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Monitoring and Evaluating Land Cover Change in The Duhok City, Kurdistan Region-Iraq, by Using Remote Sensing and GIS

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Abstract:—The rapid urban development in the Duhok city since the 1990s has dramatically enhanced the potential impact of human activities. To identify and monitor this urban development effectively, remote sensing provides a viable source of data from which updated land cover information can be extracted efficiently and cheaply. In this study, three satellite datasets, Landsat Thematic Mapper (Landsat TM), and two Landsat Enhanced Thematic Mapper Plus (Landsat 7 ETM+), acquired during 1989, 2001 and 2012, respectively, were used to detect and evaluate Duhok's urban expansion. Two change detection techniques were tested to detect areas of change. The techniques considered were image differencing, and post-classification comparison. The land use/land cover (LULC) maps of the years 1989, 2001 and 2012 were produced and the changes were determined with significant accuracies. The simplicity of our methods and the minimal investment of time and money make incorporation of remotely sensed data into urban growth a potentially powerful tool for the urban planner/manager. Moreover, the understanding of the spatial and temporal dynamics of Duhok's urban expansion is the cornerstone for formulating a view about the future urban uses and for making the best use of the limited resources that are available.

Keywords:—Change detection, GIS, Remote sensing, Satellite images, Urban growth.

I. INTRODUCTION

Land use/land cover (LULC) changes are very dynamic in nature due to several factors such as urbanization. The urbanization is a complicated process that is determined by the interactions of biophysical factors and human factors in space and time at different scales [1]. The process of urbanization has been characterized not only by population growth, but also by industrial expansion, increasing economic and social activities and intensified use of land resources [2]. Furthermore, decision-makers are in constant need of current geospatial information on patterns and trends in land cover changes. Therefore, regular and up-to-date information on urban change is required for urban planning, land use management and appropriate allocation of services and infrastructure within the urban areas [3].

Satellite remote-sensing techniques have been widely used in detecting and monitoring land cover change at various scales with useful results [2,4,5]. This is due to their potential of providing accurate and timely geospatial information describing changes in urban land cover [6]. Recently, remote sensing has been used in combination with geographical information systems (GIS) and global positioning systems (GPS) to assess land cover change more effectively than by remote-sensing data only [5]. The objective of this study is to use remotely sensed data and GIS together to monitor and evaluate the urban growth in the Duhok city in terms of urban areas, availability of vegetation, soil and water bodies. This is achieved by examining the scope and rate of urban expansion using change detection techniques, and by detecting the urban expansion directions that have occurred in the Duhok city.

II. STUDY AREA AND DATA

2.1 THE STUDY AREA

The study area extends approximately between latitudes 36°50′00″and 36°54′40″N, and longitudes 42°52′00″ and 43°04′44″E in the northwestern of Iraq, at 430-450 m above the sea level and it covers about 107 km^2 (Fig. 1). The city of Duhok has a linear shape because it embraced by two chains of mountains, Bekhair to the north and northeast and Zaiwa in the southeast. There are two rivers passing though the city; the first one is called Duhok River, whilst the second one which is smaller and seasonal called Heshkarow River. Both rivers meet up in the southwest of the city [7].

Duhok has a strategic location because it lies at the junction of the borders of Iraq, Turkey and Syria in the heart of the Iraq Kurdistan region (Fig. 1). Duhok has a growing tourist industry, its population having grown rapidly since the 1990s as the rural population moved to the city. The climate is a rainy cold in winter and sunny dry in summer where area shows a variety of land cover [7].

