RECOGNITION OF URBAN FRINGE AREA BASED ON REMOTE SENSING IMAGE: A CASE STUDY OF GUANGZHOU-FOSHAN METROPOLITAN AREA

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Abstract: Urban fringe area, which situates between the urban and rural area, is the most dynamic and vulnerable system during the urbanization process. It's significantly meaningful to offer an accurate boundary definition of the metropolitan area, which can lay a strong foundation for the research of its land cover change pattern, the urban planning and ultimately, the implementation of the urban integration scheme.

Taken Guangzhou-Foshan as an example, this study has attempted to provide a reliable method in defining the urban fringe area. Based on the "Fringe Effect" theory in landscape ecology, this study has renewed the existing RS information entropy model for defining the urban fringe by embracing scale theory, cartography and urban geography. The inflexion points of information entropy are identified in three different directions (latitude, longitude and radius), and try to put forward an accurate urban fringe area of the Guangzhou-Foshan metropolitan area. Several conclusions can be drawn from the study. 1. The urban fringe of the Guangzhou-Foshan metropolitan area covers an area of 2031.21km^2, 30.09% of the total study area. 2. The variability of the land cover pattern in the urban fringe area is much higher that it is in the urban core area and non-urban (rural) area, indicating an intersecting area of the rural and urban landscape; 3.The employment of optimal scale RS information entropy and inflexion recognition is more effective and reliable to define the urban fringe area, and provides a renewed and stronger foundation for its further study.

1 INTRODUCTION

1.1 Research Background

Urban fringe area is an area that situates between urban and rural system. It's the most sensitive, dynamic and swiftly changing area during the urbanization process (Gu & Xiong, 1989). Its boundary can be rapidly changing as the evolution of urban size and urban-rural relation. Metropolitan Area is a result fostered by the certain urban development process. With the advance of urban construction in China, urban fringe area is becoming a hot research topic, and achieving its spatial definition should be the beneficial to any further research. However, a widely-recognized spatial definition of urban fringe area has not been reached.

Complex impact has been identified on the air quality, biodiversity, surface runoff, evaporation process and urban heat island brought by the transformation of natural landscape to human landscape under intensive human activities (He *et al*., 2011; Clarke *et al*., 1997; Anbumozhi, 2007). Thus, great importance should be attached in closely and accurately monitoring and providing scientific perspective to the urban fringe area, which can help provide evidence for rational allocation of land resorces, facilitating ecological civilization and ultimately, the future planning of Guangzhou-Foshan urban integration (Xu *et al*., 2009).

In previous researches, evidences for defining urban fringe area include the ratio of agricultural population and non-agricultural population (Russwurm, 1975; Bryant & Russwurm, 1979), property area and employment opportunity (Desai & Gupta, 1987), district preference of property buyer (Lesage & Charles, 2008) and epidemiology analysis (Hall *et al*., 2006), etc. Recent years more and more domestic researchers employed Remote

Sensing and GIS technique to define urban fringe area. Methodologies mainly originated from land cover information (Cheng & Zhao, 1995; Zhang *et al*., 1999; Wang *et al*., 2010; Qian *et al.*, 2007; Fang, 1999) and threshold identification (Wang *et al*., 2004; Zhang *et al*., 2010; Qian & Chen, 2006).The above researches has contributed to the overall effort of defining the urban fringe area. However, it's considered that significant parts in the above methods are relying on human discretion, such as the analysis scale and threshold selection. Moreover, previous researches have paid little attention in the geographical characteristic of urban fringe area, making them potentially less reliable and practical.

1.2 Study Area

Guangzhou and Foshan are widely believed as the 1st and 3rd largest cities in Guangdong Province, China. They locate in the center of the Province and the core area of the Pearl River Delta (Figure 1), with long shared administration boundary, similar history, culture and tradition, complementary industrial structure highly integrated transportation system. According to the research object, Conghua County, Zengcheng City and Gaoming District, which are too far away from the urban area, are excluded from the study area.

