An Effective Urbanized Area Monitoring Method Using Vegetation Indices

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ABSTRACT:

Urban growth management is essential for sustainable urban growth. Monitoring physical urban built-up area is a task of great significance to manage urban growth. Detecting urbanized area is essential for monitoring urbanized area. Although image classifications using satellite imagery are among the conventional methods for detecting urbanized area, they requires very tedious and hard work, especially if time-series remote sensing data have to be processed. In this paper, we propose an effective urbanized area detecting method based on normalized difference vegetation index (NDVI) and normalized difference built-up index (NDBI). To verify the proposed method, we extract urbanized area using two methods; one is conventional supervised classification method and the other is the proposed method. Experiments shows that two methods are consistent with 98% in 1998, 99.3% in 2000, namely the consistency of two methods is very high. Because the proposed method requires no more process without band operations, it can reduce time and effort. Compared with the supervised classification method, the proposed method using vegetation indices can serve as quick and efficient alternatives for detecting urbanized area.

KEY WORDS: Urban area extraction, Change detection, Monitoring, NDVI, NDBI

1. INTRODUCTION

According to urbanization and urban growth, various urban problems are presented. They are growth inequality, the housing problem, and transportation problems etc (Jeong sam-seok, 2004; Proceedings Korea Planners Association, 2003). So, urban growth management is essential for sustainable urban growth. To manage urban growth, monitoring physical urban built-up area is a task of great significance. Detecting urbanized area is essential for monitoring urbanized area.

The main objective of this study is the developments of an effective urbanized area detecting method based on normalized difference vegetation index (NDVI) and normalized difference built-up index (NDBI). To verify the proposed method, we extract urbanized area using two methods; one is conventional supervised classification method and the other is the proposed method. And then, we compare the results of the satellite images in 1988 and 2000.

2. METHODOLOGY

2.1 Study area

The study area is largely urbanized area of Seoul. As the capital of South Korea, Seoul has a total area of 605.40 ㎢(2005). Land uses/covers in this area are mainly urban residential, commercial and industrial.

Due to rapid economic development, non-urban area has been converted to urban area since 1960s. But the rapid development has caused many problems such as the housing problem, a traffic problem, environmental pollution, etc. So, The Seoul Metropolitan Government makes alternative plans likewise the project of restoring the Chonggyechon stream, reorganization of public transportation system and so on.

2.2 Data and used software

Landsat TM images (26 September 1988 and 3 September 2000) were used in this study. Spatial resolution is 30m by 30m and all image processing and analyses were carried out in ER Mapper® and ArcGIS®.

2.2.1 Data processing

The image of 2000 geometrically was rectified using ground control points in a topographic map of 1:25,000. And the image of 1988 was geometrically rectified using proceed image of 2000 by image to image method. Then, these images were resampled to the same spatial resolution using the nearest neighborhood method.

2.2.2 Extract urbanized area

(1) The combination of Vegetation Indices

Understanding of the distribution of vegetation is needed for land resource management ; combating deforestation and desertification and promoting sustainable agriculture and rural development (Jensen et al., 2004). There are many vegetation indices for it. NDVI (Normalized Difference Vegetation Index) is one of the most commonly used indices and it is calculated using (1). Seasonal and inter-annual changes in vegetation growth and activity can be monitored (Rouse et al., 1974). And it can reduce many forms of noise in multiple bands of multiple-data imagery. Beyond these things, NDVI is a beneficial method which consists in many merits.

$$NDVI = \frac{band\,4 - band\,3}{band\,4 + band\,3} \quad (1)$$

As the other application of VI (Vegetation Index), this study used NDBI (Normalized Difference Built-up Index). NDBI can be used in studying for urban/suburban problems, particularly in monitoring the spatial distribution and growth of urban built-up areas. NDBI is essentially equal to Infrared Index II (Hardisky et al., 1983). However, Zha et al (2003) proposed an extract method for built-up area based on NDVI and NDBI. The technique was reported to be 92% accurate.

$$NDBI = \frac{band\,5 - band\,4}{band\,5 + band\,4} \quad (2)$$

$$Urban = NDBI - NDVI \quad (3)$$

We select some training area for investigating the digital values. The classes of training area are urban, forest, agriculture, tideland, and water. The digital numbers of training area in Landsat TM image is tabulated in Table 1. Urban and tideland classes show a sharp rise from band4 to band5 and a sharp descend from band 3 to band4 in Figure 1. This pattern is the same as a case of 1988, too. The patterns of forest, agriculture, and water classed are clearly distinguished from those of urban and tideland classes.

