Application of Satellite Images and GIS in Evaluation of Green Space Destruction in Urban Area (Case study: Boukan City)

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Abstract

The negative effects of urban development in Iran are increased due to climatic restricted and vulnerable ecosystems; especially this trend has been in existence with lack or poor planning. Change detection is a technique used in remote sensing for detecting the changes which have may occurs in the existing over two or more periods of time in a particular area. In this paper, Boukan, a city in West Azarbaijan province was chosen as study area. Three remote sensing techniques including NDVI comparison, Principle Component Analysis and the Post Classification were employed to detect the green space changes. To carry out these techniques, LANDSAT TM and ETM^{+} data within the years 1991 to 2008 were used to recognize land use changes, especially the physical development of the area and its devastating effects on the green space. In this research, the capabilities of LANDSAT data which is oriented towards determining land use changes, via the standard methods is examined. The result showed that NDVI and post classification analysis methods are better than principal component analysis in detecting the devastating effects of unplanned constructions and forming projects on Boukan's green space.

Keywords: *Change Detection; Destruction of Green space; Multi-temporal Images; urban development.*

1. Introduction

Most of the environmental impacts of urbanization are associated with green space. The loss or degradation of green space may deprive the habitats for creatures, reduce biodiversity, and disrupt the structure and process of the urban ecosystem [1,2]. However, allocation of Urban land to green spaces as a class of land use is an important policy issue in almost all cities.

Satellite image analysis through remote sensing techniques helps us to detect and manage these changes in the right way. There are several reported studies that investigate land use changes using satellite data in which some will be referred to in this section. Sunar (1998) used five techniques, including: adding, subtracting, dividing, principle component (PCI), and post classification analysis to detect land cover changes in Aykitali, Turkey [3]. He found that the technique of adding and subtracting images were the most simple among these techniques while PCI and post classification analyses showed better results in change detection. Tardi and Contalgon (2001) also used three methods including: multi-temporal color composite, subtraction, and classification in order to examine physical development of Massachusett's urban area and the resulting land cover changes. Finally, they used post classification analysis in order to estimate total accuracy [4]. Qiasvand (1996) also concluded similar study via PCI and subtraction techniques so as to present south Tehran land cover map and he reported that regression analysis in conjunction with PCI showed better results [5]. Consequently, on the basis of the earlier studies about land cover change detection, it is obvious that most researchers used subtraction and PCI techniques to detect changes in land cover and, in further steps, by classifying multi-temporal images they showed results in quantitative form.

Due to the rapid proceeding physical extension of Boukan city as this city plays several functional rules, population growth is also with a considerable fast rate. As a result, lack of sufficient green space, pollution, soil erosion, and other critical environmental outbreaks calls for new planning approach for this city. As the first stage of impact assessment, in this paper, we focus on green space changes within a particular period.

2. Study area

The Boukan county which located in same mountain and temperate region that Surrounded by Myandouab county from the North and Saqqez county from the south and to Shahindezh county from east and from west to Mahabad county. The capital of this county is Boukan city. The Boukan city located in 36˚ 31' North latitude and 46◦ 12' east longitude and its height from sea level is 1370 meters. The average elevation of the city is about 1421 meters above mean sea level. Boukan is characterized as a mountainous area which is located within Zagros Mountains rages from south-east to north-west. Figure 1 shows location of study area in West Azarbaijan province, Iran.

