Exploring the Balance Between Urban and Ecology Based on Fractal City Theory——Taking the Northern Metropolis of Hong Kong as an Example

Kehui Zhai, Xingyue Wang, Zhizhou Xu, Bowen Chen, Jing Tu
City University of Hong Kong, Hong Kong 999077, China.

Abstract: As the times progressed, the large countryside-dominated area to the north of Hong Kong, adjacent to Shenzhen, needed further development. This research is based on fractal urbanism and horizontal urbanism and attempts to explore a new urban development model from the perspective of balancing urban and countryside areas. At present, there is a contradiction between ecological conservation and urban development in the area. Recent urbanization has resulted in habitat fragmentation, which has led to a significant decline in biodiversity, a lack of natural green space within the city, and low environmental quality, etc. To improve the above urban problems, we propose an evaluation method that divides the greening rate within the scope of human activities into five grades. And put forward a greening promotion method. Taking the Deep bay area in North New Territories of Hong Kong as an example, an ideal solution is proposed.

Keywords: Fractal City; Biodiversity; Northern Metropolis; Urban Development; Ecological Conservation

1. Introduction

Fractal urbanism originated from the simulation and empirical study of urban form and structure based on the idea of fractals. The theory of Fractal city has positive significance for exploring the ideal city. Therefore, this study takes the ecological city as the starting point and uses the principle of fractal city to construct innovative syntheses between the need for urban expansion and sustainable responses to rising environmental concerns, within the framework of the ecological civilization.

The theory of Fractal city has positive significance for exploring the ideal city. Therefore, this study takes the ecological city as the starting point and uses the principle of fractal city to construct innovative syntheses between the need for urban expansion and sustainable responses to rising environmental concerns, within the framework of the ecological civilization.

This study focuses on the New Territories in the northern metropolitan area. This region has rich natural resources with great potential for development. We choose the Deep Bay area near Tin Shui Wai as the design object. Within the scope of the land, there are modern residential areas, traditional village settlements and waterfront resources, which are able to fully reflect the result of this research.

2. Literature Review

2.1 Northern Metropolis Development Strategy

To integrate into the national strategy as well as improve the economic situation, the Hong Kong government set the Northern Metropolis Development strategy (GovHK, 2021). Since the ecological resource in abundant in this area, proactive conservation is one of the most important plan principles set by the government, holding a view of building a sustainable urban area (GovHK, 2021). Therefore, except for setting up conservation areas, it's also significant to construct a sustainable city that less leading ecological fragmentation.

2.2 Ecological urbanism in the fractal city

To describe landscape matrix or spatial distribution, fractal dimensions have been used as a tool extensively at sketchy scales (Halley, 2004) because it is already found that although the spatial distribution of many habitats or species is not perfectly fit fractal geometry, creating fractal models is an available method to set simulating spatially complex landscapes and serves as habitat models (Azovsky, A. I., 2000). Therefore, to prevent ecological fragmentation, trying to create green spaces in different scales may be a good method to enhance proximity and ecosystem services to both nature and people (Tian, Y., Jim, C. Y., & Wang, H., 2014).

2.3 Having more connections with green spaces would increase happiness.

Compared to the urban environment, people's well-being is increased in green spaces (MacKerron, G., & Mourato, S.,2013). More social activities being happened in green spaces would not only enhance social cohesion (Wan, C., Shen, G. Q., & Choi, S., 2021) but also would promote people's health (Jennings, V., & Bamkole, O., 2019). Therefore, the distribution of green spaces in urban areas and accessibility to green spaces are crucial for ecological and social functions in urban planning and design (Barbosa, O., 2007).

3. Influence Factors & Site Selection

3.1 Map Overlapping

3.1.1 Vegetation and Water

Through overlapping both vegetation and water images (Figure 3.1), we discovered the obvious regulation from the vegetation and water image is that the apparent place in Northern Metropolis, ecological fractism is the most obvious to notice.

3.1.2 Wildlife Habitat and built history

Through overlapping both wildlife habitat and the built history images (Figure 3.2), we discovered brown and black regions reflect the step-by-step expansion of the city, cutting off the pink conservation areas and the gray habitats, leading to ecological fragmentation, which will lead to a bad impact on both humans and wildlife.

