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# LAND-COVER DENSITY-BASED APPROACH TO URBAN LAND USE MAPPING USING HIGH-RESOLUTION IMAGERY

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**ABSTRACT**: Nowadays, remote sensing imagery, especially with its high spatial resolution, has become an indispensable tool to provide timely up-gradation of urban land use and land cover information, which is a prerequisite for proper urban planning and management. The possible method described in the present paper to obtain urban land use types is based on the principle that land use can be derived from the land cover existing in a neighborhood. Here, moving window is used to represent the spatial pattern of land cover within a neighborhood and seven window sizes (61m×61m, 68m×68m, 75m×75m, 87m×87m, 99m×99m, 110m×110m and 121m×121m) are applied to determining the most proper window size. Then, the unsupervised method of ISODATA is employed to classify the layered land cover density maps obtained by the moving window. The results of accuracy evaluation show that the window size of 99m×99m is proper to infer urban land use categories and the proposed method has produced a land use map with a total accuracy of 85%.

**KEY WORDS**: urban land use; land cover density map; high-resolution image

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## 1 INTRODUCTION

Timely up-gradating of urban land use and land cover information is essential for urban environmental monitoring, planning and management purposes. Traditionally, field survey and visual interpretation from aerial photography are primary ways to collect such needed information. However, these methods are both time-consuming and expensive with very low temporal resolution. Satellite remote sensing imageries, especially those with high spatial and temporal resolutions like IKONOS (1m for the pan data) and QuickBird (0.6m for the pan data), have the advantages of large-scale coverage and low cost, which can provide multi-temporal data for urban land use mapping and environmental monitoring.

Land cover refers to the type of physical feature of the Earth's surface, e.g. vegetation, soil, and impervious surface; whereas land use indicates the types of human economic activities in a particular area, for example, residential and commercial area (LILLESAND and KIEFER, 2000). It is well known that remote sensing imagery represents the physical features on the earth through their characteristics of emissive and reflective electromagnetic spectrum. Thus, land use is more difficult to be identified directly from remotely sensed images. However, land use information can be indirectly obtained from the land covers recognized from remotely sensed data because land use can be depicted as complex spatial arrangements of different land cover types, which leads to considerable spectral heterogeneity within the same land use types.

Many researchers have been seriously involved in searching for methods to obtain land use information from high-resolution images for various developmental activities of towns or cities, for example, the kernel classification techniques for land use mapping (BARNSLEY and BARR, 1996; KONTOES *et al.*, 2000), rule-based urban land use inferring method (ZHANG and WANG, 2001; ZHANG and WANG, 2003), parcel-based urban land use classification approach based on land cover density map (WANG and ZHANG, 2002), and land use classification method based on the V-I-S (vegetation-impervious surface-soil) model (HUNG, 2002).

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The present research aims to develop an efficient method to attain urban land use map using IKONOS image. The general hypothesis is that urban land use can be attained based on the composition and arrangement pattern of land cover existing in a neighborhood. To define the spatial pattern of land cover within the neighborhood, moving window is used here to consider neighborhood characteristics as it is used in textural and contextual analysis.

What window size is the most suitable for urban land use mapping has been a debate in many studies. HODGSON's (1998) work indicated that the minimum window size of 60m×60m was required to identify three urban land use categories of commercial, residential, and transportation areas. However, it is not the case that the larger the window, the better accuracy the land use mapping, for the boundaries determined by moving window are not certain because of mixing signatures of two or more land uses within the moving window along boundaries among different land use types. To decide the most suitable window size for our method to extract urban land use information, 61m×61m, 68m×68m, 75m×75m, 87m×87m, 99m×99m, 110m×110m and 121m×121m are chosen to process the neighborhood.

## 2 DATA DESCRIPTION

Radiometrically and geometrically corrected, pan-sharpened, multi-spectral IKONOS sub-scene of 1-m pixel resolution acquired during May of 2000 is employed in the present study. This imagery is produced by fusing 11-bit of 1-m resolution panchromatic (0.45–0.90μm) and 4-m resolution multi-spectral—blue (0.45–0.53 μm), green (0.52–0.61μm), red (0.64–0.72μm) and near infra-red (0.77–0.88μm) channels via principal component analysis. The image of the test area (Fig. 1) has 1404 pixels and 800 lines, covering a part of Nanjing of Jiangsu Province in China.