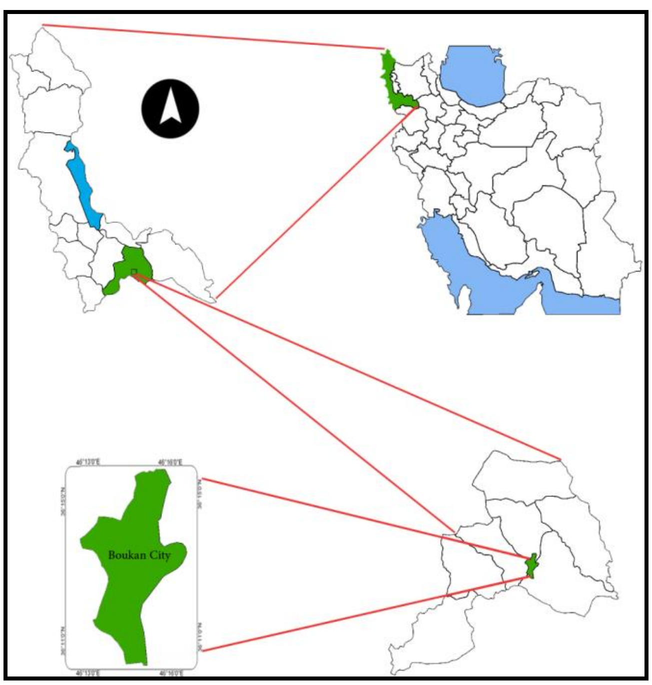

Fig. 1. Location of Study Area

3. Methodology

3.1. Image Preprocessing

Preprocessing of satellite images prior to image classification and change detection is essential and commonly comprises a series of sequential operations, including atmospheric correction or normalization, image registration, geometric correction, and masking [2]. In the preprocessing stage, it is vital to eliminate any kind of atmospheric effects before any image analysis or information extraction are carried out [6]. This becomes especially important when scene to scene comparisons of two or several images in applications, such as change detection, are being sought [7]. In this research, Dark Object Subtraction (DOS) is used as an approach for atmospheric correction, which is perhaps the simplest yet most widely used image-based absolute atmospheric correction approach for classification and change detection applications [8,9]. This approach assumes the existence of dark objects (zero or small surface reflectance) throughout a LANDSAT TM scene and a horizontally homogeneous atmosphere. The minimum DN value in the histogram from the entire scene is thus attributed to the effect of the atmosphere and is subtracted from all the pixels [4]. It is notable that Dark object subtraction method is used only for TM image (ETM^+ image was already corrected atmospherically via USGS center and image histogram showed no offset value within the image).

To conform the pixel grids and remove any geometric distortions, TM images of July 31, 1991, was registered to the topographic map, UTM coordinate system Zone 38 North, based on 16 ground control points collected from throughout the study and 2008 scene were registered to the July 31, 1991 image utilizing similar sets of ground control points (GCP's). For geo-referencing GCP collection, first order transformation, and the nearest neighbor re-sampling of the uncorrected imagery were performed. It should be noted that in change detection studies, the accuracy of less than one-fifth of a pixel is required to achieve a change detection error of less than 10% [6]. Overall, RMS errors of less than 0.2 pixels were achieved for each transformation (3.79 m for TM, 1991 and 3.79 m for ETM^+, 2008). In order to subset the study area from each of the two LANDSAT scenes, a vector file defining the city boundary having the same geo-referenced coordinates system as the LANDSAT images was utilized. Then the scenes of city area were overlaid with the city boundary's vector file which was first converted into a binary bitmap mask and overlaid on to each of the TM scenes.

3.2 Change detection methods

Three remote sensing techniques namely NDVI comparison, Principle Component Analysis and the Post Classification were applied on the data to make model of green space changes in a studied period. Healthy vegetation absorbs most of the red light, and reflects a large portion of the near-infrared spectrum of incident electromagnetic radiation. Consequently, NDVI can be used as an index for monitoring vegetative cover in a given time period [1]. NDVI is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands. NDVI for TM and ETM+ images can be computed using the following formula (Eq.1):

$$NDVI = \frac{B_4 - B_3}{B_4 + B_3} \quad (1)$$

Resulting index value ranges from +1 to -1 indicates sensitivity to the presence of vegetation on the land surface of the earth which can be used to address issues of vegetation type, amount, and condition. NDVI is less affected via atmospheric condition than the other indices, therefore, it is suitable for application such as change detection [10]. In this research, the extracted NDVI from TM (1991) and ETM+ (2008) images were used in order to compute the green space reduction of Boukan during these 17 years.