Table 1. The DN of Landsat TM spectral bands in 2000

TM spectral	band	1	2	3	4	5	7
urban	min	79	53	49	24	39	32
	max	122	110	139	75	170	135
	mean	96.2	78	81.4	47.3	79.5	68.8
forest	min	57	38	26	44	41	19
	max	72	60	57	90	89	54
	mean	61.7	44.7	33.5	66.4	66.2	32.4
agriculture	min	69	57	40	56	60	31
	max	88	84	90	140	122	67
	mean	73.7	68.4	50.4	113.2	90.4	45.7
tideland	min	88	72	72	33	45	30
	max	94	78	81	40	70	51
	mean	92	75.4	77.7	37.9	63.8	43.9
water	min	71	50	32	10	9	7
	max	92	80	79	20	15	14
	mean	80.4	61.5	49.1	13.7	11.2	10.2

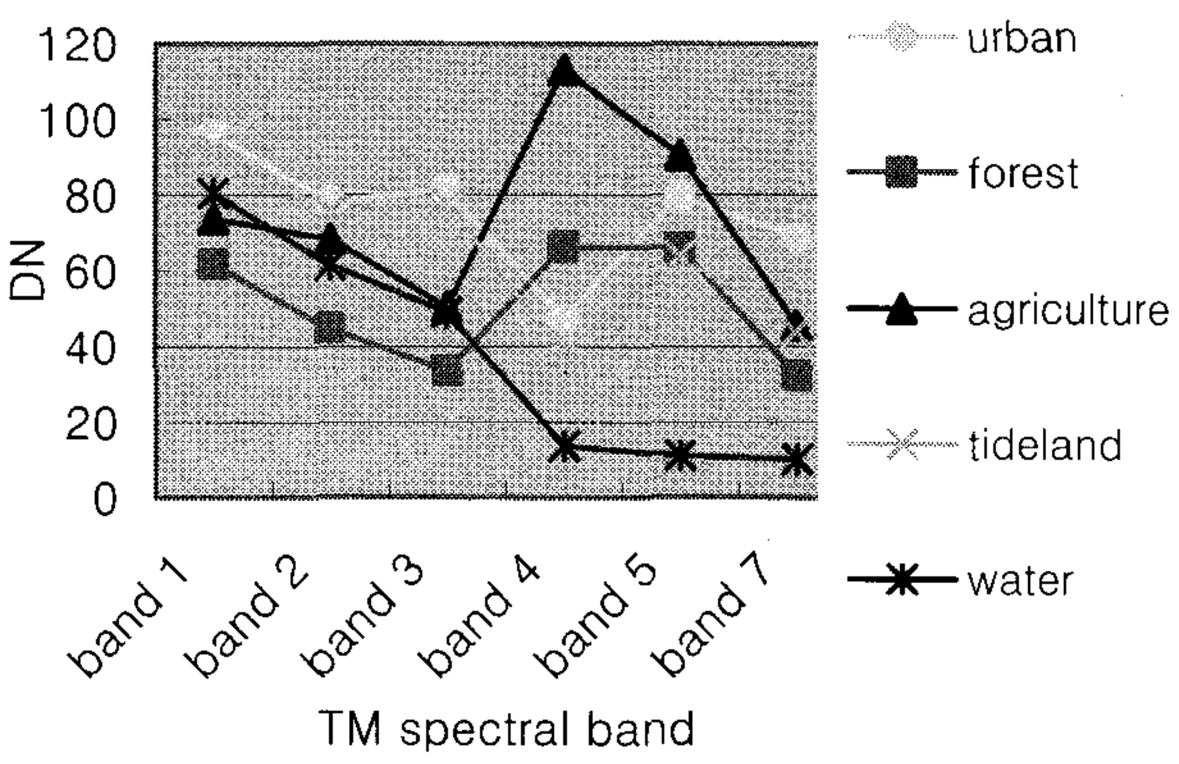

Figure 1 The DN of Landsat TM spectral band in 2000(mean value)

The use of this principle enables built-up area extraction. If NDVI is negative and NDBI is positive, the pixels could be allocated in built-up category (Urban and tideland have same patterns, but tideland could be easily distinguished with urban by means of masking or band combinations). For the comparison with a supervised classification method, the results are converted into the grid file using ArcGIS®. Built-up area has a value of 1 and the others have a value of 0.