The geographic location of Guangdong in China

The geographic location of Guangzhou and Foshan (excluding Gaoming District) in Guangdong

Figure 1: Study are

1.3 Data Acquisition & Processing

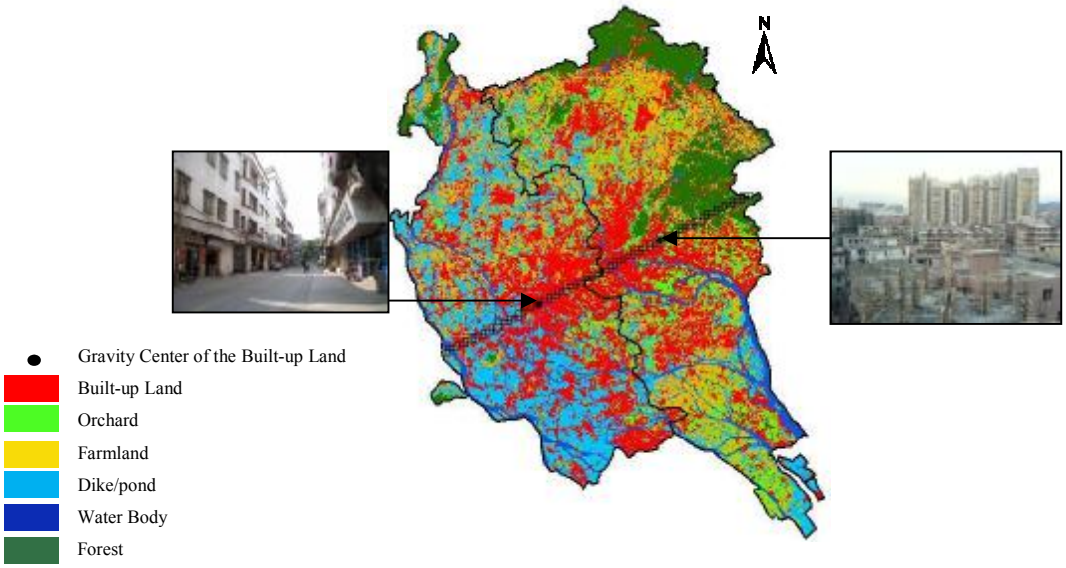
In this study, one scene of predominantly cloud-free Landsat TM images (WRS path 122, row 44, acquired on December, 2008) covering all the study area was selected, the image resolution is 30m. Under the support of ENVI 4.7 software, a series of image preprocessing practices are conducted, followed by a delineation practice by the study area administration boundary shapefile. Land cover is classified into eight categories: Urban residential land, Industry land, Orchard, Farmland, Forest, Dike/pond, Water body and Newly-developed land. Based on fieldwork and eye interpretation verification, the overall classification accuracy is 88.21%, the Kappa coefficient is 0.827, that have satisfied the accuracy requirement for this study (Campbell, 2007).

2 METHODS AND EQUATION

2.1 Information Entropy Model

According to the theory of landscape ecology, Ecotone, a transition area between two biomes or different patches of the landscape (Senft, 2009), has presented a tendency of increase biodiversity referred to as the "fringe effect" under the force of biomechanics and non-biomechanics (Graves *et al*., 2010). Ecology researches usually use Shannon Diversity Index(SDI) to estimate the level of biodiversity in a certain biome. Here we adopted this model to measure the land cover disorder degree reflected by remote sensing image, the equation is:

merge into bigger, more appropriate size, therefore to minimize the negative effect generated from supervision classification accuracy (Yu & Ng, 2007). (Figure 2)



Gravity Centers Photo: Dasha Village, Nanhai, Foshan(left); Jingxi Village, Tonghe, Guangzhou(right)

Figure 2: The land cover of the study area in 2008 and the cross gravity center sample belt

2.2 Quantitative Definition of Urban Fringe Area

2.2.1 Latitude Direction & Longitude Direction In ArcGIS, we created a fishnet consisted of 960m side length square fishnet to cover to whole study area. First, we processed a six-time polynomial fitting for the entropy values for different lines and rows using Matlab, and get the inflection points of all rows and lines. The convex part(s) between two inflection points is representing the high entropy value part; the remaining concave part(s) between two inflection points is representing the low entropy value part (Figure 3).

2.2.2 Radius Direction On the 960m side length square fishnet, we take the gravity center of the built-up land of the whole study area as center point, and 60km as the radius length to create a circle, within which the fishnet squares in 16 directions of N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW and NNW are selected as recognition samples. Same method as mentioned in 2.2.1 is employed to identify the inflection points to clarify the high value part and low value part. Normally two inflection points could be identified. The ones closer to the circle center point are considered as the inner fringe of the high value part, while the ones further are considered as its outer fringe. Connect all 24 points respectively to generate the inner and outer fringe line, surrounded by which is the high information entropy value part in this step.