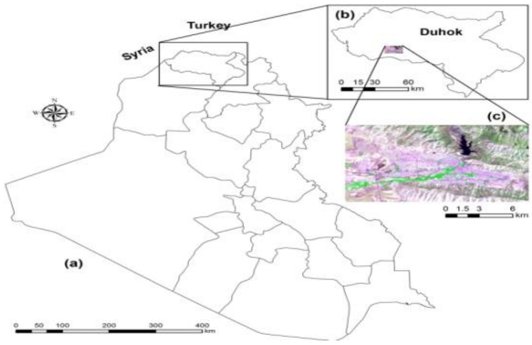

Fig. 1: (a) Map region of Iraq. (b) Location of Duhok governorate. (c) Location of study area.

2.2 SATELLITE IMAGES AND REFERENCE DATA

The effectiveness of information on urban changes in planning, management, and decision-making, particularly in developing countries, depends upon the availability of useful data [8]. To achieve the objectives of this study, Landsat Thematic Mapper (Landsat 5 TM) data acquired on 30 July 1989, and two Landsat Enhanced Thematic Mapper Plus (Landsat 7 ETM+) data acquired on 13 June 2001 and on 11 June 2012, respectively, (Fig. 2) were used. Data from the three images cover a time period of 23 years. The Landsat ETM and ETM+ images of the study area is shown in Fig. 2, resulting from a combination of three bands 7, 4, and 2 by using ENVI software. The TM-1989 data were used as the reference situation and Landsat 7 ETM+ of 2012 data were used as the up-to-date situation of the Duhok city. The datasets are cloud-free scenes acquired, relatively, during the summer of the year. Reference data for ground control points (GCPs) and accuracy assessment, including topographic maps (scale 1:250 000), and a land use map (scale 1:250 000) were used in this study.

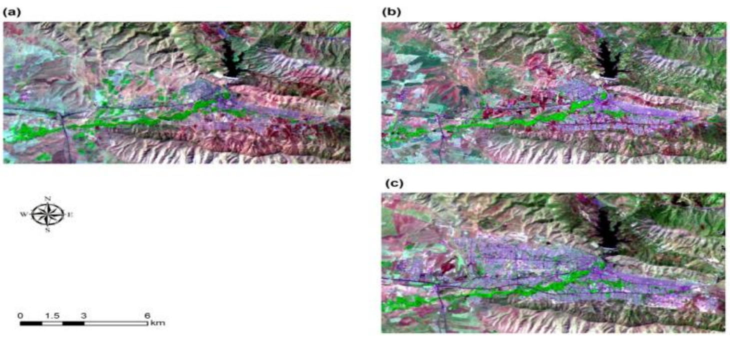

Fig. 2: Colour composite satellite images of the study area.
(a) Landsat TM, 1989. (b) Landsat ETM+, 2001. (c) Landsat ETM+, 2012

III. METHODOLOGY

Digital change detection is the process of determining and/or describing changes in land cover and land use properties based on co-registered multi-temporal remote sensing data [9]. Digital image processing may involve numerous procedures including formatting and correcting of the data and digital enhancement to facilitate better visual interpretation. Land use was categorized into 7 types based on the signature of the images, such as woodland, water field, dry land, town land, work and traffic land, village land, water bodies. The data processing and manipulation were conducted using ENVI (V. 4.7, ITT Visual Information Solutions Group (ITT VIS), formerly known as Research Systems Inc. (RSI), Boulder, CO, USA) and ArcGIS (V. 10.0, Environmental Systems Research Institute (ESRI), Redlands, CA, USA) softwares. In addition, a field survey was carried out in June 2012 to collect ground control, and ground truth points by using Garmin eTrex GPS. The GPS device had an accuracy within a range of ±3 m for 95% of time as a confidence interval. The processing procedures which are adopted in this study are summarized in Fig. 3 and will be discussed in the following sections.