(2) Supervised classification method

Supervised classification method selects the training sites based on the regions which are known as a priori. Then, multivariate statistical parameters are calculated for each training site. Every pixel both within and outside the training sites is the evaluated and assigned to the class of which it has the highest likelihood of being a member. We select five training areas of urban; forest, agriculture, tideland, and water, and classify the images. To compare the result with the former results, the results also are converted into the grid file using ArcGIS®. Urban class has a value of 1 and the others have a value of 0.

3. RESULTS

The results of two methods, the combination of VIs and supervised classification, are shown in Figure 2 and Figure 3. Because images in 1988 and 2000 show a same region, we can use these images to check temporal urban expansion. In both methods, we can easily see the urban sprawl. In 1988 images, the method using supervised classification has larger amount of urban area that using the other method, but in 2000 images, the area of urban area using supervised classification is as much as that using combination of VIs.

For quantitative analysis, each results are compared (refer Table 2 and Table 3). Total agreement level using two methods is 76.6% in 1988 and 96.5% in 2000. Agreement level of built-up area using two methods is 98.1% in 1988 and 99.3% in 2000, agreement level of all other covers using two methods is 62.7% and 92.3% in 2000. In 2000 results(Table 3), we can know that the results of two methods are consistent. So, we can result in that the combination of VIs is usable in extracting built-up area. But the result in1988 is not a same aspect as the result in 2000. In 1988 results, only 63% of urban area using classification method agrees with urban area using combination of VIs and urban area in 1988 image using classification method is similar with that in 2000 image using classification method. This implies that urban area using classification methods may be over-estimated.

Table 2. Comparison the result of the combination of VIs with the result of the supervised classification method(1988)

classification / VIs	non-urban	urban	total	agreement level
non- urban	255839	152520	408359	62.70%
urban	5098	260971	266069	98.10%
total	260937	413491	674428	
agreement level	98.00%	63.10%		76.60%

Table 3. Comparison the result of the combination of VIs with the result of the supervised classification method(2000)

classification / VIs	non-urban	urban	total	agreement level
non-urban	246681	20635	267316	92.30%
urban	2909	404203	407112	99.30%
total	249590	424838	674428	
agreement level	98.80%	95.10%		96.50%

