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Urban Change Detection in Jeddah City, Saudi Arabia

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Abstract: This paper investigates the capabilities and robustness of different remote sensing data for the area between the years1990 and 2000; using Landsat TM images in particular, to extract the urban and vegetation land covers in the city of Jeddah in Saudi Arabia. Locating the land cover changes in Jeddah; from 1990 to 2000 determines the relationship between urban growth and vegetation. Supervised classifications were carried out to extract four urban land covers, namely: urban, vegetation, barren lands and water. Results show that the most remarkable change is witnessed in the expansion of urban lands over the agricultural lands and bare lands through the whole study period of ten years. This paper demonstrates that remote sensing is capable of extracting urban land cover through supervised classifications method using minimum distance classifier algorithm with highly acceptable results. This gives an indication that the agricultural lands are likely to decrease in the future in the city of Jeddah .This paper also discusses that urban land covers information have a tremendous capability for improving urban planning processes in Jeddah.

Keywords: change detection; urban land cover; vegetation cover; Landsat.

1- Introduction

The majority of the world's population now resides in urban environments, information on the internal composition and dynamics of these environments is essential to enable preservation of certain standards of living (Phinn et al., 2002). The availability of urban land cover data is critical to policy makers, particularly for planners, because of their ability to monitor the impact of planning policies, the direction of urban growth and the development progress. Urban land cover in metropolitan areas continually changes over time and space. Local government must be able to update their databases to reflect current land use. However conventional methods of obtaining urban land cover data require a great deal of time, effort and money to meet fast growing cities.

Image classification, which is the systematic grouping of remote sensing and other geographically referenced data by categorical or increasingly fuzzy decision rules, is considered the best-known and most widely used information extraction technique in remote sensing (McDermid et al. 2005).

Research problem and objectives

In recent decades the significant rate of growth that has taken place in Jeddah; the second largest city of Saudi Arabia, has led to an acceleration in urban growth by transformation of the land cover areas into urban areas, which are consequently converted into cities with roads and infrastructure. This remarkable speed of urban growth, which created the need for this study, has led to the acceleration of land cover change and urban change in the city of Jeddah. Most of the studies on land cover and land use changes in Saudi Arabia focused on studying these changes in different period of times for big cities such as Makkah and Al-Taif (Alqurashi & Kumar, 2014). Thus, the main aim of this study was to investigate the urban change and land cover change between the years 1990 and 2000 using the Landsat satellite imagery data. The objectives of this study were to: (a) identify the urban change and land cover change using the supervised classification method for Landsat images (b) produce thematic maps that track the changes in urban areas and land cover areas in Jeddah city in the period of this study(c) discuss the impacts of these changes in urbanization and land cover in the study area, and (d) to shed light on the importance of using remote sensing data in the urban planning process in Jeddah.

2- Methodology

2.1 Study area

Jeddah is the second largest city in the Kingdom of Saudi Arabia after the capital Riyadh, with a population exceeding more than three million. Jeddah is located on the west coast of the Kingdom at the confluence of latitude 29.21 north and longitude 39.7 east, it is in the middle of the eastern shore of the Red Sea and the surrounding plains of the Tahoma from the east (Figure 1).

Figure1. Geographic Location of Jeddah (source: en.wikipedia.org/wiki/Jeddah)

The city of Jeddah has witnessed a dramatic increase in population, due to out-migration from villages and suburbs to the city in search of jobs and a better life. Furthermore the fall in mortality rate in the Kingdom has led to a natural increase in population. Where there were only 700,000 inhabitants in 1975, by 2006 that number had risen to more than three million persons (Municipality of Jeddah, 2004).

2.2 Data and methods

This paper focuses on locating and analyzing land cover changes in Jeddah city by conducting supervised pixel-based classification methods on Landsat TM images for the year 1990 and the year 2000 (Figure 2).

Landsat TM images acquired by Landsat 4 and 5 satellite between 1999 and 2000 used for this study. The United States Geological Survey (USGS) is the primary data source for this study. USGS archives Landsat data for more than forty years of records of different Landsat sensors data (Woodcock et al., 2008). Landsat data can be accessed and downloaded free of charges to users through the USGS Global Visualization Viewer Interface (GLOVIS) website: (https://glovis.usgs.gov/). The TM images are orthorectified and are acquired in six spectral bands with a spatial resolution of 30 m and a thermal band at 120 m and a revisiting period of 16 days (Chander et al.,2009; Helder et al., 2012).

All the images processing steps were carried out using ERDAS IMAGINE 8.4 software. ERDAS IMAGINE is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications and it is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in geographic information system (GIS) or in computer-aided design (CAD) software (Geosystems, 2006). It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions.