The following categories of land use patterns could be recognized from the study area such as industrial area (M1) at the southwestern corner, water surface around the study area (E1), vegetation stripe along the road and river (G12), park area (G11), main roads (S1), old-building residential area (R4) and new-building residential area (R2). All of them belong to either Ⅱ or Ⅲ class in the urban land use classification system stipulated by Urban Management Committee of China (2000).

Fig. 1 shows that some land use categories are simply made up of one or two land cover types and their spatial arrangements are relatively more regular. Three major roads could be clearly seen from the imagery. The one located in the upper part is made of dark impervious asphalt, while the other two, one on the left side and another on the right side of the imagery, are made of medium impervious concrete. The Qinhuai River and its branch constitute water surface and the vegetated stripes are seen only along riverbanks and main streets.

The other land use categories are composed of three or more land cover types whose spatial arrays are complicated. One- or two-storied buildings with dark roofs and embodied with vegetation patches primarily comprise the old-building residential area. Five- or more-storied concrete buildings with readily visible shadow constitute the new-building residential area. Large and low buildings dominate the industrial area. The park areas are characterized by densely covered vegetation.

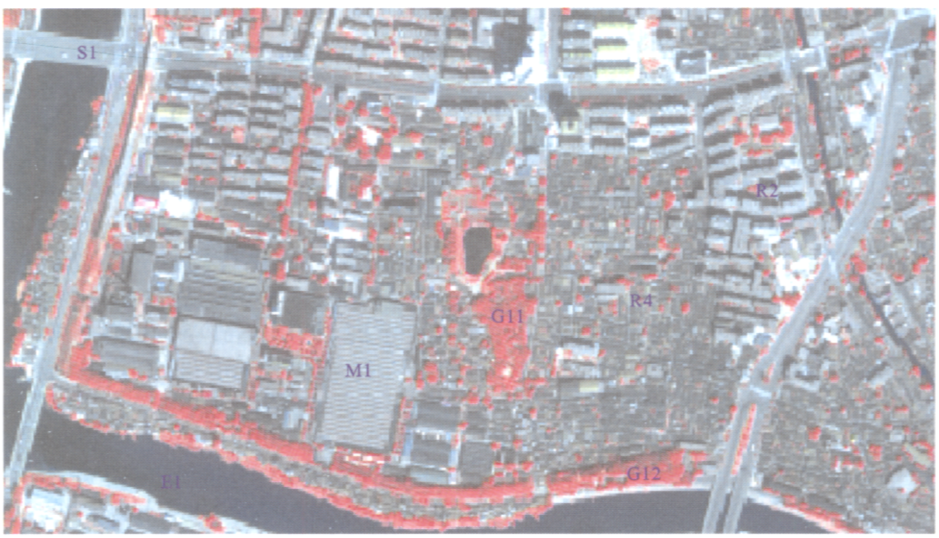


Fig. 1 IKONOS sub-scene in test area

## 3 METHODOLOGIES

This research attempts to explore a technical approach for obtaining different land use categories from the land cover map obtained from high-resolution remotely sensed data. The whole process is carried out in three steps. Firstly, the land cover map is acquired via hierarchy tree classification method; secondly, the water surface, roads, vegetation stripes along road and river are obtained through the spatial analysis from land cover map directly; thirdly, the residential, industrial and park areas are obtained through the unsupervised classification based on land cover density map.

The first two steps were depicted in detail in ZHANG's research (ZHANG *et al*., 2004). This paper will emphatically present the method to obtain the land use types composed of several different kinds of land cover types within a neighborhood and mainly talk about the most suitable window size for the method to attain land use information. As mentioned above, moving window is used here to consider the spatial pattern of land cover within a neighborhood. This can be stated as the "density" of different land cover types calculated using the moving window over the image. Based on the former researchers' work (HODGSON, 1998; ZHANG and WANG, 2003) and the uncertainty caused by moving window along the boundaries between different land use types, seven window sizes are evaluated in this research: 61m×61m, 68m×68m, 75m×75m, 87m×87m, 99m×99m, 110m×110m and 121m×121m. To produce the final land use result, the following steps are taken.

(1) The characteristic layers composed of the special land uses are chosen from the land cover map. For example, if the study area includes commercial area with high buildings, light industrial area with large building, and new residential area with middle-high buildings, then the characteristic layers will include the layers of large shadow representing the high building, shadow representing the high building and large building. It should be noticed here that not all of the land cover types are involved as the source for classifying, but the only layers representing the characteristics of the land use constitution.