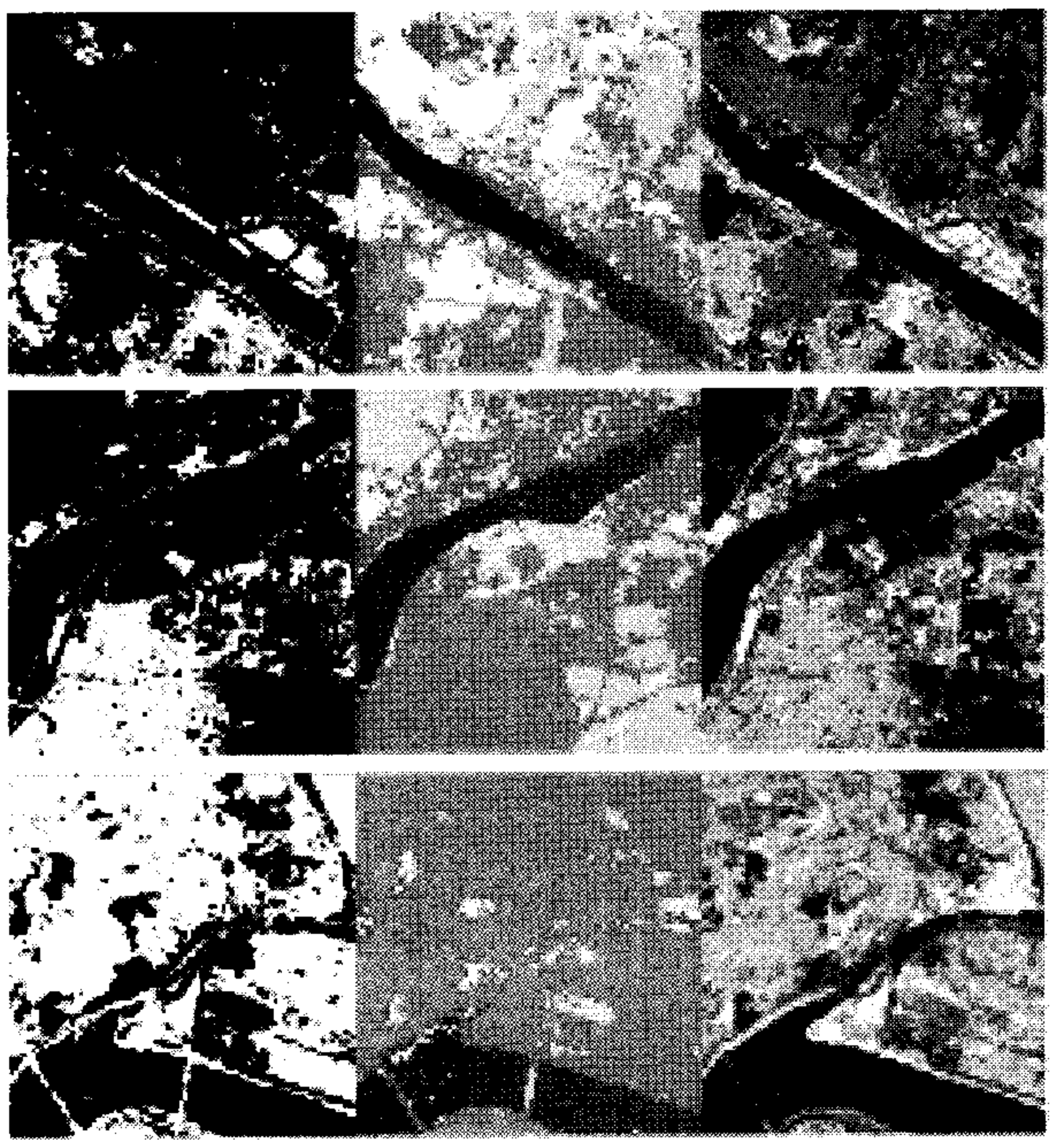

Figure 2. Classified images using two methods and Landsat TM original image in 1988(image using the combination of VIs, image using the supervised classification method, Landsat IM image; from the left)