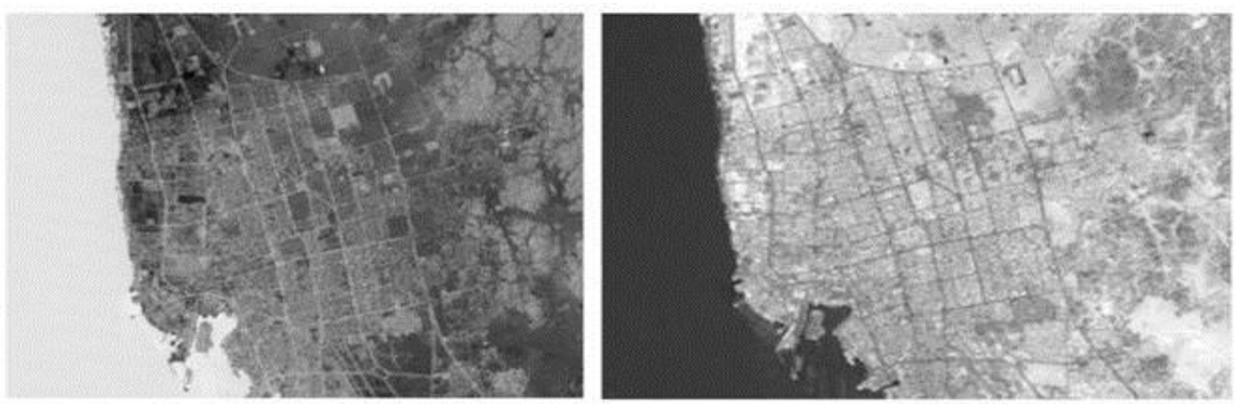
(a) (b)

Figure 2.(a) Landsat TM image shows the city of Jeddah in 1990 (b) Landsat TM image shows the city of Jeddah in 2000 (source: https://glovis.usgs.gov/)

Four main land cover classes were specified to be extracted: urban, vegetations, barren lands and water. The processes of extracting urban land covers started with exploring the raster profile to create a signature or a selection of training fields/samples. After that signatures were evaluated by using signature separately. Finally the process ended with an evaluation of the classification results.

2.3 Image Enhancement Techniques

Principle component analysis (PCA) is an image enhancement technique that has been widely used for remote sensing image analysis of land cover change detection (Lodwick, 1979; Singh & Harrison, 1986; Deng et al., 2008; Estornell et al., 2013; Butt et al., 2015; Song et al., 2017). The purpose of using a principle component analysis is to enhance the display of the bands information content and improve the appearance of the TM image for human visual interpretation and digital analysis (Jensen & Lulla, 2005). This analysis has been successfully applied in Landsat images multispectral TM six bands showing that the best principle component was the second component in both images (Figure 3).



(a) (b)

Figure 3. (a) PCA image for Landsat image acquired in 1990 (b) PCA image for Landsat image acquired in 2000

(Landsat images source: https://glovis.usgs.gov/)

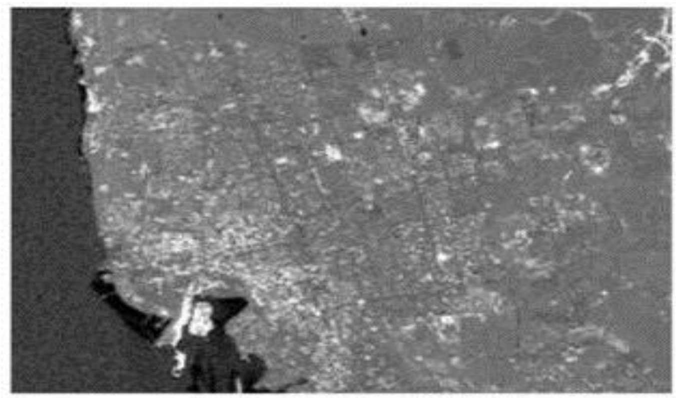
Although PCA is an effective technique for enhancing image information about detecting changes, it usually neglects seasonal variation for the vegetation land cover by intentionally summarizing time series data. This results in losing temporal change information (Millward et al., 2003; Lu et al., 2003; Lasaponara, 2006; Deng et al., 2008), therefore another image enhancement technique which is wavelet decomposition, normally using vegetation indices such as the Normalized Difference Vegetation Index (NDVI), the most commonly used index of vegetation cover (Kleynhans et al., 2011) , was used for the development of land cover change analysis for Landsat TM images (Figure 4).