(2) Each characteristic land cover layer is encoded as a binary map, with values of 0 or 1. Pixels valued 1 represent where the particular land cover exists, and 0 represent everything else. For instance, the characteristic layer "shadow" map contains two values, with 1 representing "shadow" and 0 representing "non-shadow".

(3) An average filter of size 61m×61m, 68m×68m, 75m×75m, 87m×87m, 99m×99m, 110m×110m, and 121m×121m is then applied to the binary characteristic land cover map. The results are considered as the land cover density map calculated from a moving window. In the resultant map, such as the shadow density map, values represent the density of the shadow in the neighborhood from 0 to 100%.

(4) All land cover classes are combined as the source of the unsupervised classification method. Here, we use the approach of ISODATA to classify the image. Each class is given a unique identifier in the resultant map.

(5) Water surface, roads and vegetation stripes along river and road acquired directly by the spatial analysis from the land cover map (ZHANG *et al*., 2004) substitute the corresponding area in the resultant land use map. Such disposal will avoid the uncertainty caused by the moving window in the area of the above land use types.

(6) Small polygons are removed and small holes are filled based on the surrounding land use context. These polygons receive the land use identifier of the overwhelming surrounding class.

## 4 RESULTS AND DISCUSSION

According to visual interpretation of the study area, five layers are considered as the characteristic land cover layers: medium impervious building, dark impervious building, buildings whose area is greater than 2000m$^2$, shadow, and vegetation without vegetated strips. It should be noticed that shadow layer is included for excluding impervious roads and separating the new buildings (five- or more storied) and old buildings (one- or two storied). The buildings whose area is greater than 2000m$^2$ are filter layers to separate industrial buildings from residential buildings. The vegetated strips are not included in the vegetation layer because they have been confidently separated and they will influence other land use type through moving window.

A total of 60 clusters are produced from the unsupervised ISODATA classification. They are then visually checked and labelled against ground reference data. In the end, the labelled clusters are aggregated into 4 land use classes: park area, light industrial area, and old-building and new-building residential area. At last, vegetation strips, water surface, road area substitute the corresponding land use types in the classified map. In results, there are 7 land use categories in the final map. Fig. 2 shows the land use results by different window sizes.

To evaluate the accuracy of final land use classification, the real-world land use maps of the test area were identified by using an aerial image and field survey. The resultant land use map is then compared against the ground information and accuracy measurements are pro-