The second method of change detection performed in this study was Principal Component Analysis (PCA). PCA is an ordinary technique that applies a linear transformation onto the original data. It has been shown to be a notable value in the analysis of remotely sensed imagery [11]. Traditionally it has been applied to image enhancement and channel reduction [12]. However, it has also been effectively utilized in terrestrial change detection studies. In the simplest way of change detection via the PCA technique, one may use multi-temporal single spectral band [13]. It is notable that there is no need to stretch data before using PCA.

PCA was run on NDVI images with the two dates, and a new PCA image was generated with two principal components, which were later treated as separate bands for the interpretation and analysis of the changes within the green space of Boukan. The last most straightforward method of change detection namely post classification method was also conducted. It involves the overlay (or "stacking") of two or more classified images. Change areas are simply those areas which are not classified the same at different times. The Post–classification comparison method is one of the most widely used methods of remote sensing change detection. Some of the main advantages of this method are as follows: there is no need for radiometric co-registration of images involved in the analysis [11]; its sensitivity to the spectral variations due to the difference in the soil moisture, vegetation, and phenology is lower than that of the spectral change detection methods; its provision of "from-to" change information; it's very high change detection accuracy [14].

The classification scheme includes the following classes: the built up lands (low density residential, high density residential, commercial and industrial lands), green area, roads network and sterile lands. In order to develop true assumptions about the normal distribution of samples, all the training sites are evenly distributed throughout the study area. Afterwards, a supervised classification by means of the maximum likelihood approach has been performed on TM (1991) and ETM+ (2008) data and, as the next step, a Majority Filter with a 3 by 3 window size was utilized to suppress the isolated pixels, poor classified pixels or the pixels brought about by noise. The Majority Filter replaces central value pixels by a majority value (Fig. 2).

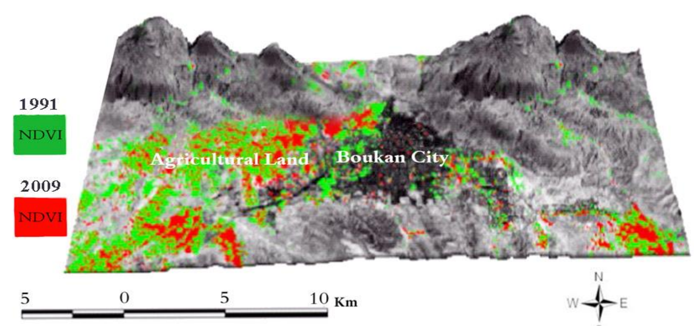

Fig.2. NDVI indices derived from the overlap of green space in the city Bukan in 1991 to 2008

4. Results and Discussion

As a result of this NDVI analysis, we noticed that green space was reduced from 490 hectares in 1991 to 216.3 hectares in 2008 (Table 1).

Table 1. Comparing vegetation density from 1991 to 2008 in Boukan city, which was computed using NDVI

Relative Density of	Area (Hectare)	Density Code	Area (Hectare)
Low	185.21	0.1 - 0.2	236.89
Moderate	103.25	0.2 - 0.3	231.11
High	79.34	0.3 - 0.4	124.62
Very High	560.44	0.4 - 0.5	25.64

With regard to the results of NDVI analysis, it is obvious that there is a major loss of vegetative cover with "very high density" rank over a period of time (1991-2008). This is probably due to the physical development of the city in the north-eastern and western parts of the city (Fig. 3 and 4).