NDVI is derived from the red and near infrared bands. The ratio is computed from Landsat TM bands as follows (Tucker & Sellers, 1986):

$$NDVI = \frac{(\mathrm{NIR} - \mathrm{R})}{(\mathrm{NIR} + \mathrm{R})}$$

Where: The red (R) for Landsat TM is band 3; and the near-infrared bands (NIR) for Landsat TM is band 4.

(a)



(b)

Figure 4. (a) NDVI image for Landsat image acquired in 1990 (b) NDVI image for Landsat image acquired in 2000

(Landsat images source: https://glovis.usgs.gov/)

2. 4 Selecting Training Samples and Analysis Process

Supervised classification is the procedure most frequently used for quantitative analysis of remote sensing data; it rests upon using suitable algorithms to label the pixel in an image as representing particular ground cover types or classes (Richards, 1999). Selecting training samples is an important step in supervised classification. In this process, there will be selections for the pixels, which represent the different patterns based on the requirements. In this study the selected classification system includes the following four land cover classes: urban, vegetation, barren lands and water.

After identifying the four classes, signatures extraction steps were conducted for each training class by digitising 20 polygons samples on the enhanced TM images. These samples have the same spectral signatures features for each defined class in the enhanced TM images. The field knowledge was helpful in preparing and selecting these different samples. Finally, each 20 samples for the same class were merged together to represent the same class for both enhanced TM images.

Signatures were evaluated by performing separability using three bands (4, 3, 2) for both classified images. Separability is a measure of the spectral distance between two signatures and helps in deciding how different the signatures are (Lea & Curtis, 2010; Appiah et al., 2015). The spectral separability was assessed using the Jefferies – Matusita method which gave the best average separability of 1414 (Table 1 and 2).

Table 1: The Jefferies – Matusita results for the classified TM image1990

	Signature Name	1	2	3	4
1	URBAN	0	1281.46	1383.79	**1414.21**
2	LAND	1281.46	0	1399.13	**1414.21**
3	VEGETATION	1383.79	1399.13	0	**1351.88**
4	WATER	**1414.21**	**1414.21**	**1351.88**	**0**

Table 2: The Jefferies – Matusita results for the classified TM image 2000

	Signature Name	1	2	3	4
1	URBAN	0	1393.01	1368.48	**1414.21**
2	LAND	1393.01	0	1413.88	**1414.21**
3	VEGETATION	1368.48	1413.88	0	**1414.21**
4	WATER	**1414.21**	**1414.21**	**1414.21**	**0**

2.5 Image Classification using Supervised Classification Method

The supervised classification method has been conducted for both TM images using ERDAS Imagine software. Each image has been integrated with the signature, which has been created before for each image including the four defined land cover classes. The minimum distance classifier algorithm was used in the supervised classification (Figure 5). The minimum distance algorithm assigns a pixel to a class on the basis of its proximity to the class mean vectors, hence all pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria (Jensen & Lulla, 2005).