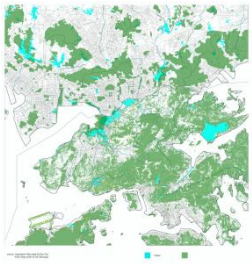

Figure 3.1 Vegetation and Water

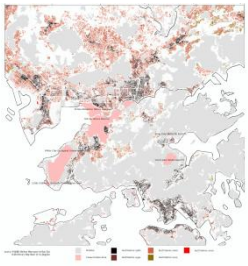

Figure 3.2 Wildlife Habitat and built history

3.2 Influence Factors

3.2.1 Ecological Fragmentation and Species in Hong Kong

According to the species data from the Hong Kong government, we got the Proportion of vertebrate species taxonomy in Hong Kong and the taxonomy of terrestrial vertebrate species. The result suggests that Hong Kong has a relatively high proportion of bird species

According to the GD-HK-MO OBSERVE BLUE BOOK, we got the East Asia-Australia Migratory Bird Migration Routes and found that the location of relatively frequent bird migration paths to the study destination demonstrates that bird activity is relatively pronounced here compared to other areas and that there are implications for ongoing study observations.

3.2.2 Natural Elements Correlate with People's Emotions

A survey was done by Civic Exchange among 3600 Hongkongers across 18 districts. 97% of them prefer visiting open spaces within walking distance. Open space visiting frequency has a significant positive relationship with happiness. 75.8% of respondents found open space is important for their stress relief. A study in the U.S. also found that increased greenspace contributed to lower depression symptoms.

3.3 Site Selection

Combining the above analysis of site location from both macro and meso perspectives, the study site was finally identified in the Lau Fau Shan - Tin Shui Wai area of the northern metropolitan area in Hong Kong.

4. Methods

4.1 Fractal Urbanism & Voronoi Diagram

As the literature recording, fractal urbanism is being used to manage the green growth in the city intelligently (M., & Hafida, M., 2021).

Voronoi diagram is one of the typical methods of fractal urbanism, which consists of a set of continuous polygons formed by the perpendicular bisector of a line joining two neighboring points.

Based on the principle of the Voronoi Diagram, we have set up a set of methods to solve the problems of urban aggression and the reduction of urban green rate caused by the above factors: The first step, Gathering Points; the second step, Form Voronoi; the third step, Overlap Green Area; the fourth step, Assess Greening Ratio.

Before that, we used five different colors to represent different percentages of green space, depending on how much green space overlaps with built-up areas. Among them, red represents 0-20% green space; orange represents 20-40% green space; yellow represents 40-60% green space; green represents 60-80% green space; blue represents 80-100% green space.

After analyzing a rough strategy, we tried to find a quantitative way to visualize the five models.

4.1.1 Points Representing People's Gathering

First of all, we use the points about sports centers, villages, shopping centers and community centers as the target points (Figure 4.1), which represent the gathering of human activities.

4.1.2 Voronoi Diagram

According to the gathering points, we set them into QGIS and use the tool Voronoi polygons in Vector Geometry. By changing the points into the face, forming the smooth -shaping Voronoi Diagram (Figure 4.2).

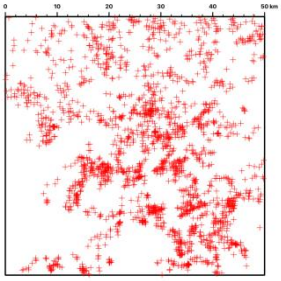

Figure 4.1 Points Representing People's Gathering

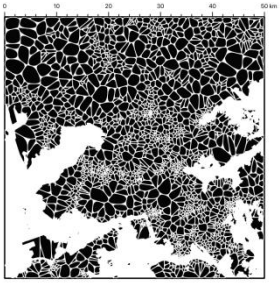

Figure 4.2 Voronoi Diagram

4.1.3 Green Area

Next, we extracted the green area in the whole site (Figure 4.3), and then overlapping with the Voronoi diagram, we got the intersection of green areas and Voronoi cells (Figure 4.3)

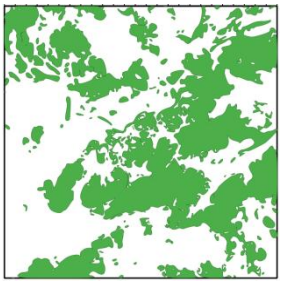

Figure 4.3 Green Area

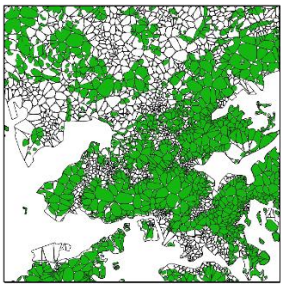

Figure 4.3 Intersection of Green Areas and Voronoi Cells

4.1.4 Voronoi Cells with 5-Level Greening Ratios

Through calculating the percentage of green space occupied in each polygon, in other words, the greening ratio. Lastly, we classified the greening ratio in five levels from the red to the blue, representing the greening ratio increasing gradually (Figure 4.4).

We can find that these polygons are either largely devoid of green space or almost entirely covered by green space, which is not a good sign. Therefore, we need to add more middle levels into the cities to balance the construction areas and the natural areas.