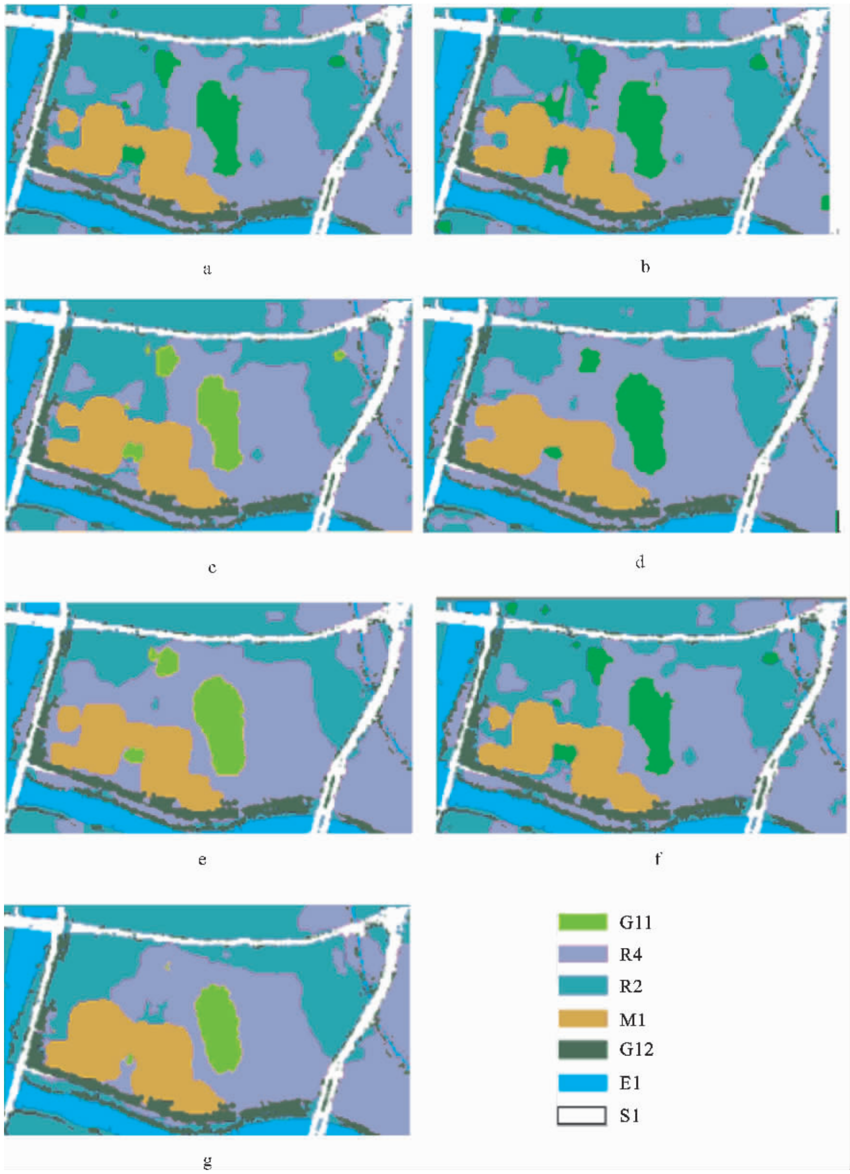


Fig. 2 Land-use maps from the window sizes of 61m×61m (a), 68m×68m (b), 75m×75m (c), 87m×87m (d), 99m×99m (e), 110m×110m (f), and 121m×121m (g) respectively

duced. The producer's accuracy and user's accuracy of different land use types are described respectively in Fig. 3 and Fig. 4, and the total accuracy and Kappa coefficient using different window sizes are listed in Fig. 5.

Fig. 3 shows that the producer's accuracy of different land use behaves different tendencies with the increasing of window sizes. The producer's accuracy of new-building residential area increases with the extending of window sizes, and it reaches highest when using 110m×110m window size, and then declines. The producer's accuracy value of old-building residential area is at high level and does not change much with the change of window sizes. The tendency of the producer's accuracy of industrial area shows the same as that of old-building residential area. The producer's accuracy of park area changes much with widening of window sizes, first

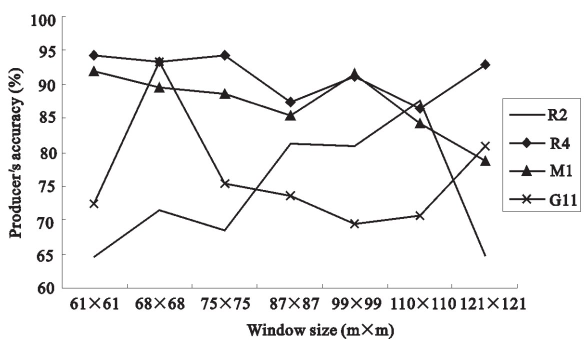


Fig. 3 Producer's accuracy of R2, R4, M1, and G11 from the seven window sizes

abruptly increases and attains the highest when using the window size of 68m×68m, and then declines and remains at low value level until using the 110m×110m, and increases then.

Fig. 4 shows the user's accuracy of different land use types. The user's accuracy values of new-building residential, industrial and park area are at high level and does not change much between 61m×61m and 110m×110m window sizes and then, the values of new-building residential and park area's increase, while industrial area's declines. The tendency of the user's accuracy of old-building residential area is different from the three others: the value is at low level until using 87m×87m window size, then it keeps at high level until using 110m×110m, and at last, declines.

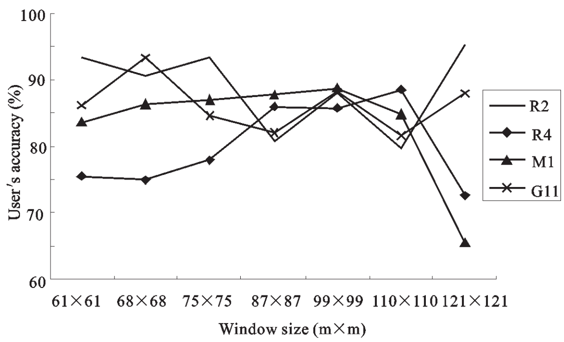


Fig. 4 User's accuracy of R2, R4, M1, and G11 from the seven window sizes

Fig. 5 shows that the total accuracy (80%–87%) and Kappa coefficients (0.69–0.79) from the seven different neighborhood sizes are very close. With the increasing of window sizes, the total accuracy and Kappa coefficient increase, and then, decrease. Thus, the 99m×99m window size resulted in slightly higher accuracy as noted with other researcher's work (ZHANG and WANG, 2003).