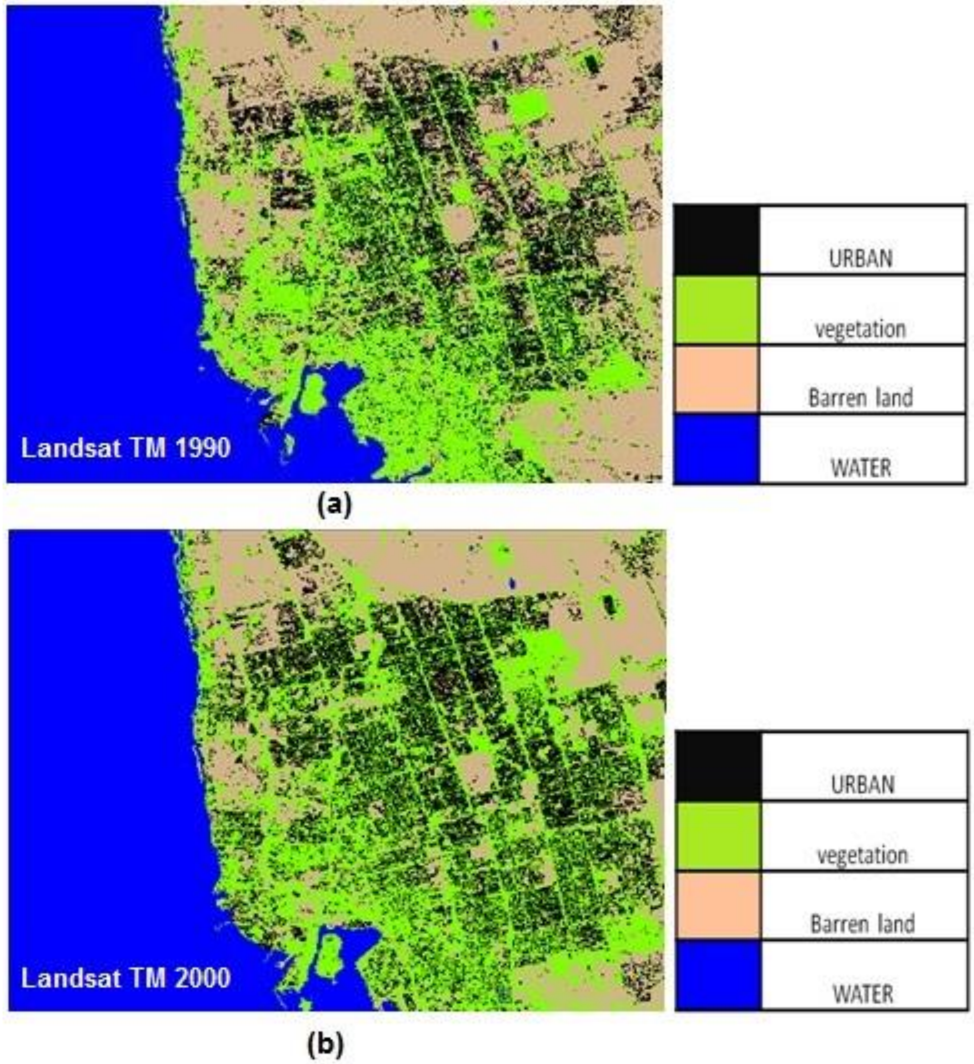


Figure 5. (a) Supervised Classification image of Jeddah city of year 1990 (b) Supervised Classification image of Jeddah city of year 2000 (Landsat images source: https://glovis.usgs.gov/)

2.6 Change Detection Analysis

Thematic change method performed in ERDAS Imagine software, was used for change detection in the study area. Thematic change method has been successfully used in many studies in urban environment and land cover due to its efficiency in detecting the location, nature and rate of changes (Hardin et al., 2007).

The two previously classified TM images of the years 1990 and 2000 were used in this method to detect changes in specific features over time, such as building, roads, and land cover. This method highlighted the changes that have occurred within those four classes.

The last step was converted recode value to calculated area using the final thematic Change Detection . a Matrix Union was run to find all the changed pixels and a "Summary Report of Matrix" was generated to show the rate of change in percentage and the total area changed in square mile focusing on classes changed to urban and vegetation.

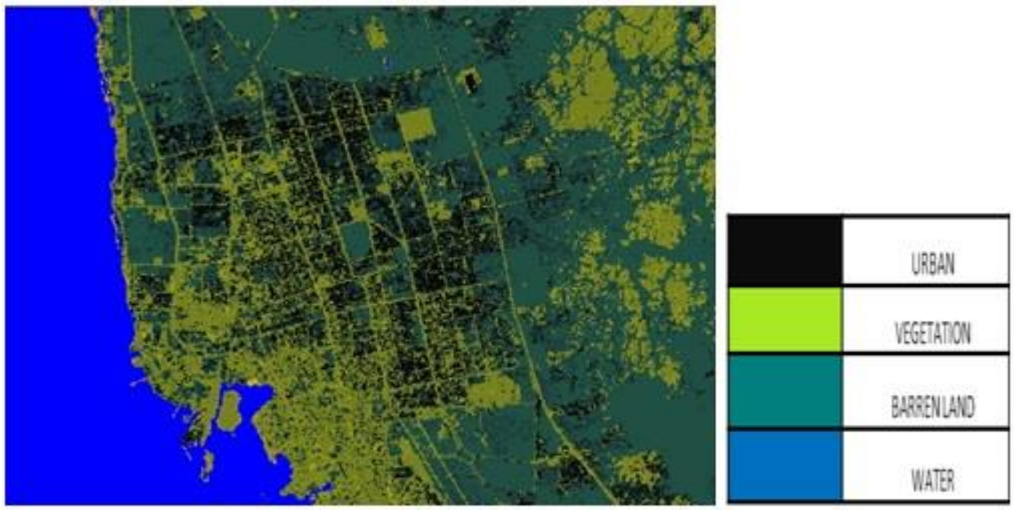


Figure 6. shows change detection for the classified Landsat TM images for Jeddah city by applying Thematic change method (Landsat images source: https://glovis.usgs.gov/)

