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Factors Affecting the Eco-Environment Identification Through Change Detection Analysis by Using Remote Sensing and GIS: A Case Study of Tikrit, Iraq

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Abstract Changes in eco-environment that are caused by climate changes and human exploitation have been a significant problem around the whole world for a long time. The eco-environment of Iraq is exposed to degradation, particularly in the middle and southern parts. By using an approach that combines remote sensing and GIS, this study examines the changes that have occurred during various periods between 1972 and 2010 in the Tikrit district in Iraq and identifies the factors responsible for the degradation. A significant change was observed in the area covered by vegetation and water, especially between 1990 and 2010, which exacerbated desertification as the vegetation and water area decreased by 16 and 59.6 %, respectively. Also, the urban area increased with varying paces of growth. In the period 1990–2000, the urban area increased by 8.8 % only, which is not surprising considering the population increase. However, between 2000 and 2010, the urban area increased dramatically by 47.5 %, due to the war which led to migration from Baghdad (Iraq Capital) to Tikrit. This study proves that climate change, desertification, and immigration due to wars were the major roles in changing the environment. Also, it reveals that geospatial techniques can be successfully used to monitor the effects on the land cover/ use changes and, hence, on the eco-environment.

Keywords Change detection · Remote sensing · GIS · Factors

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الخلاصة

تمثل التغيرات في البيئة الطبيعية التي تنتج عن التغيرات المناخية واستغلال البشر مشكلة كبيرة في جميع أنحاء العالم كله لفترة طويلة. وتتعرض البيئة الطبيعية في العراق إلى تدهور، ولا سيما في الأجزاء الوسطى والجنوبية. وباستخدام النهج الذي يجمع بين الاستشعار عن بعد ونظم المعلومات الجغرافية، فإن هذه الدراسة تفحص التغييرات التي حدثت خلال فترات مختلفة بين أعوام 1972-2010م في منطقة تكريت في العراق من أجل التعرف على العوامل المسؤولة عن التدهور. وقد لوحظ وجود تغير كبير في المنطقة التي يغطيها الغطاء النباتي والمياه، وبخاصة بين عامي 1990 و 2010م، الذي تفاقم التصحر حينها ، حيث نقص الغطاء النباتي ومساحة المياه بنسبة 16٪ و 59.6٪، على التوالي. وأيضا ازدادت المساحة الحضرية مع خطوات نمو متفاوتة. وفي الفترة من 1990 إلى عام 2000م زادت المساحة الحضرية بنسبة 8.8٪ فقط، وهو أمر ليس بمستغرب بالنظر إلى الزيادة السكانية. ومع ذلك، بين عامي 2000 و 2010م زادت المساحة الحضرية بشكل كبير بنسبة 47.5٪، وذلك بسبب الحرب التي أدت إلى الهجرة من بغداد (عاصمة العراق) الى تكريت. وتثبت هذه الدراسة أن تغير المناخ، والتصحر، والهجرة بسبب الحروب كانت أدوارا رئيسية في تغيير البيئة. أيضا، فإنها تكشف أن التقنيات الجيومكانية يمكن أن تستخدم بنجاح لرصد الآثار على الغطاء الأرضي / تغيرات الاستخدام، وبالتالي على البيئة الطبيعية.

1 Introduction

The changes in eco-environment that are caused by changes in regional climate and human exploitation have long been an important global concern, especially in arid and semiarid areas because of the ecosystems' susceptibility [1]. In addition, deforestation, agriculture, urban centers and expanding farmland are some of the many ways man has contributed to changing the landscape of the world [2].

Change detection is the process of identifying changes that take place in a time series (i.e., through time). The analysis of change detection is implemented by using multi-date imageries. Each of the single date images represents the land covers and land uses of a certain point of time while the difference in the land cover and land use in a place at a certain period of time is identified by multi-date imagery. According to Jensen [3], mapping of land use (residential, utilities, commercial, transportation, and cadastral) and land cover (urban, agriculture, and forest etc.) has been improved during the last years due to the use of multi-date imagery as these images are used to detect gradual changes in the environment such as deforestation or erosion when two or more images are required to implement this procedure. In addition, multi-temporal and accurate detection of the changes occurring on the earth's surface features gives a practical picture of the relationship between humans and the environment, which serves to improve the management of environmental resources [4].

Iraq, especially the middle and southern regions, is similarly exposed to the problem of degradation in the eco-environment. The area that is susceptible to the degradation is estimated to be one million hectares [1]. Several causes of degradation of the land and changes in the covers were identified [5], such as misuse of the cover of the plant, overgrazing, and sand dunes. Dougrameji [6] added to the causes the use of unsustainable practices continuously, deterioration of the infrastructure through wars and poor maintenance which was worsened by the sanctions between 1990 and 2003. In fact, since 1980, Iraq has been involved in many wars, starting with the Iraq-Iran war and ending with the American invasion. In this period, especially after 2003, the demography of Iraq has changed dramatically. Not surprisingly, therefore, the growth in urban areas has been severely compromised.