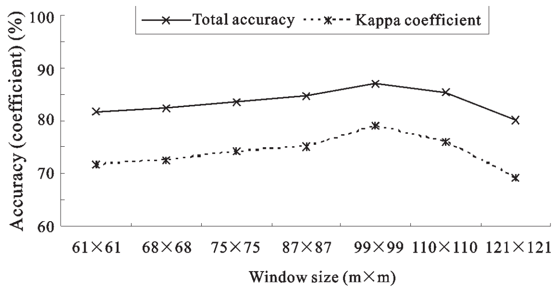


Fig. 5 Total accuracy and Kappa coefficient from the seven window sizes

The distribution of the misclassified cell using 99m×99m window size (Fig. 6) demonstrates that most of the cells have been classified accurately. The misclassified cells mainly existed within the boundary area for the mixing signatures of two or more land use classes within the moving window. The larger the window size, the greater the possibility of mixed land use classes existing


Fig. 6 Spatial distribution of the misclassified cell

in the boundary area. Consequently, this may cause more conflicts along the boundaries between two different land use classes and thus reduce the accuracy.

## 5 CONCLUSIONS

Land use and land cover information is very much required for urban studies. However, there are no mature methods readily available so far to interpret high-resolution images. The land use identification method based on characteristic land cover density map can produce credible land use categories from high-resolution images which are at levels Ⅱ and Ⅲ in urban land use classification system. From this study, the following conclusions can be made:

(1) The characteristic land cover layers of each land

use category's substituting for land cover layers used in the density map improves the classification accuracy, and such disposal especially adapt to land use extraction in sub-scene of an image.

(2) Through comparing classified results by different window sizes, we can conclude that the window size influences the classified results (the total accuracy change from 80% to 87%). The most proper window size for inferring urban land use categories used in the proposed method is 99m×99m. This figure also can provide useful information for the derivation of urban land use in formation in other method or for other landscape analysis.

(3) The misclassified cells are mainly distributed in the boundary of different land use types, which is caused by the method itself. The efficient way to conquer this limitation is to employ small window size at the prerequisite of obtaining urban land use type.

## REFERENCES

BARNSLEY M J, BARR S L, 1996. Inferring urban land use from satellite sensor using kernel-based spatial reclassification [J]. *Photogrammertric Engineering and Remote Sensing*, 62(6): 949–958.

HODGSON M E, 1998. What size window for image classification? A cognitive perspective [J]. *Photogrammetric Engineering and Remote Sensing*, 64(8): 797–807.

HUNG Ming-chih, 2002. Urban land cover analysis from satellite images [EB/OL]. www.isprs.org/commission1/proceedings/paper/00099.pdf

KONTOES C C, RAPTIS V, LAUTNER M *et al*., 2000. The potential of kernel classification techniques for land use mapping in urban areas using 5m-spatial resolution IRS-1C imagery [J]. *International Journal of Remote Sensing*, 21(16): 3145–3151.

LILLESAND T M, KIEFER R W, 2000. *Remote Sensing and Image Interpretation* [M]. New York: John Wiley & Sons, Inc.

Urban Management Committee of China, 2000. The collection of urban planning law [M]. Beijing: Architecture Industrial Publishing House, 25–30. (in Chinese)

WANG Jin-fei, ZHANG Qiao-feng, 2002. Mapping urban land use from high resolution IKONOS imagery [A]. In: *Geoinformatics' 2002 GIS and Remote Sensing for Global Change Studies and Sustainable Development, Celebration of the 10th* [C]. Nanjing: Nanjing University.

ZHANG Qiao-feng, WANG Jin-fei, 2001. Inferring urban land use from1 meter resolution IKONOS imagery [A]. In: *Proceedings of the 23rd Canadian Symposium of Remote Sensing* [C]. Ottawa : Canadian Aeronautics and Space Institute, 173–181.

ZHANG Qiao-feng, WANG Jin-fei, 2003. A rule-based urban land use inferring method for fine-resolution multispectral imagery [J]. *Can. J. Remote Sensing*, 29(1): 1–13.

ZHANG Xiu-ying, FENG Xue-zhi, BEHARA Satyanarayana *et al*., 2004. Inferring urban land use from IKONOS image [A]. In: *Proceedings of IGARSS 2004* [C]. New York: Institute of Electrical and Electronics Engineers Inc., 2695–2698.