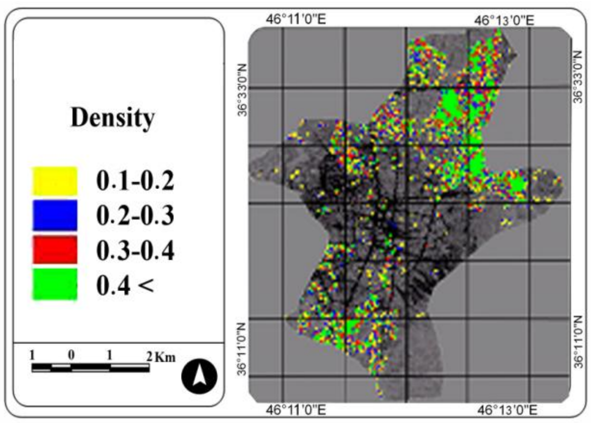

Fig. 3. Green area classification of Boukan upon NDVI value for TM image (1991)

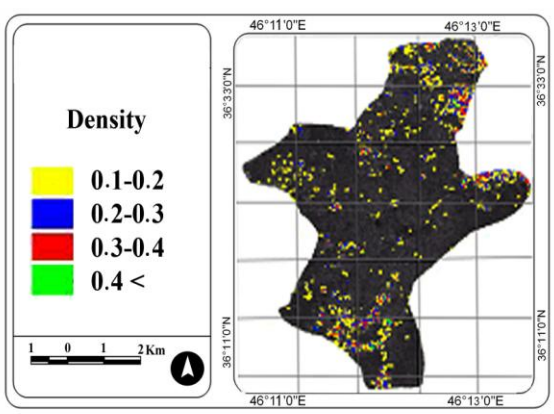

Fig. 4. Green area classification of Boukan upon NDVI value for ETM+ image (2008)

PCA result that first component, which accounts for the maximum individual difference, with an approximate variance of 82.26, is indicated by the green color; the second principal component, with an approximate variance of 17.74, is a combination of variables uncorrelated with the first component and it is indicated by a red color. Figure 5 shows the change regime of the green space over the given period of time (1991-2008). The green color implies less disturbed vegetation cover; whereas, red shows the disturbed vegetation cover of the green space. The vegetation with no change from June 1991 to July 2008 is indicated by black.

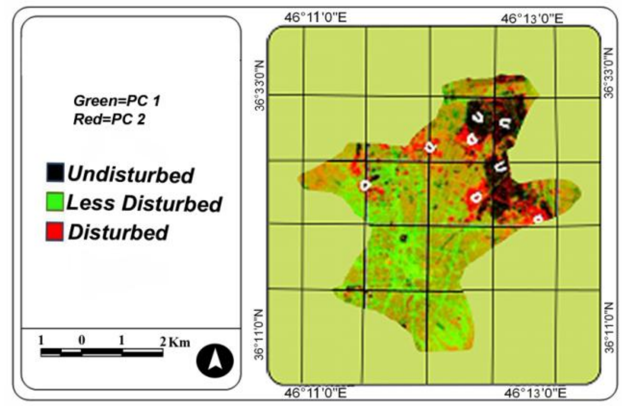

Fig. 5. The classified map, derived from the PCA, shows the disturbance regime of the green area in Boukan

The overall accuracy of classification scheme for each of two images was estimated by means of the standard accuracy assessment procedure (error matrix). The image classification for TM, 1991 has been done with approximate overall accuracy of 95.37%, while overall accuracy of 97.12% was obtained for ETM+, 2008. Finally, the classified images were overlaid by means of the same coordination and projection systems and the accurate percent of the change over this period of time (1991-2008) was calculated for each class by subtraction technique. However, the accuracy of the post-classification comparison is totally dependent on the accuracy of the initial classifications. The final accuracy very closely resembles that the result from the multiplication of the accuracies of each individual classification [15]. The result of the data processing sequence for classification and change detection using remotely sensed data is illustrated in the following figures (6 and 7) and tables (2 and 3):