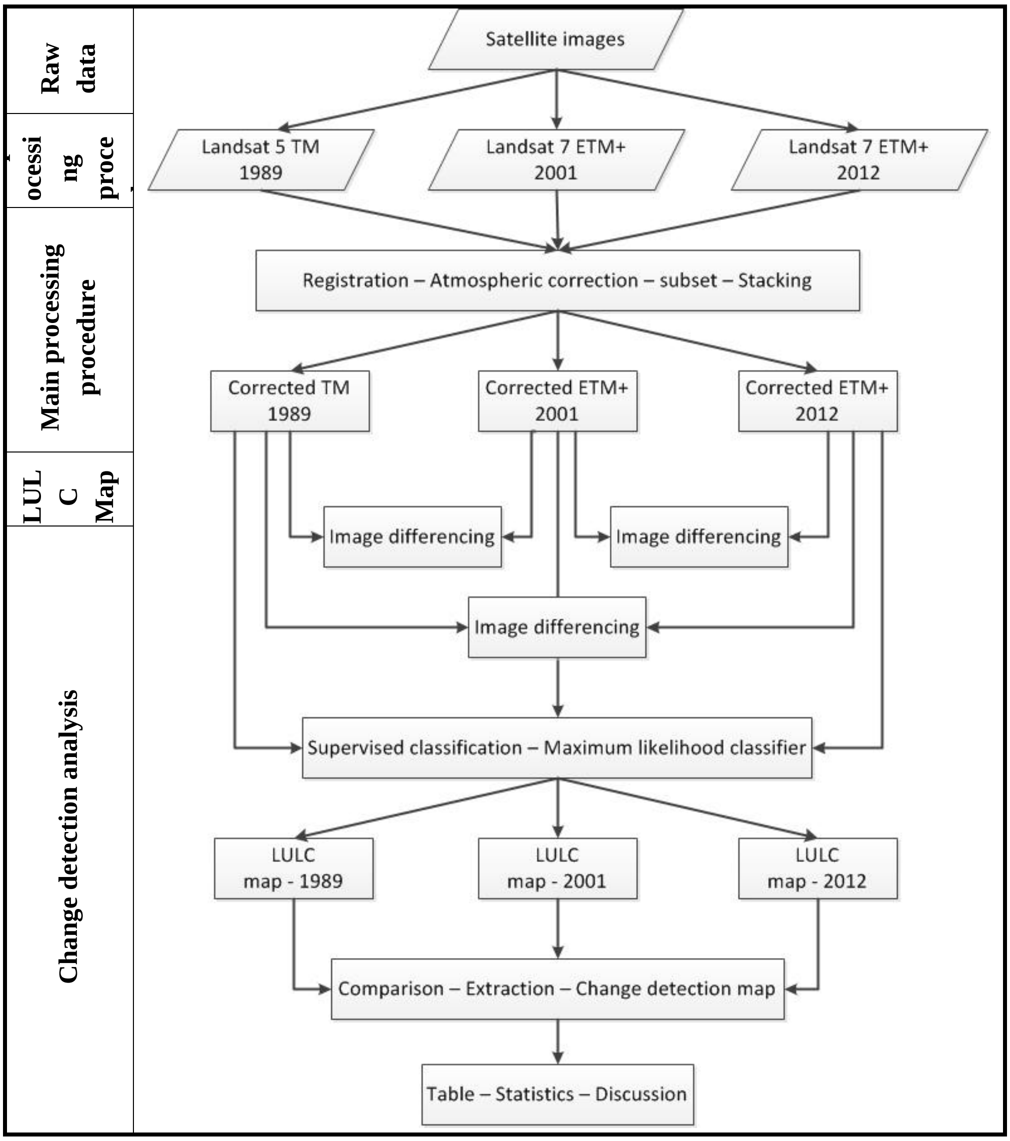

Fig. 3: Flow diagram showing the adopted methodology and data processing of remote sensing datasets.

3.1 SATELLITE IMAGES PREPROCESSING

Two outstanding requirements needed to preprocess satellite images for land cover change detection: multi-temporal image registration and atmospheric correction [9].

