~31° 37′ N and 120° 50′ ~121° 45′ E (Fig.1). In 2001, it had approximately a population of 13.5 million and area of 6340km$^2$. The developed area of the city is located mainly inside the outer ring road where the major parks are distributed. The continuous suburbanisation together with the growing density of the transportation infrastructure, are causing a constant decrease and severe fragmentation of the green space.

### B. Data Management

The remote sensing data used in this paper mainly includes Landsat 7 ETM+ L1G product, dated on Jun 14, 2002 and SPOT image dated on May 1, 2002. Based on Shanghai reference frame, we correct the SPOT image with an error less than half a pixel (15m). Then by digitizing it we obtained all the green spaces of 107 parks (also including several large grasslands).

## III. METHODOLOGY

First step is to evaluate the attractiveness of each park. Then the attractiveness is allocated into each grid in the study area with the new model based on the spatial interaction theory put forward by Ravenstein E.G. in 1880, which says

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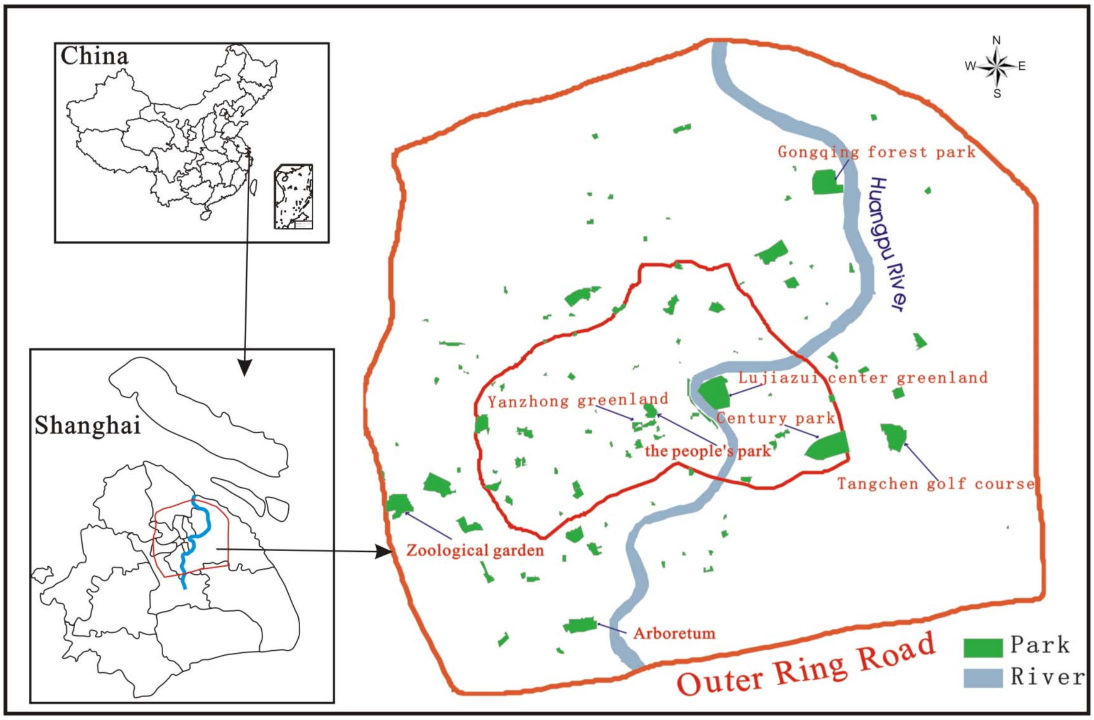


Fig. 1 Study area and major parks

that the interaction between two districts is direct ratio of 1 power with their scale (quantity) while inverse ratio of 2 power with their distance [4]. In the 1970s, Wilson A. G. furthered the theory. It is proved by maximum entropy theory that the interaction decays according to the exponential distance [5]. Then this article designs a new model to calculate how much green gross the citizens enjoy actually, as in (1).

$$G_{ij} = K_i \times (M_i \bullet 1) \times \exp(-pr_{ij}) \qquad (1)$$

$G_{ij}$: attractiveness between green space i and grid j; $K_i$: correction coefficient of restrict factors of green space i ; $M_i$: green gross of green space i; $r_{ij}$: Euclidean distance between green space i and grid j; p: coefficient of distance decay.