GIS and remote sensing are excellent tools to monitor and analyze the identification of land use and land cover changes [7,8]. By remote sensing, images at different points of time can be acquired to produce images of at least two points of time (t1, t2. . ..) in order to be compared to obtain the changes between these times. Also, geographic information system (GIS) can be used to produce ancillary information or even used to prepare surrogate data, and it can be used for comparing thematic maps which are derived from images to identify the changes.

Globally, in the last three centuries, about 6.8 million km^2 of land in the form of grasslands, forests, and woodlands have transformed with respect to their land uses [9]. These changes have significant effects on many aspects of life such as the resources of the earth, the climate, the weather, the agriculture and so on. In the same manner, the world is witnessing a fast expansion in urban areas and urban population and it is expected that by 2030, 60 % of the world's people will be living in urban areas. Developing countries are expected to see the greatest share of urban expansion [10].

Locally, since 1980, due to the wars that Iraq has been involved in, the climate change (i.e., significant increase in the temperature, great decrease in the precipitation, and clear increase in the number of dust storms), and the decrease in the level of the river that passes through the study area, land use and land cover in Iraq have been changed significantly without being monitored. Due to the same reasons, there is a phenomenon called desertification which is the degradation of the land till it becomes dry. Hence, the study and the understanding of these changes would be very beneficial for many reasons, such as planning of the cities in Iraq, controlling the sprawl that has happened because of the absence of security, identifying the human impacts and managing the resources.

This study aims to identify the influential factors on the environment by studying land use and land cover change dynamics in the last four decades and comparing the changes between different periods. Also, this study examines the use of GIS and Remote Sensing in land use/cover monitoring.

2 Study Area

The methodology of integration between GIS and remote sensing was applied in Tikrit city which is located in Salahaldin province in Iraq. Its center is 155 km from Baghdad that is the capital of Iraq. Its population is 172,119 in 2007 [19]. The reason of choosing this area is the big number of environmental effects that happened on it due to the wars, particularly that of 2003 invasion, that led also to a large number of migrants to it from Baghdad and other provinces. Also, it was chosen because of its importance, as it is the administrative and economical center of the Salahaldin province. The study area extends between 43°07′37.69″ and 44°6′15.02″ east and approximately between 34°26′20.41″ and 35°4′1.96″ north. Its area is about 2,554.8 km^2. See Fig. 1.

3 Data and Methods

In this study, three types of software were used:

1. ArcGIS- was used for Georeferencing one image, creating slope constraint and providing the administrative shape file.
2. ENVI- was used for pre-processing, processing (classification) and change detection analysis.
3. IDRISI Taiga- was used for presenting change detection graphs and for modeling land use and land cover.

This study has followed the steps as shown in Fig. 2 to identify eco-environment through change detection.

The data used in this study could be classified into; satellite data and ancillary data.