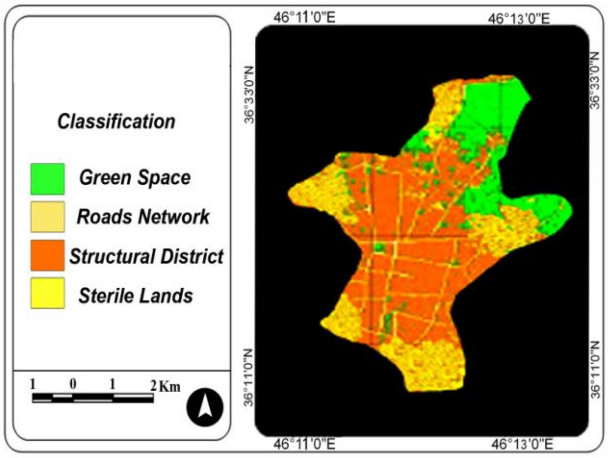

Fig. 6. the classified map of TM image

Table 2. the classification error matrix of TM image

Class Name	Green Space	Roads Network	Built up Lands	Sterile Lands	Sum
Green Space	231	0	0	0	231
Roads Network	0	3	5	1	9
Built up Lands	2	0	22	1	25
Sterile Lands	1	1	3	163	168
Sum	234	4	30	165	433
Prod. Acc.	0.984	1	0.543	0.984	
Omission (0/0)	0.003	0	0.376	0.003	
User. Acc.	2	0.4	0.825	0.864	
Commission (0/0)	0	5	0.043	0.025	

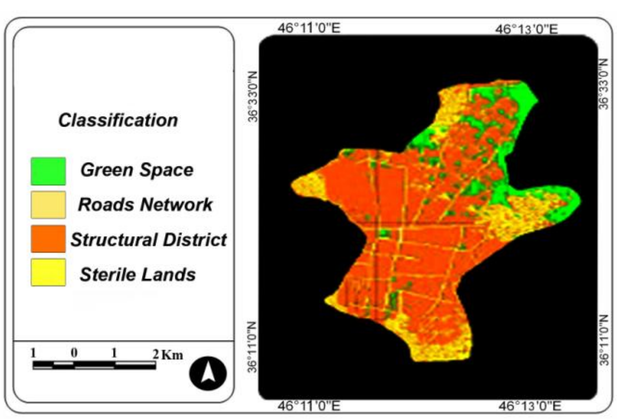

Fig.7. the classified map of ETM+ image

Table 3. The classification error matrix of ETM+ image

Class Name	Green Space	Roads Network	Built up Lands	Sterile Lands	Sum
Green Space	136	0	0	0	136
Roads Network	0	5	0	0	5
Built up Lands	0	6	21	0	27
Sterile Lands	0	0	1	86	87
Sum	136	11	22	86	255
Prod. Acc.	1	0.454	0.954	1	
Omission (0/0)	0	0.545	0.045	0	
User. Acc.	1	1	0.807	0.988	
Commission (0/0)	0	0	0.272	0.011	

The result of the post classification analysis showed that the green space has been reduced from 490 hectares in 1991 to 216.3 hectares in 2001. It is notable this negative change in the green space was due to the devastating role of unplanned constructions and housing projects (Built up Lands) of Boukan city, West Azarbaijan, Iran.

5. Conclusion

The results of this analysis reveal the devastating effects of the physical development of Boukan city on the green space by its 51.58 percent area reduction over a period of 17 years (1991-2008). Although, the investigation of green space changes using NDVI and image subtraction is the best, we also used PCA and post classification techniques as complementary methods to show change variation and change elements respectively. The results of NDVI comparison shows that the green space has been reduced from 490 hectares in 1991 to 216.3 hectares in 2008. Afterwards, PCA scheme was run successfully with two components to show the degree of variation in the green space of Boukan, which was explored by NDVI comparison. Finally, the post classification comparison shows the devastating role of unplanned constructions and housing projects on Boukan green space. In the last section, the difficulty lies in identifying land classes; some land cover types have very similar spectral characteristics; some classes have a constant low reflectance over the whole spectral range with no or only trivial distinct absorption features.

Acknowledgment

We are thankful to the Department of Remote sensing in Universiti Teknologi Malaysia (UTM) and International Doctorial Fellowship (IDF) for providing the facilities for this investigation.

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