*A. Calculation of Parameter M*

Green gross is equal to the sum of vegetation fractions derived from Thematic Mapper images using the linear mixture model. The linear mixture model has a basic hypothesis that spectra reflectance of any grid in TM images is the mixture of three components which are substrate, vegetation and dark surface. The percentage of each component is worked out with the method of least squares, as in (2) [6].

$$\begin{cases} \rho(\lambda_i) = \sum_{j=1}^{m} F_j \rho_j(\lambda_i) + \varepsilon(\lambda_i) \\ \sum_{j=1}^{m} F_j = 1 \qquad and \qquad F_j \geq 0 \end{cases} \qquad (2)$$

Where the indices i and j indicate the spectral band and endmember of each element. $\rho(\lambda_i)$ is the observed reflectance vector derived from discrete estimates of integrated radiance within the six ETM+ bands. $\rho_j(\lambda_i)$ are the endmember reflectance vectors corresponding to the substrate, vegetation, and dark endmembers. The corresponding endmembers fraction we seek to estimate are Fj. Furthermore, this article limits green gross value between 1 and 100 by means of no-dimensional quantities, as in (3).

$$M' = \frac{M - M_{\min}}{M_{\max} - M_{\min}} \times 99 + 1 \qquad (3)$$

Where M' is green gross after managed. M is original green gross. $M_{min}$ and $M_{max}$ are minimum and maximum of M values respectively.

*B. Calculation of Parameter K*

This model considers four important factors including accessibility, spaciousness, quietness and entrance fees.

Accessibility is weighed by the number of bus stations within a certain distance around the green space and the minimum distance from the green space to railway stations.

Spaciousness is the feeling of being in a forest or park, which has no boundaries, is a major quality. This paper uses fragmentation(C) to estimate spaciousness, as in (4).

$$C = \sqrt{A_c / A_p} \quad (4)$$

Where $A_c$ is area of a circle with the same perimeter as the examined green space. $A_p$ is area of the green space.

It is one of the most striking conclusions in recent studies that there is a great need for quiet and peaceful places [7]. As To city, the noise of the green space mainly comes from the vehicles in the neighborhood. Obviously, the roads of higher rank and nearer to the green space will make more noise, as in (5).

$$Q_i = \sum_{j=1}^{n} f_j \frac{S_{ij}}{L_{ij}} \quad (5)$$

$Q_i$: Quietness of green space i; $f_j$: weight of road j; $S_{ij}$ : the length of road j within a certain buffer of green space i ; $L_{ij}$: the distance from green space i to road j.

*C. Giving Weights on the Factors*

Generally speaking, there are three kinds of methods for giving weights on the factors including subjective judgement, completely quantitative and accurate estimation and fuzzy comprehensive assessment based on fuzzy mathematics [8]. This paper adopts fuzzy comprehensive appraisement and applies Hopfield neuron nerwork to give weights on the factors affecting the model. The principles are as follows: Taking comprehensive grades (I, II, III, IV, V) as the horizontal axis and the factors as the vertical axis, a moulding board (5×4 grids) is formed (Fig.2).

When sample data of one green space is presented to the network, then based on the moulding board stored in the network, the green space can be classified into one of the five classes. As a result the weights can be given from 1, 0.9, 0.8, 0.7 to 0.6 corresponding to the rank from I to V.

*D. Spatial Allocation of the Attractiveness*

We calculate the value of each grid by summing attractiveness of all the green spaces to this grid. This paper adopts pointinterp method to solve the problem above based on ARCGIS software (Fig.3.). The radius takes the value of 36553m so that all cells in the output raster have all the points within the neighborhood. The decay controls how quickly the weighting of points diminishes as they are further away from the output cell center. For the EXP options, {decay} is the distance from the cell center at which the weighting function equals 0.5. In order to make the weights decaying more quickly when nearer to the green space, the value of decay is taken as 671m which is the maximum radius of all the green paces. The plateau indicates s that the weighting of points is

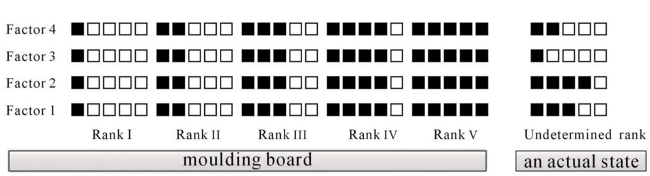


Fig.2 Moulding board of Hopfield network

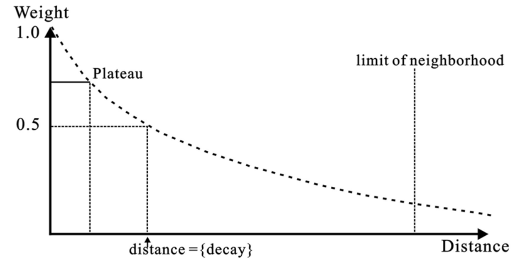


Fig.3 Graph of nonsmoothed Exp weighting function

constant for all points less than this distance from the output cell center. This paper takes value as 165m which is the mean radius of all the green spaces.

## IV. Results And Discussions

The results are shown in Figure 1, 2 and 3. The color in the three figures above grading from yellow, green to blue means green gross from low to high. Figure (a) shows the result without considering the factors. Figure (b) is the result after considering the factors.