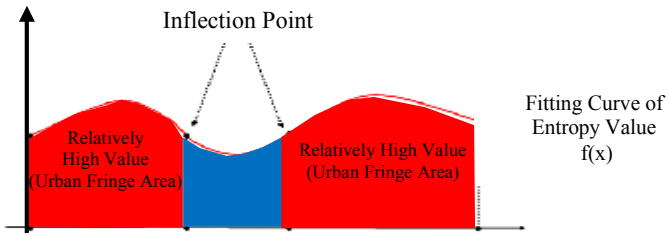


Figure 3: Inflection point recognition diagram

2.2.3 Fusion of Recognition Results The latitude direction & longitude direction recognition methods mentioned in 3.1 are based on cartography theory and have advantages in distinguishing the urban fringe area in one particular direction. The radius direction method mentioned in 2.2.2 relies more on urban geography and urban expansion theory. In our study, we have merged the two images in ArcGIS generated from 3.1, which then clipped by the high information entropy value part generated in 3.2 as the final definition of the urban fringe area of Guangzhou-Foshan metropolitan area.

3 RESULTS

3.1 Quantitative Recognition of the Information Entropy Image

3.1.1 Latitude Direction As in figure 7, the area covered by green stripes is the relative high entropy value area in this process, and the remaining area is the relative low entropy value area. The green stripes cover an area of 3,295.64 km^2, occupying 48.82% of the total study area. This recognition method has its advantage on clarifying the urban area (Guangzhou downtown, Sanshui District of Foshan, Foshan downtown, Panyu District of Guangzhou) and rural area as relative low value part, and the urban fringe area (green stripes) as relative high value part in the latitude direction, but still need more evidence to quantitatively define the urban fringe area.

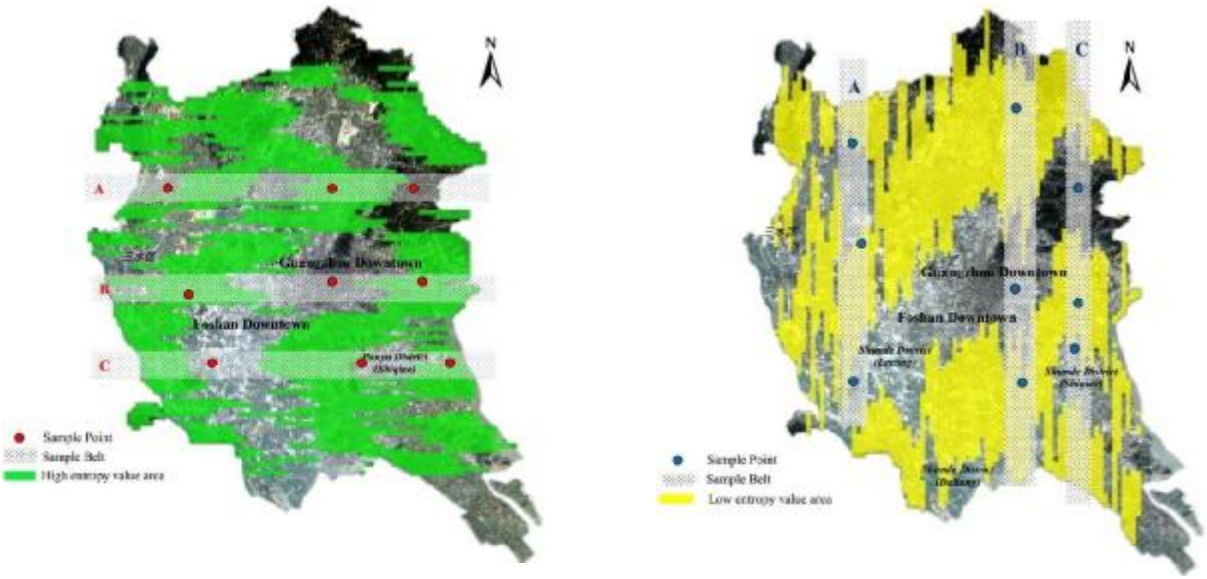


Figure 7: Latitude(left) and Longitude(right) direction recognition image

3.1.2 Longitude Direction As in figure 7, the area covered by yellow stripes is the relative high entropy value area in this process, and the remaining area is the relative low entropy value area. The yellow stripes cover an area of 3,510.37 km^2, occupying 52% of the total study area. This recognition method also has its advantage on clarifying the urban area (Sanshui District of Foshan; Foshan downtown, Lecong of Shunde District, Foshan; Guangzhou downtown and Shiqiao, Panyu District, Guangzhou) and rural area as relative low value part, and the urban fringe area (yellow stripes) as relative high value part in the longitude direction, but still need more evidence to quantitatively define the urban fringe area.