Table 3: Percent Changes to Urban between years 1990 and 2000

Change Area		
1990-2000	Percent (%)	**Square miles**
land to Urban	1.77	**54.18**
vegetation to Urban	0.47	**11.41**
Water to Urban	**1.30**	**93.97**

Table 4: Percent Change to Vegetation between years 1990 and 2000

Change Area		
1990-2000	Percent (%)	**Square miles**
urban to vegetation	1.93%	**107.511**
land to vegetation	2.80%	**85.5**
water to vegetation	**0.21%**	**15.11**

2.7 Accuracy assessment

Assessment of the classification accuracy of the TM images 1990 and 2000 was performed to determine the quality of the information derived from the Landsat images data. To perform accuracy assessment, training areas were selected as randomly points by ERDAS software to represent the four land cover classes of the study area based on ground truth data and visual interpretation. Error matrices were generated to compare the references data and the classification results. Also Kappa test was performed to measure the extent of the classification accuracy.

The overall accuracy classification for the classified TM images for the years 1990 and 2000 was 88.67% and of 89.06% respectively and the overall Kappa statistics was 0.84 and 0.85 respectively.

Table 5: Accuracy Assessment results from the 1990 Landsat TM image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
URBAN	82	82	61	74.00%	**74.39%**
VEGETATION	42	36	35	83.33%	**97.22%**
BAREEN LAND	32	38	31	96.88%	**81.58%**
WATER	**100**	**100**	**100**	**100.00%**	**100.00%**

Table 6: Accuracy Assessment results from the 2000 Landsat TM image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy(%)	Users Accuracy(%)
URBAN	94	96	72	76.60%	**75.00%**
VEGETATION	18	20	17	94.44%	**85.00%**
BAREEN LAND	45	41	40	88.89%	**97.56%**
WATER	**99**	**99**	**99**	**100.00%**	**100.00%**

3- Results and Discussion

After applying the change detection method of Thematic change technique for the period between 1990 and 2000, the extracted results in Table 3 and 4 show that the most remarkable change is witnessed in the expansion of urban lands over the agricultural lands and bare lands through the whole study period (10 years). The more plausible explanations for this change are the urban development and human modification and activities in the region. This gives an indication that the agricultural lands are likely to decrease in the future in the city of Jeddah. This study could show better results if Landsat images for the past 20 years were available, but the lack of images of the study area has been limited to only ten years from 1990 until 2000.

The rapid development in the city of Jeddah poses many challenges, including the problems associated with urbanization planning and policy makers. The face of these challenges requires from local authorities to establish sustainable development plans that consider both urban expansion and human activities for any future change to minimize the undesirable impacts of these changes on the natural resources and the environment.

This paper has shown that remote sensing data can provide ground cover in urban areas in a timely and relevant manner, which is often difficult to obtain using conventional methods of data collection.

4- Conclusion

The land cover changes have been significant in Jeddah during the period of this study (1990-2000). The results presented in this study suggest, that the changes resulted from urban growth and human activities have caused a decrease in agricultural lands during the study period .

Local authorities should benefit from the use of remote sensing as a tool to extract information for better sustainable development plans for land management, to minimize the undesirable impacts on land use and land cover changes on the environment and natural resources.

Further research is needed to study and integrate the use of moderate and high resolution remote sensing data to cover long period of these changes in the city of Jeddah.

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كشف التغير الحضري في مدينة جدة، المملكة العربية السعودية

الملخص: تتناول هذه الدراسة التغير في أنماط الغطاء الأرضي والنباتي في مدينة جدة بالمملكة العربية السعودية. استخدمت بيانات الاستشعار عن بعد(Land Sat TM)للمنطقة ما بين عام (1990 و 2000) لاستخراج الغطاء الحضري والنباتي في مدينة جدة وإيجاد العلاقة بينهما. وقد أجريت عمليات التصنيف المراقب لتصنيف الغطاء الأرضي إلى أربع فئات: المناطق الحضرية، الغطاء النباتي، الأراضي القاحلة، و المياه. تشير النتائج إلى زيادة في مساحة الأراضي المبنية على حساب الأراضي الزراعية و القاحلة. وذلك يعطي إشارة إلى أن الأراضي الزراعية من المرجح أن تقل في المستقبل في مدينة جدة. ناقشت هذه الدراسة أيضا أهمية دراسة التغير الحضري في تحسين عمليات التخطيط العمراني في مدينة جدة.

الكلمات المفتاحية: اكتشاف التغيير، التغير الحضري ،الغطاء النباتي، Land Sat TM، التصنيف المراقب