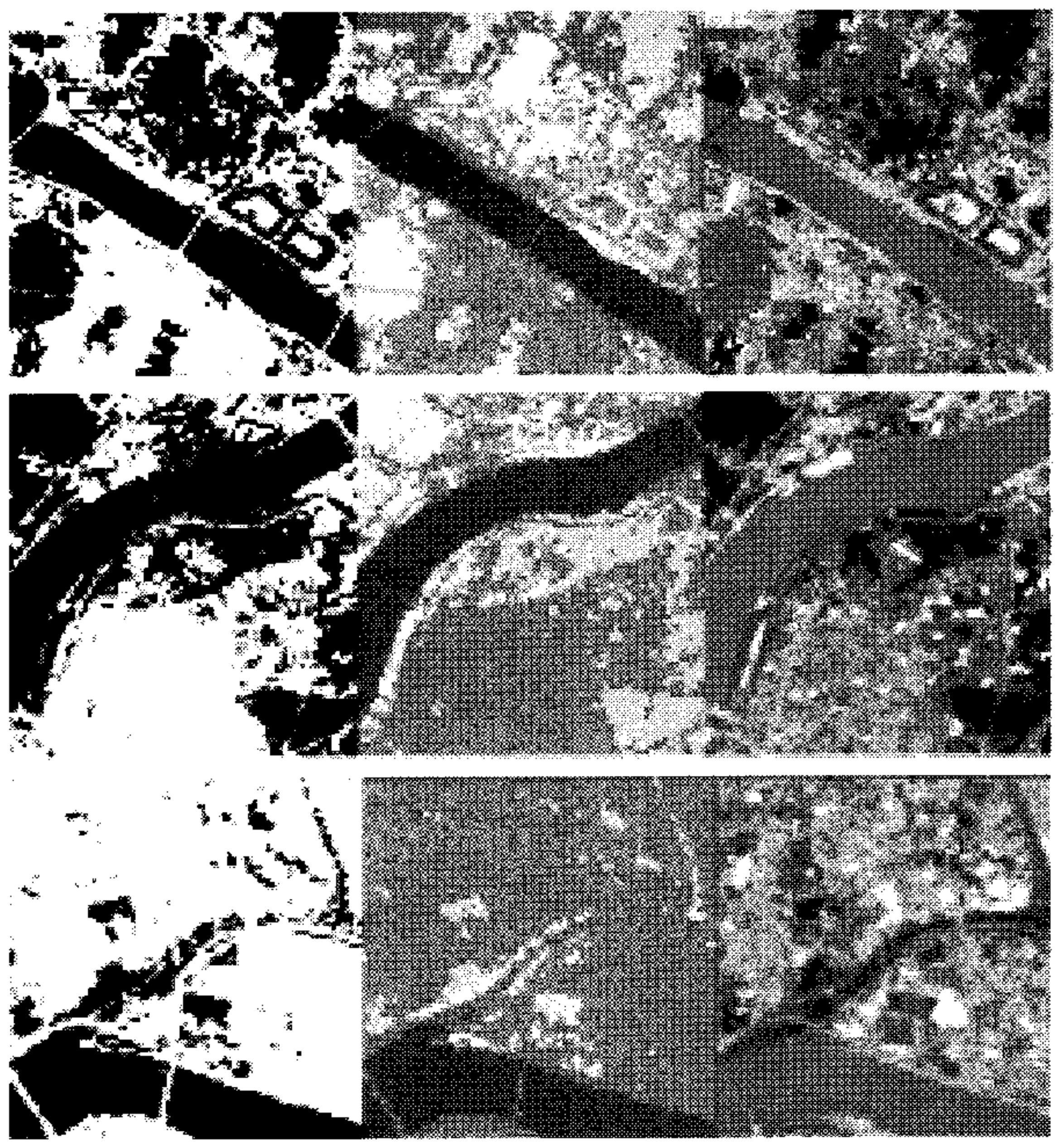

Figure 3. Classified images using two methods and Landsat TM original image in 2000(image using the combination of VIs, image using the supervised classification method, Landsat IM image; from the left)

To verify the possibility of over-estimation, we compare the results of two methods (1988, 2000) with land use/cover classification maps of the ministry of environment (http://www.egis.go.kr) in 1999. Comparison with built-up pixels of land cover classification of the ministry of environment indicates that the built-up area is over-assumed in the result of supervised classification method in 1988(table 4). In Table 4, built-up pixels of classification in 1988 are more than that of land use/cover maps in 1999. This can not be true.

However, this does not imply that combination method can not extract urban area. 98% of urban area in 1988 image using combination of VIs agrees with urban area using classification method(Table 2). This may imply that urban pixels using combination VIs are largely classified into urban pixels in classification (98.1%) although urban pixels in classification are always not allocated into urban pixels in combination of VIs (63.1%). Therefore, if a pixel is allocated in urban using combination VIs, the pixel will be a member of urban class.

Table 4. Comparison the built-up pixels

	The supervised classification method	The combination of VIs
1988 (experiment 1)	413491	266069
2000 (experiment 2)	424838	407112
1999(MOE)	373855	

4. CONCLUSION

While urbanization appears a glow flow, Korea also goes through a radical urbanization. So, urban growth management is essential for sustainable urban growth. In this study, we propose an effective urbanized area detecting method based on normalized difference vegetation index and normalized difference built-up index. To verify the proposed method, we extract urbanized area using two methods; one is conventional supervised classification method and the other is proposed method. Experiments show that urban area using combination method is consistent with urban area using classification method (98.1% in 1998, 99.3% in 2000), namely the consistency of two methods is very high. Because the proposed method requires no more process without band operations, it can reduce time and effort. But classification method requires training data collection, classification method selection, etc, and the results may be different according to training data, classification method. Compared with the supervised classification method, the proposed combination method of vegetation indices can serve as quick and efficient alternatives for mapping urbanized area.

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