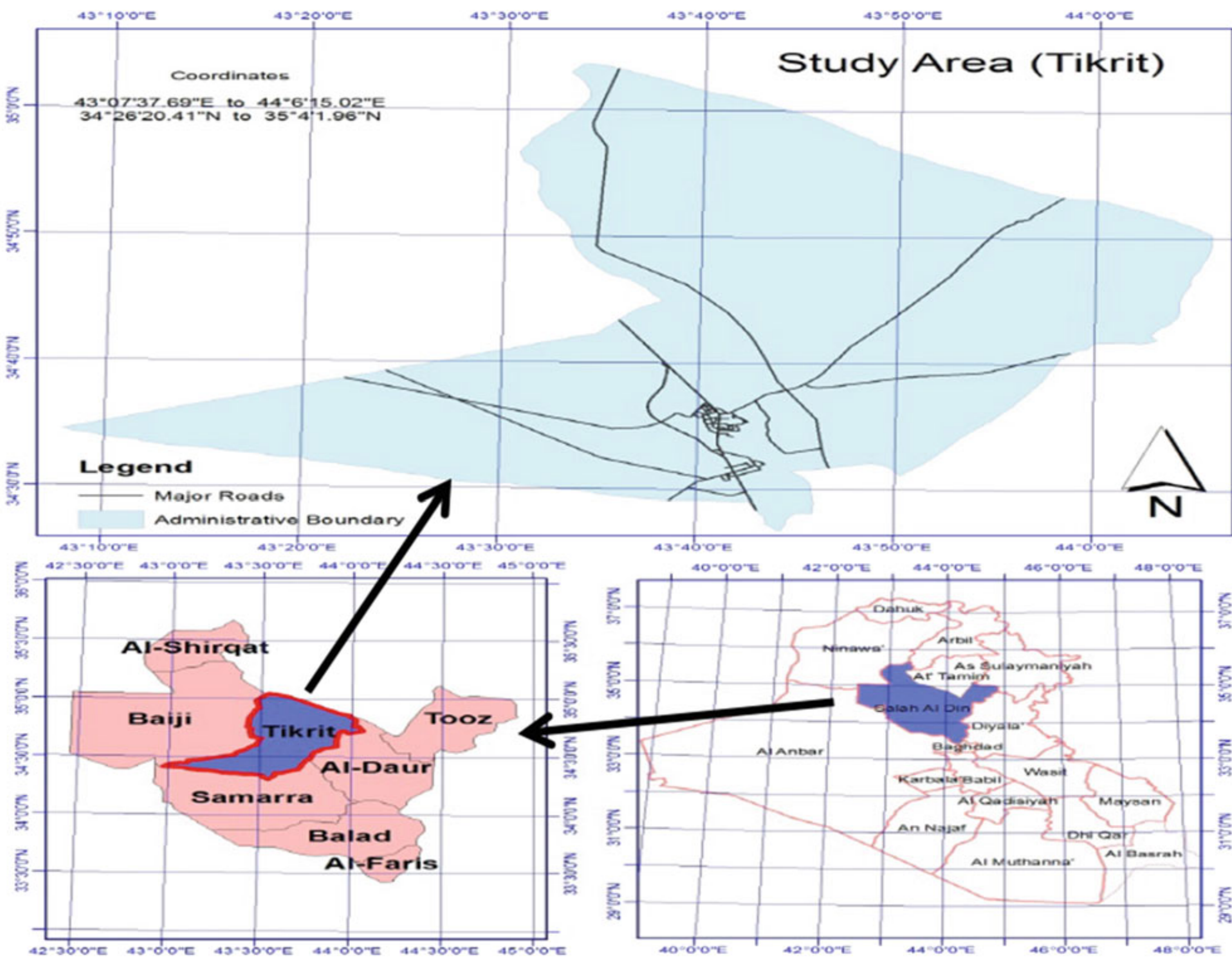

Fig. 1 The area of study

Fig. 2 Method scheme of this study

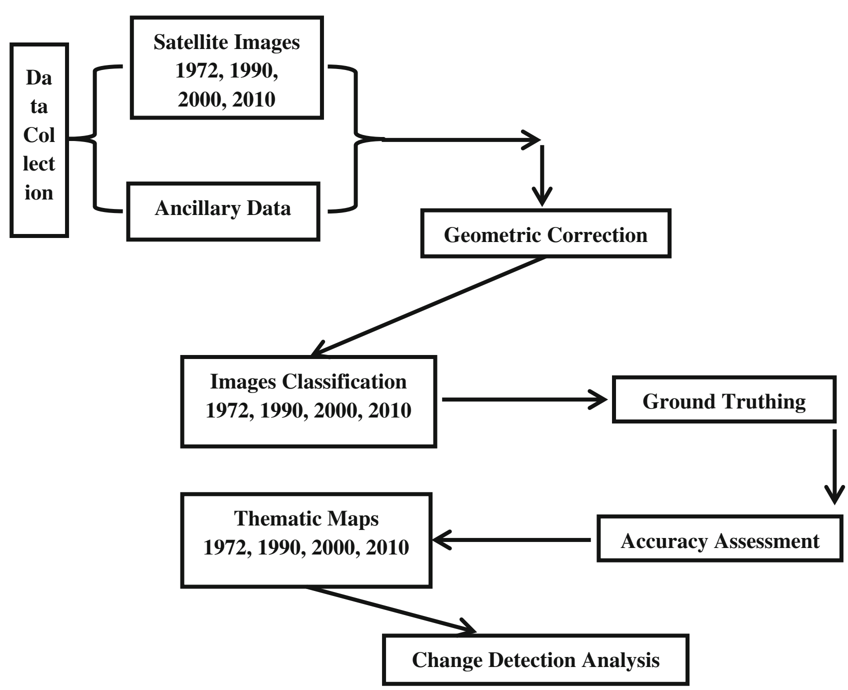

Table 1 Summary of data used for the study

No.	Data type	Acquisition date	Resolution	Source
1	LandSat MSS	21/11/1972	80 m	USGS
2	LandSat TM	23/05/1990	30 m	USGS
3	LandSatETM+	22/08/2000	30 m	USGS
4	LandSat ETM+	01/07/2010	30 m	USGS
5	LandSat ETM+	17/07/2010	30 m	USGS
Ancillary data				
6	ASTER global digital elevation model V002 (DEM)	2011-03-16	30 m	NASA
7	Quick bird image	2008	0.6 m	SAD Province
8	Administrative and local government map	2011	Vector	SAD Province
9	GIS map for Iraq (UN)	2003	Vector	SAD Province
10	Topographic map in Russian	1972	1:200,000	Texas University

3.1 Satellite Data

The data studied included satellite images for four decades: 1970, 1980, 1990 and 2000s. For 1970s, Landsat MSS image was acquired dated 21/11/1972. The Landsat Multi spectral sensor (MSS) is the first generation of Landsat. It had a spatial resolution 79 × 79 m and four spectral bands. A Landsat TM image was obtained for the 1980s dated 23/05/1990. The thematic mapper (TM) is the second generation of Landsat which is a more advanced sensor with spatial resolution 30 × 30 m and seven spectral bands [11]. For the 1990s, A Landsat ETM+ image also was obtained that was acquired on 22/08/2000. Landsat ETM+ images have 30 × 30 m spatial resolution and eight spectral bands. Finally, for 2000s, two Landsat ETM+ images were used, the first one was acquired on 01/07/2010 and the second image acquired on 17/07/2010, because the ETM+ sensor failed to collect data after 2003 due to detector problems USGS [13]. Finally, the availability of 1970s images, the high temporal resolution, the acceptable spatial and spectral resolution and the freely availability of Landsat images were the reasons of choosing these images in this study.