3.1.1 Geometric correction: The major task of the image preprocessing is the geometric registration [10]. In this study, Landsat data were co-registered to the topographic base maps at a scale of 1:250 000 (i.e. image-to-map registration) using the Universal Transverse Mercator (UTM) Projection Zone 38 North with a World Geodetic System (WGS) 84 datum. Image-to-map registration was done using 26 GCPs at a root mean square error (RMSE) of less than 0.65 pixels. The first-order polynomial transformation and the nearest neighbour method of sampling were used to maintain the original pixel brightness values and to resample the pixels at a spacing of 30 m in both directions.

3.1.2 Atmospheric correction: Many atmospheric correction methods have been proposed for use with multi-spectral satellite imagery [11]. The Darkest Pixel (DP) atmospheric correction method, also known as the histogram minimum method, was applied to the current study. The simplest DP correction method provided a reasonable correction, at least for cloud-free skies [11]. To assure that the three images used in this study appear as if they were acquired under the very same conditions, a relative radiometric normalization technique was performed.

3.2 CHANGE DETECTION APPROACHES

3.2.1. Image differencing: Image differencing includes the process of subtracting one digital image pixel by pixel from another, to generate a third image composed of the numerical differences between pairs of pixels

[10]. The difference in the areas of no change will be very small, and areas of change will reveal larger positive or negative values [12]. In this study, an image differencing routine was carried out using ENVI software to extract a difference map representing the differences between the initial state and final state images.

3.2.2. Post-classification comparisons: The post-classification comparisons of derived thematic maps go beyond simple change detection and attempt to quantify the different types of change [4]. Supervised classification was chosen in this work. A priori defined five LULC classes in the classification scheme were: (1) urban/built-up areas, (2) dense vegetation areas, (3) sparse vegetation areas (4) soil areas, and (5) water bodies. The three images of years 1989, 2001 and 2012 were subjected to the maximum likelihood classifier independently using the training classes of each date. For the 1989 LULC map, a total of 271 pixels were randomly selected, which were then checked with reference to topographic maps. The results revealed an overall accuracy of 68.8% and a kappa coefficient of 0.74. For the 2001 LULC map, a total of 334 pixels were randomly selected, which were checked with the land use map of the Duhok city. The result showed an overall accuracy of 76.9% and a kappa coefficient of 0.81. For the 2012 LULC map, a total of 510 pixels were randomly selected, which were validated by the land use map and field surveying, which was carried out during June 2012. The results showed the overall accuracy of 89.0% and the kappa coefficient of 0.87.

IV. RESULTS AND DISCUSSION

4.1. IMAGE DIFFERENCING

The resulting maps from image differencing technique between 1989 and 2001, between 2001 and 2012, and between 1989 and 2012 are shown in Fig. 4 (a), (b), and (c) respectively. The resulting maps are colour coded with 11 classes indicating the magnitude of the changes between the two images. Positive changes are displayed in shades of red, while negative changes are displayed in shades of blue. The results show that the urban areas are extended, however, it is not very clear from the figures. The analysis of the image differencing technique is subjective and the choice of the spectral band depends on the specific type of change to be detected. Therefore, in spite of the simplicity and widespread use of this technique, it exhibits a major drawback: a lack of automatic and non heuristic techniques for the analysis of the difference image.

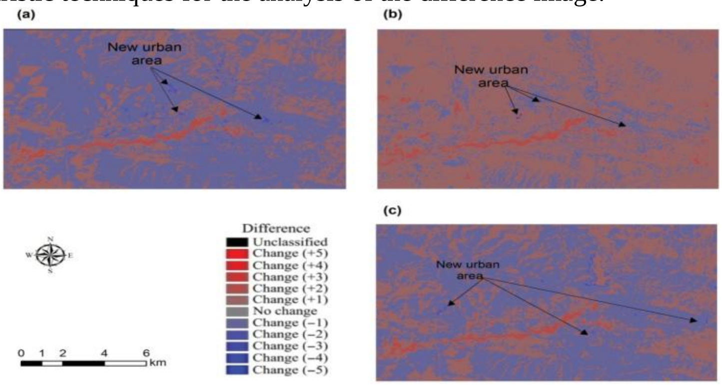

Fig. 4: Images differencing maps. (a) Between Landsat TM, 1989 and Landsat ETM+ 2001. (b) Between Landsat ETM+, 2001 and Landsat ETM+ 2012. (c) Between Landsat TM, 1989 and Landsat ETM+, 2012.