3.1.3 Radius Direction As in figure 8, each circle in the radar chart representing 10km of field distance. The green part is high information entropy value area while red part is low. As an additional support for 3.2.2 and 3.2.3, this method, based on urban expansion theory, has its advantages in generating a complete boundary of urban fringe area. However, it has a defect in interpreting the image in multi-core level as the local urbanization characteristic tends to be fragmented.

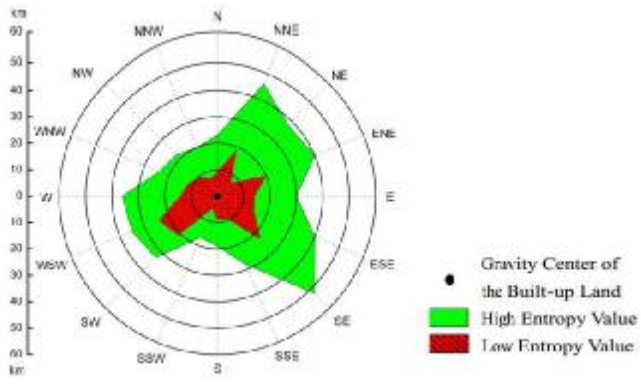


Figure 8: Radius direction recognition image

3.2 The Final Definition of the Urban Fringe Area and Analysis

As in figure 9, the urban areas of Guangzhou and Foshan City are appeared to be merging across the administration boundary. It's believed that a large-scale metropolitan area is emerging and has become the core of the Pearl River Delta urban system.The urban fringe area of Guangzhou and Foshan Metropolitan Area covers an area of 2031.21km^2, and it's occupying 31.37% of the total study area. It roughly includes: Baiyun District, Huangpu District and Panyu District of Guangzhou; Nanhai and Shunde District of Foshan.

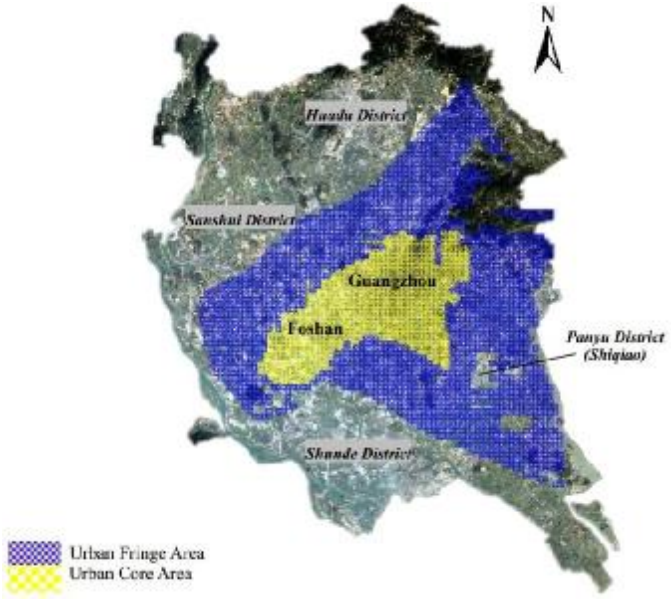


Figure 9: Definition of the urban fringe area

4 DICUSSION

This proposed method is attempted to reduce the uncertainty of defining urban fringe, therefore it's believed to be more objective and reliable. However, we are far from achieving a well-rounded methodology. The fundamental data sources of this method is the land cover status acquired by computer-aid remote sensing image classification, which subject greatly to the classification accuracy, and the spatial solution of the image. On the other hand, urban fringe area is a dynamic geographical entity influenced by social and cultural factors. Better accuracy can be achieved if more socio-economic models and data can be taken into consider.

A further step can be taken to discuss the expansion and dynamic process of urban fringe, as well as the internal landscape ecology and land use structure. Further effort may also be devoted to investigate into the regional landscape ecology security, or quantitative evaluation of the ecological effects of human activities.

5 CONCLUSION

Several conclusions can be drawn for this study: The urban fringe area of Guangzhou-Foshan Metropolitan Area is 2,031.21km^2, occupying 31.37% of the total study area. It mainly covers Baiyun District, Huangpu District and Panyu District of Guangzhou, Nanhai District and Shunde District of Foshan. This study has confirms that the renew method we proposed to define the urban fringe area quantitatively, incorporating landscape ecology, cartography, urban geography and scale science theory, is accurate and reliable, and it's beneficial to the overall effort to promoting sustainable development in urban fringe area.

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