Landsat images were used in this study due to some reasons: it is available for the 1970s which cannot be found in another satellite, the high temporal resolution which helps in finding images in almost whatever time needed, and the high spatial and spectral resolution of its images specially for the last two decades.

3.2 Ancillary Data

In this study, large number of supplementary data was collected to support the processing of the images. Digital elevation model (DEM) data derived from ASTER images were obtained from NASA. Moreover, Quick Bird images for the whole area of study, and GIS maps (i.e., administrative, local government, rivers, and roads maps) for the whole of Iraq were obtained from the GIS center in Salahaldin province. Finally, a topographic map in Russian language with a scale of 1:200,000 was downloaded from the Texas University website. The whole data obtained have WGS84 datum and UTM projection. This data is summarized in Table 1.

Several pre-processing steps should be implemented on the images before being processed: geometric correction, radiometric correction, atmospheric correction and so on. In this study, there is no need of radiometric correction because the method of change detection applied is a post-classification comparison as the images are classified individually and then compared to detect the change [5]. The obtained images for the four epochs were with L1T level of production, which means they were geometrically corrected based on USGS [12]. Also, the Quick Bird image which is used in accuracy assessment was previously geometrically corrected by the GIS centre in Sallah Aldeen province where the image was obtained.

As mentioned earlier, the images that acquired after 2003, only 2010 images in this study, have some gaps due to the detector failure. Therefore, a method developed by USGS [13] based on using ENVI or Erdas software to fill the gaps by matching two scenes was used. ENVI software method was used by putting the two scenes (band by band) of the Landsat ETM+ 2010 images, and because the images cover the same area, they have same projection and datum, and the gaps are different location in the two scenes, mosaicking was used to give a gap-filled image. The next step was to subset the four period images to match them with the study area. A shape file (ArcGIS vector file) that contains the administrative boundary of Tikrit was converted to ENVI vector file and then was used to subset the area (AOI) from the whole scene. So, the output images of 1972, 1990, 2000 and 2010 are only of the Tikrit district.

Pan sharpening algorithm [14] was applied to enhance the resolution of ETM+ images (2000 and 2010 images) from 30 × 30 m to 15 × 15 m. After pan sharpening, 2000 and

Table 2 Summary of areas and their percent of the classification for (1972, 1990, 2000 and 2010) images

Year	1972		1990		2000		2010	
Class	Area (km^2)	Percent (%)	Area (km^2)	Percent (%)	Area (km^2)	Percent (%)	Area (km^2)	Percent (%)
Water	26.355	1.03	23.222	0.91	12.870	0.50	14.543	0.57
Vegetation	106.478	4.17	172.566	6.75	213.242	8.35	148.661	5.82
Barren land	517.104	20.24	308.712	12.08	334.289	13.09	296.795	11.62
Soil	1,859.560	72.79	1,977.39	77.40	1,915.093	74.96	1,977.878	77.42
Urban	45.198	1.77	72.806	2.85	79.201	3.10	116.818	4.57

2010 images were in 15 × 15 m resolution, while 1972 image is 79 × 79 m and 1990 image is 30 × 30 m, therefore, to ensure the consistency in the pixel size during the comparison process, 1972 and 1990 images were resampled to 15 × 15 m, knowing that there would not be any increase in the information content obtained from these images [3].

Finally, 1972, 1990, 2000 and 2010 datasets were ready for starting the analysis and image processing as the preprocessing procedures were completed.

The scheme of the classification is important as it is used to organize and categorize classes or clusters which can be extracted from satellite digital image [15]. Moreover, there are a large number of sources of information about land use and land cover. This information is used by many agencies who classify the data based on their specific goals. Due to the differences in classification, the data cannot be shared and aggregated and thus ends up being duplicated repeatedly. For this reason, a proper standardized classification system should be used to unify, organize the data and prevent the duplication [16]. In this study, several classes were adopted from Anderson et al. [16] with some modification: Water which represents water bodies represented by Tigris River, Vegetation which represents any green area, Barren land that is the area that cannot be green such as Bare exposed Rock, Soil is the area that could be green, and finally urban area that represents any human built object.

Supervised classification relies on prior knowledge (which can be achieved by aerial photographs, field work, or other sources of ancillary data) that is used to define training samples that help a computer to classify the image [17]. Despite the presence of many other algorithms, Maximum Likelihood was chosen due to its wide usage [18]. The assessment of this study was done using the ancillary data and the knowledge of old residents of the area. The test points (points used in accuracy assessment) were obtained as follows: for 1972, a topographic map in the Russian language; for 1990, visual interpretation and knowledge of the area; for 2000, a GIS map created by UN; for 2010, a Quick Bird image obtained in 2008.

Post-classification Comparison method of change detection was used in this study. This method compares the two classified images (Thematic maps) pixel by pixel and marks the changes. It was implemented using two types of software: ENVI and IDRISI. The change detection matrix was extracted which shows the behavior of the change; how each class has changed to another class and what the amount, or percentage of this change is during a given period.