Fig.4 shows that the northeast area with high green gross becomes small and separated after considering the factors. Because the area of the green space is large while the accessibility is too bad. Figure 5 reveals that the fringe of the blocks of high green gross in the east of Shanghai becomes the area of low green gross after considering the factors. From figure 6 we can see that the spatial pattern of green gross per people has no essential changes whether considering the factors or not. But there is a common characteristic that if taking the inner ring road as a boundary the green gross inside it is lower than that outside it.

In conclusion, the spatial characteristic of green gross in Shanghai is the following:

① The regions with higher green gross are distributed mostly in the neighborhood of several large parks such as Lujiazui center grassland, century park and Tangchen golf course in the east, Gongqing park in the northeast and zoological garden & arboretum in the southwest.

② The green gross in the east of Shanghai is higher universally than that in the west of Shanghai. Because the west bank of Huangpu River is economic and political center of Shanghai and the population density here is also higher. Recently the number of parks here has increased, however, the level of green space enjoyed by the residents herestill remains low.

③ The green gross in the northwest of Shanghai is very low. Because there are few parks and the scale is also not big. In order to raise the people's living level the government should pay more attention to the problem and eliminate the blind zone of green space.

## V. Conclusion Remark

Aiming at the disadvantages of those conventional methods, this paper develops a new model that considers the spatial interacion and some constraint factors to evaluate the green space system. Then applying the model into the area inside the outer ring road in Shanghai, China, the results reveal:

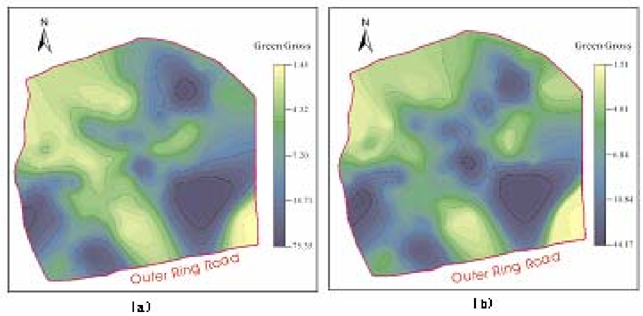


Fig.4 Green gross taking a grid as statistics unit

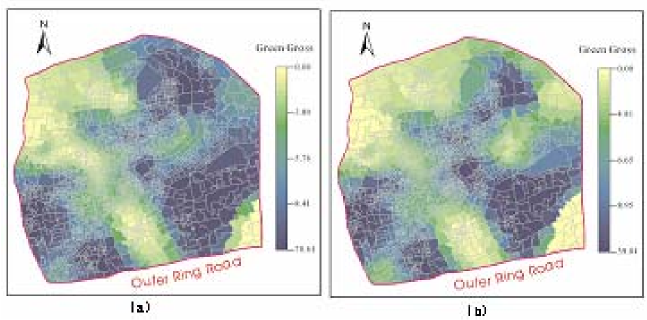


Fig.5 Green gross taking a block as statistics unit

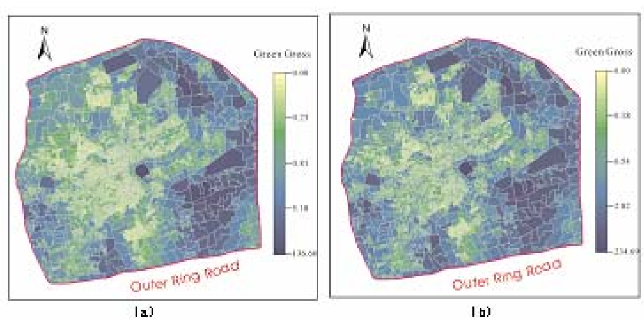


Fig.6 Green gross per people taking a block as statistics unit

①Vegetation fraction derived from Thematic Mapper images has the potential to provides a useful tool for monitoring time-space variety of green space.

② The innovations of the model lie in the following aspects. First, green space's influence on the citizens decays with their exponential distance. Secondly, the model thinks that the attractiveness of green space is in direct with green space's qualities and is affected by some constraint factors such as accessibility, spaciousness, quietness and entrance fees and so on. The weights of the factors are given by Hopfield neuron network. The model can be carried out by pointinterp. To sum up, the approaches and model are made operational easily and useful for evaluating the level of green space enjoyed by urban dwellers actually.

③ The attractiveness calculated by the model is based on the minimum dimension. So the research of larger dimension can be made by zonalstatistics.

In addition, the major originality of the research lies in the attempt to span a bridge between scientific theories and planning practice. Of course the model also exists some shortages because of limited data, methodological feasibility, etc. For example, some factors are not involved in the model such as facilities' level, plant categories, geographic characteristic, etc. Furthermore, how to give more reasonable weights on the factors affecting the model is worthy of further study.

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