4.2. POST-CLASSIFICATION COMPARISONS

Change detection analysis is performed not only to detect changes that have occurred, but also to identify the nature of those changes and to determine the areal extent and spatial pattern of those changes [13]. Therefore, the main advantage of the post-classification comparison approach is its capability of providing descriptive information on the nature of changes that have occurred [14]. The LULC maps of years 1989 (Fig. 5(a)), 2001 (Fig. 5 (b)) and 2012 (Fig. 5(c)) were produced.

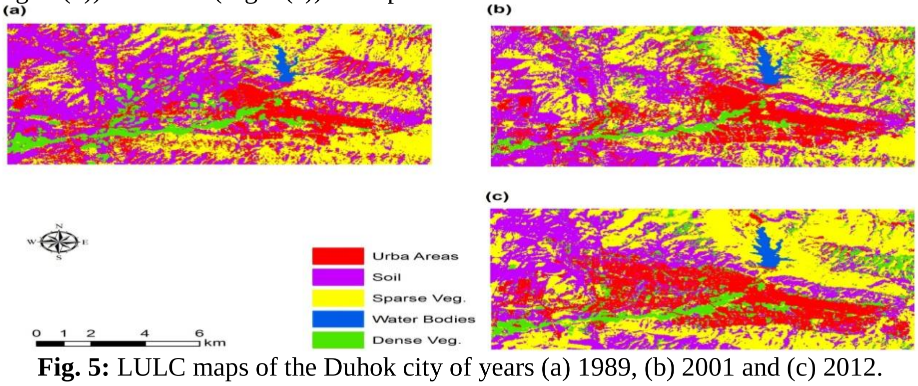

Fig. 5: LULC maps of the Duhok city of years (a) 1989, (b) 2001 and (c) 2012.

Table 1. LULC for the Duhok city as extracted from the satellite data.

Land cover class	LULC-1989 Area (km^2)	LULC-1989 %	LULC-2001 Area (km^2)	LULC-2001 %	LULC-2012 Area (km^2)	LULC-2012 %	Area changed (km^2) 1989-2001	Area changed (km^2) 2001-2012	Area changed (km^2) 1989 -
Urban	25.43	17.70	28.48	19.82	44.54	31.00	03.04	16.06	19.11
Dense Veg.	12.72	08.85	14.52	10.11	11.85	8.25	01.80	-2.67	-0.87
Sparse	51.77	36.04	52.34	36.43	49.36	34.36	00.56	-2.98	-2.41
Soil	52.56	36.59	46.70	32.51	36.38	25.33	-05.85	-10.32	-
Water	01.14	00.79	01.58	01.10	1.51	1.05	00.43	-0.07	0.37
Total	143.64	100	143.64	100	143.64	100	00.00	00.00	0.00

4.3. LAND COVER CHANGE AND STATISTICS

From the classification maps generated for the years 1989, 2001 and 2012 (Fig. 5(a)–(c)), the individual class area and change statistics are summarized in Table 1. In addition, the classes areas and changed areas are graphically presented in Fig. 6. Attention was paid to the urban and green land classes (especially the dense vegetation land), because they represent the main objective of this study. The urban/built-up areas covered about 25.43 km^2 in the year 1989 and were increased to 28.48 km^2 in the year 2001 with an average rate of 0.25 km^2 $year^{-1}$. The area was increased by a further 44.45 km^2 by the year 2012 with an average rate of 1.46 km^2 $year^{-1}$. The Duhok city was expanded by 19.11 km^2 over the entire study period from 1989 to 2012, with an average rate of 0.83 km^2 $year^{-1}$. On the other hand, the dense vegetation land expanded from 12.72 km^2 (in 1989) to 14.52 km^2 (in 2001) with an average rate of 0.15 km^2 $year^{-1}$ and to 11.85 km^2 (in 2012) with an average rate of -0.22 km^2 $year^{-1}$.