4 Results and Discussion

The results obtained from the aforementioned methodology are described period by period starting from 1972 and ending with 2010 to display the result in their historical order. Also, Table 2 contains the percentage and area of all the classes through the entire study area.

First, the percentages and a thematic map of land cover types in 1972 are shown in Fig. 3. From the figure and from Table 2, it can be seen that barren land had an area of 517.104 km^2 which represented 20.24 % of the study area. The Barren Land was distributed like a network of roads which were not paved at that time. Also due to the rural nature, the urban class had a small area of 45.198 km^2 with a percentage of 1.77 %. The same figure shows that the urban class was scattered in the whole area and there was no clear city, nor a big group of clustered houses to indicate a city. The last class was vegetation as 106.478 km^2 with a percentage of 4.17 %. Vegetation was clustered around the Tigris River only due to the existence of the water.

In 1990, based on Table 2, the soil class was still dominant with a 1977.388 km^2 area that represented 77.40 % of the entire area. The water class was still the class with the least area 23.222 km^2 with a percentage of 0.91 %. The vegetation area was 172.566 km^2 which represents 6.75 %. Barren Land represented a 308.712 km^2 area which was 12.08 % of the total land use and land cover area. From Fig. 4, it is obvious that the urban class had a big change in terms of clustering in one area to represent a city in the time of 1990. The area of urban class was 72.806 km^2 with a percentage of 2.85 % from the total LULC area.

In 2000, based on Fig. 5 and Table 2, the most prominent observation is that the urban area is almost similar between

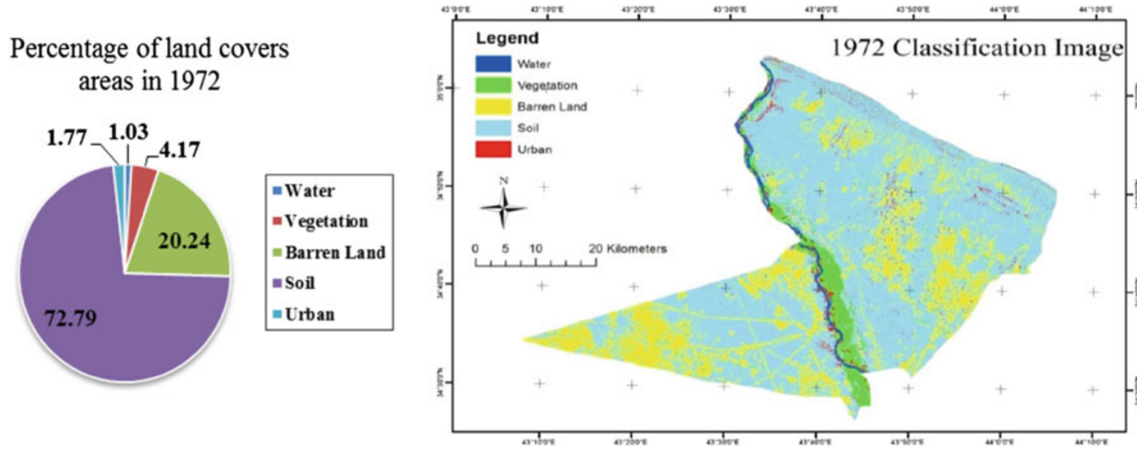

Fig. 3 Classified map and percentage of land cover types in 1972

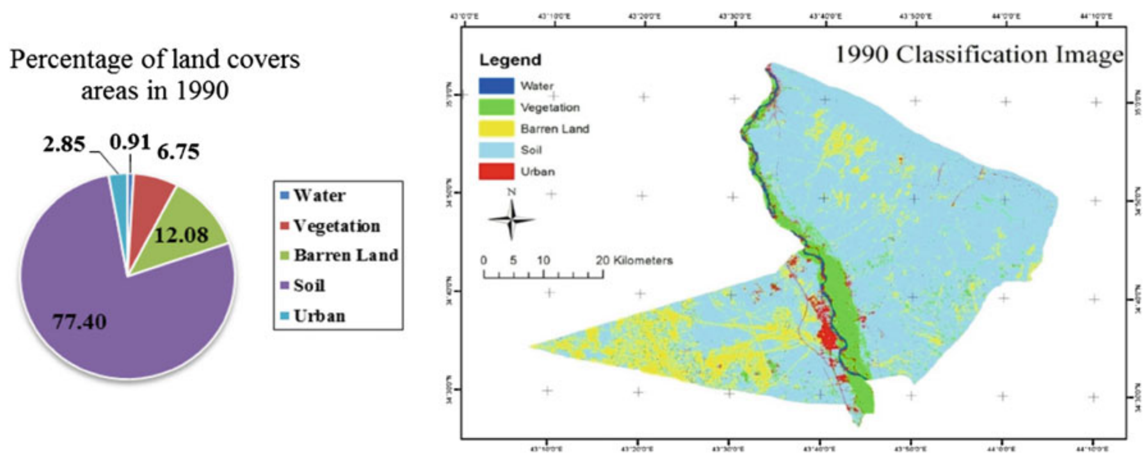

Fig. 4 Classified map and percentage of land cover types in 1990

1990 and 2000 in terms of the distribution because of the control of the government on the expansion of the city using the base map. The total area of the urban class in 2000 was 79.201 km^2 with a percentage of 3.10 % from the total study area. This area was still growing in the shore lines of the Tigris River due to its closeness to the source of the water. In addition, the water represented 0.5 % of the total area with an area of 12.870 km^2 which is small compared to the entire study area. In fact, even the soil area, which is not used for anything, is a much larger 1915.093 km^2 which is 74.96 % of the total area. Vegetation represented 8.35 % with an area of 213.242 km^2. Finally, the barren land was 13.09 % of the study area with an area of 334.289 km^2.