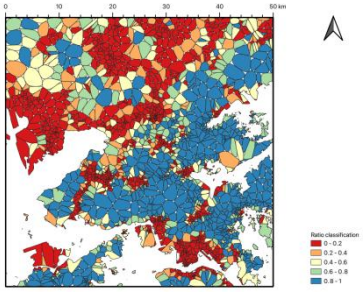

Figure 4.4 The intersection of Green Areas and Voronoi Cells

5. Findings

Put the theory to the test by choosing a square site by 2 miles times 2 miles (3.2 km times 3.2 km) in Lau Fau Shan in Hong Kong.

To help people better contact nature, there are two ways to achieve it. The first is to add vegetation in areas with low greening rates (Figure 5.1), and the other is to increase gathering points in areas with high greening rates (Figure 5.2). Through a variety of means to increase the greening ratio and gathering points, the overall greening ratio of this site has been improved. According to the comparative analysis before and after calculation, the proportion of green areas increased from 61% to 73% (Figure 5.3).

In addition, the proportion of Voronoi in the five grades also changed greatly. The number of blue areas rose sharply, from 23% to 63% (Figure 5.4). There are more areas with a greening rate of more than 80%. As a result, the environment is closer to the natural environment and restores the natural ecology. But the other four levels all declined, showing a significant decrease in the areas where people have no access to nature. Through the design transformation, people living and working here can get closer to nature more easily, in other words, nature becomes more accessible. This design transformation realizes the assumption put forward in this theory.

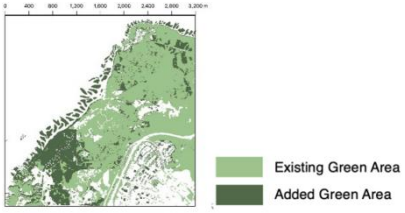

Figure 5.1 Add Green Space

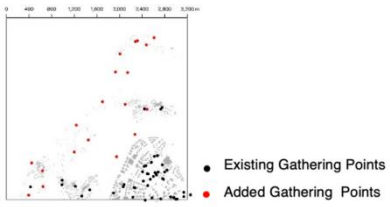

Figure 5.2 Add Gathering Points

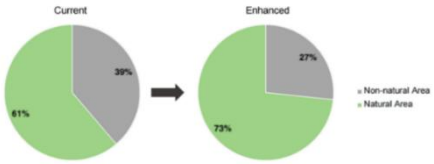

Figure 5.3 Changes of Green Area

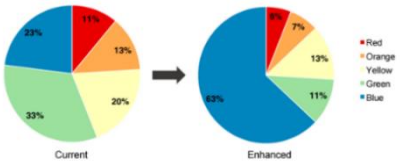

Figure 5.4 Proportion of Green Area

6. Discussion and conclusion

The objective of this paper is to investigate the equilibrium between urban development and ecological conservation from the standpoint of fractal urbanism. This research evaluates the efficacy of utilizing Voronoi diagrams in the quantitative assessment of this balance while also examining the necessity of maintaining equilibrium.

The theoretical approach encompasses the quantitative analysis of Voronoi diagrams and proposes ideal methods for enhancement. From a practical standpoint, this study highlights the significance of preserving nature within urban areas.

Several limitations are considered, such as the comprehensive definition of greenery, which could potentially yield significantly different outcomes. Future research could delve further into the various aspects of urban and natural symbiosis, rendering this study more applicable as a tool in design processes.

References

[1] GovHK. (2021). Northern Metropolis Development Strategy. Available from https://www.policyaddress.gov.hk/2021/eng/pdf/publications/Northern/Northern-Metropolis-Development-Strategy-Report.pdf.

[2] Halley, J.M., Hartley, S., Kallimanis, A.S., Kunin, W.E., Lennon, J.J., & Sgardelis, S.P. (2004). Uses and abuses of fractal methodology in ecology. Ecology letters, 7(3), 254-271.

[3] Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. International journal of environmental research and public health, 16(3), 452.

[4] Messaoud, M., & Hafida, M. (2021). Environmentalist approach integrated with ecological urbanism in the fractal city. Case of optimization of the (urban-nature) rapport the AEU2 process.

[5] Tian, Y., Jim, C.Y., & Wang, H. (2014). Assessing the landscape and ecological quality of urban green spaces in a compact city. Landscape and urban planning, 121, 97-108.

[6] Wan, C., Shen, G.Q., & Choi, S. (2021). Underlying relationships between public urban green spaces and social cohesion: A systematic literature review. City, Culture and Society, 24, 100383.

[7] Yang, C., Zhang, C., Li, Q., et al. (2020). Rapid urbanization and policy variation greatly drive ecological quality evolution in Guangdong-Hong Kong-Macau Greater Bay Area of China: A remote sensing perspective. Ecological Indicators, 115, 106373.

Author: Kehui Zhai (29 February 2000), female, Yuncheng, Shanxi Province, Master's degree student at City University of Hong Kong, research interests: urban design and regional planning.