4.4. THE SPATIAL PATTERNS OF URBAN EXPANSION

In order to analyse the patterns and locations of urban land change, an image of urban and built-up land was extracted from each LULC map (Fig. 5 (a)–(c)). From this urban expansion images, it can be concluded that the urban region is largely broadened. The growth of the Duhok city has not taken place evenly in all directions but has occurred much faster in certain directions. The surrounded mountains represent a natural constraint for expansion of the city in the northward and southward direction. The city has tremendously expanded in the northwest and southeast directions (Fig. 5). In order to analyse the speed of the urban growth of the Duhok city, we divided the study time into two stages. In the first (1989-2001), the speed and the expansion of the urban area was relatively slow. The expansion was to the southeast direction of the Duhok city. However, in the second stage (2001-2012), as a result of the improvement of the infrastructures in Duhok city, the urbanization was developed. Moreover, after 2004 Duhok became a more peaceful and secure area compared to other parts of Iraq, led to the migration of many people from all over Iraq to Kurdistan region especially to Dohuk city. Consequently, this resulted in the development of the urbanization processes particularly in the northwest direction.

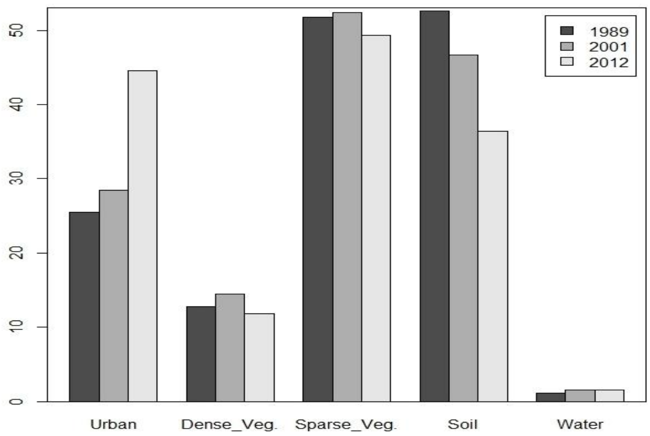

Fig. 6: The land use areas of the 5 classes derived from the classified maps.
Note that each hatching represents a class in the studied 3 years (1989, 2001 and 2012)

V. CONCLUSIONS AND RECOMMENDATIONS

This study is considered to be an attempt to detect and evaluate urban land use change in the Duhok city by applying remote sensing and GIS techniques. The results of the change detection techniques showed that the Duhok city has changed significantly. The urban area has increased more than 19 km^2 from 1989 to 2012. This study emphasized that spatial information (i.e. GIS) and remotely sensed data are particularly helpful in providing time-series information on urban landscape evaluation and this, in turn, provide interesting supports for decision-making for future planning and monitoring plans. Moreover, this study offers some recommendations to be used as guidelines in the future planning for the urban expansion of Duhok city as follows.

- Detail field work needed to get LULC map more accuracy.
- Short-term and long-term planning are needed because they play an important role in guiding appropriate development to the right place and in preventing development which is not acceptable.
- Monitoring programmes for the urban area and shoreline changes must be adopted by the relevant authorities.
- Careful planning for expansion over the faulted blocks and serious assessment of the earthquake activities should be made.
- Preventing expansion along landfill area, degraded soil areas or any areas that unstable geologically, this should be done according to environmental laws and regulations.

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