For the final classified map shown in Fig. 6, there is a significant increase in the urban area in comparison with the previous epochs, which based on Table 2 was 116.818 km^2 with a percentage of 4.57 %. The smallest class is water which had an area of 14.543 km^2 which was 0.57 % of the whole study area. The figures were largest for the soil area with a percentage of 77.42 % and area of 1977.878 km^2. The barren land was an influential class on the environment with an area of 296.795 km^2 and a percentage of 11.62 %. Finally, the vegetation covered 148.661 km^2 which was 5.82 %.

By examining Table 2, which summarizes the statistics of the land cover in the study area, it is obvious that the soil class was dominant throughout the four decades. For example, in the year 1972, the soil class was 1859.56 km^2, which was 72.79 % of the entire area. This is far greater than the other classes. Water was only 1.03 % of the entire study area with an area of 26.355 km^2, which on the earth represents only the Tigris River that passes through the middle of Tikrit.

To examine the four epochs' areas in one figure, Fig. 7 can be seen. It is evident that water land cover in Tikrit is the smallest area for the period 1972–2010 and it increases and decreases through this period, much like barren land cover does. On the other hand, soil is the largest land cover in Tikrit through the period examined in this study and it also increases and decreases without a consistent trend. The urban land cover shows an increasing trend, with an area that is

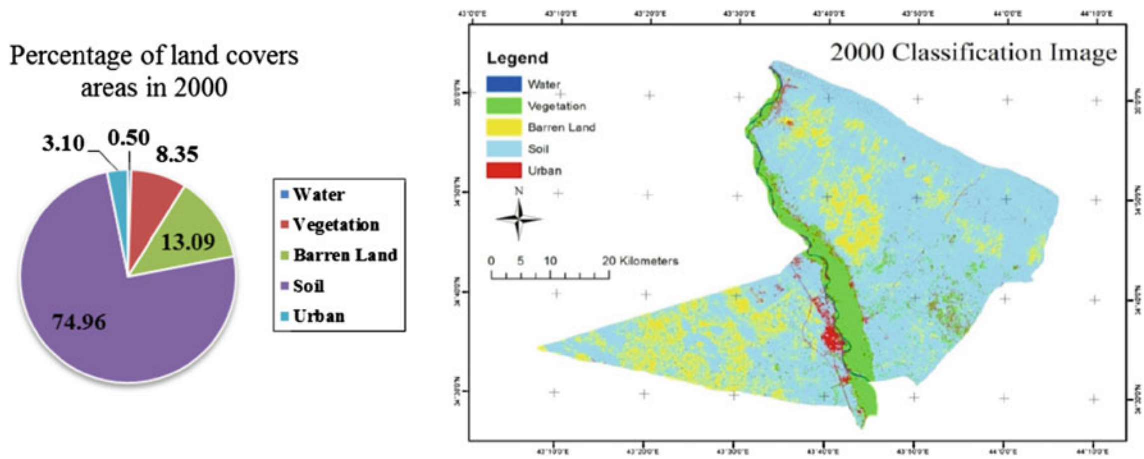

Fig. 5 Classified map and percentage of land cover types in 2000

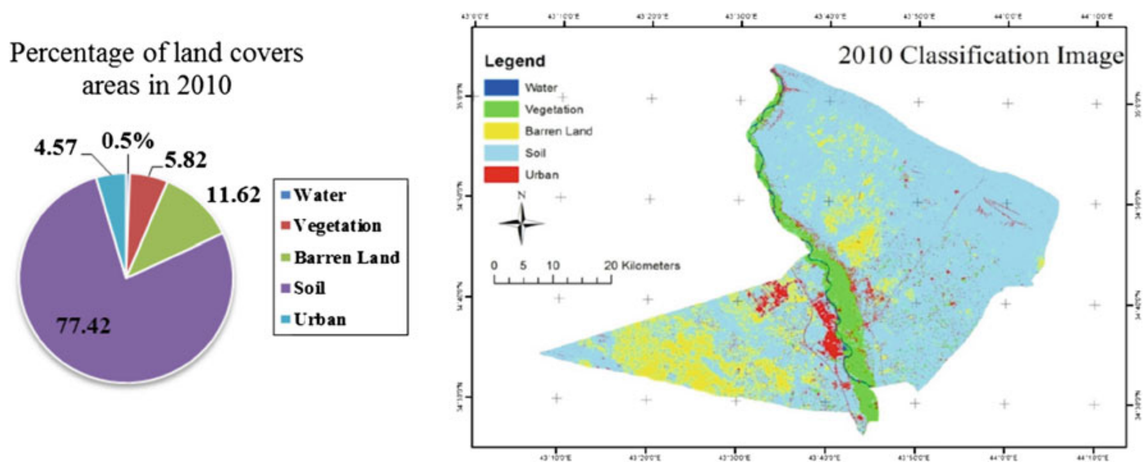

Fig. 6 Classified map and percentage of land cover types in 2010

smallest in 1972 and keeps growing till 2010. Vegetation has no consistent trend, but increases and then decreases. These increases and decreases can be identified significantly using change detection quantitative comparison which is discussed in the next section.

5 Short-Term Change Detection Analysis

To compare the change between any two periods, the change detection matrix can be used as it is one of the advantages of using the post-classification comparison method. Table 3 shows the most interesting result in the period of 1972–1990 to be the urban area, which was small compared to other land covers at only 13.87 %, due to the low accuracy (28.18 %) of the classification. The change percentage from water to urban area is 15.24 % because of the distribution of the urban area in the boundaries of a close water source (Tigris River). This is considered as the first factor affect the environment that is the changing of water and its surrounded area to a human

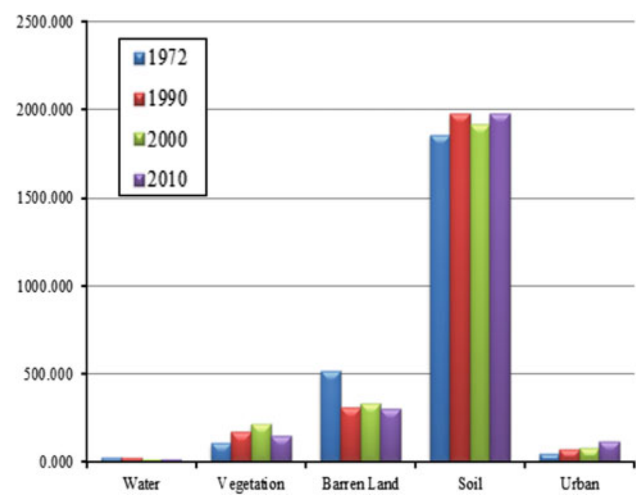

Fig. 7 Areas of the five lands cover types in the four epochs (Km^2)

used area such as urban. Also, it is worth mentioning that the percentage of vegetation converted to soil was 15 %, which is a large value considering the effect on the environment due

Table 3 Matrix of the change percentage between 1972 and 1990

	1972				
1990	Water	Vegetation	Barren land	Soil	Urban
Water	66.95	1.59	0.00	0.11	4.22
Vegetation	17.42	77.07	1.75	3.51	25.77
Barren land	0.03	0.29	28.85	8.51	2.14
Soil	0.32	15.00	66.53	85.65	53.98
Urban	15.24	6.05	2.87	2.22	13.87

Table 4 Matrix of the change percentage between 1990 and 2000

	1990				
2000	Water	Vegetation	Barren land	Soil	Urban
Water	49.46	0.33	0.00	0.00	1.08
Vegetation	30.46	77.02	0.51	2.75	23.55
Barren land	0.00	1.08	35.90	11.10	2.83
Soil	1.32	16.20	62.95	84.26	35.12
Urban	18.58	5.29	0.61	1.85	37.36

Table 5 Matrix of the change percentage between 2000 and 2010

	2000				
2010	Water	Vegetation	Barren land	Soil	Urban
Water	91.40	0.40	0.00	0.01	2.25
Vegetation	3.39	59.17	0.13	0.76	8.92
Barren land	0.00	0.95	36.13	9.03	1.35
Soil	0.18	30.98	62.23	86.92	49.34
Urban	5.03	8.50	1.50	3.28	38.13

to the LULC transforming from green to yellow by desertification. Another important change is the 66.53 % conversion from barren land to soil, which is attributable to the construction of new roads and the implementation of the base maps which decreased the unpaved and uncontrolled expansions.

Table 4 provides the change percentage information for the period of 1990–2000. It is seen that the water land cover changed by 18.58 % to urban area, which formed at the boundaries of the water bodies represented by the Tigris River and this largely affects the environment as mentioned above. Also, the urban area changed to Soil by 35.12 % and to Vegetation by 23.55 %. These changes can be attributed to the government deconstruction of the old city and the building of a new city in a planned place in addition to several places being built that extended the old city to newer regions.

Based on Table 5, which shows the change for the period between 2000 and 2010, 5.03 % conversion of water to urban area is observed, attributable to the aforementioned reason of urban areas growing close to water sources. Also, 30.98 % of the vegetation area is converted to soil land cover due to the spread of desertification phenomena around the region, while 8.50 % turned into urban area. The latter conversions of vegetation to soil and urban area were the most contributable factor in the degradation of the environment as it decreases the green area and increases the yellow area.

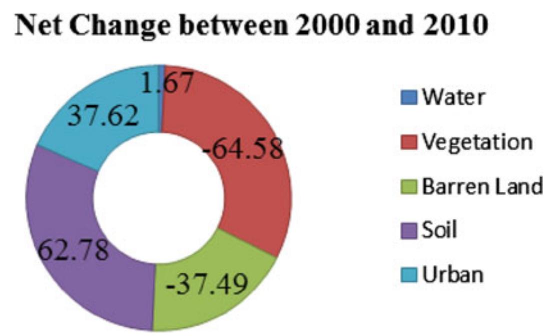

Fig. 8 Net changes on the area of land cover/use types in 2000–2010 (km^2)

Table 6 Losses and gains of the land cover/use types between 1990 and 2010 measured by km^2

	Loss	Gain	Net change
Water	−11.08	2.4	−8.68
Vegetation	−66.45	42.55	−23.9
Barren land	−201.23	189.32	−11.91
Soil	−265.88	266.37	0.49
Urban	−43.16	87.17	44.01

From Fig. 8, it is easy to visually examine the changes that took place in the period of 2000–2010. The water land cover shows a small net change during this period, while the vegetation underwent the largest change. Also, the barren land decreased by a value close to 40 km^2, while the soil land cover increased with a significant value of more than 60 km^2.

6 Long-Term Change Detection Analysis

In this section, a period of 20 years is studied, from 1990 to 2010, to understand the trend of long-term change. The 1972 classified image was neglected for the long-term change analysis because of its low accuracy.

Land cover changes from 1990 to 2010 are shown in Table 6. From that table, it can be identified that the vegetation land cover area decreased by 23.9 km^2 in the long period, which indicates possible desertification and hence large effect on the environment. Also, the decrease of 8.68 km^2 in the area of the water bodies that are represented by the Tigris River is another supportive factor of this phenomenon. In addition, the urban area increased by 44.01 km^2 which is understandable with the increase in the population of Tikrit.

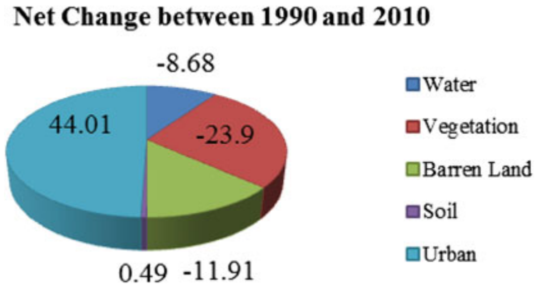

Fig. 9 Net changes on the area of land cover/use types in 1990–2010 (km^2)

From Fig. 9, a significant change is seen in the urban area which can be attributed to the dramatic increase in the population, especially after the 2003 US invasion of Iraq. While an urban growth has been observed for all periods studied, the pace of growth has varied. Also, the period 1990–2000 shows the movement of families from Tikrit to Baghdad to work in government security agencies, a trend which was reversed after the invasion, due to which people lost their jobs and returned to Tikrit. Moreover, Vegetation decreased by a significant value in the long-term period which can be regarded as a huge contributor to environmental degradation. With the exception of 1990 till 2000, the vegetation decreased noticeably in all periods studied because of the low precipitation in Iraq as a whole, besides Tikrit in particular. The decrease in water land cover can also be considered a major contributor to environmental degradation in Tikrit.

7 Urban Growth and Population

The urban area increases in the four epochs that have been studied. From Fig. 10, it can be seen that the biggest contributor to adding to urban land cover is soil in all periods except 1972–1990, in which the contribution from barren land was the highest. In 1990–2000, vegetation had a negative contribution to urban land cover, with the former converting to the latter. Similarly, from 2000 to 2010, urban area turned to water, although the value is small and compensated by a much larger contribution of soil to urban growth.

To compare the population growth with the urban area of the four periods of time, the populations of the years of the classified images need to be known (i.e., of 1972, 1990, 2000 and 2010) because the national censuses were implemented in the years 1967, 1977, 1987 and 1997. There was no census after 1997, until 2007 when the population was calculated by the Ministry of Planning. To calculate the target year population from the rate of growth, Eqs. (3.1) and (3.2) can be used.

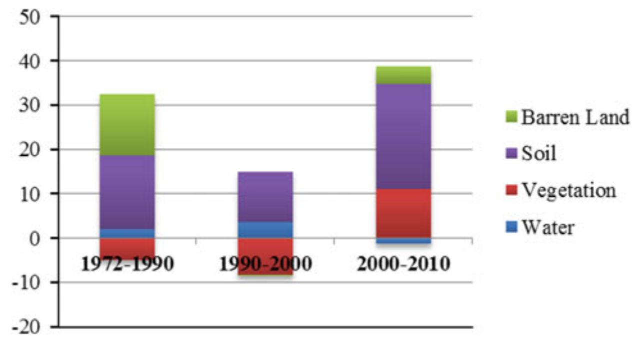

Fig. 10 The values of contribution by land covers in the net changes in urban area in 1972–2010

$$n = r/100 * Po \quad (3.1)$$

$$Pn = Po + (n * t) \quad (3.2)$$

where:

Pn = Estimated population,
Po = Base year population,
n = Annual population growth,
t = Number of years from the base year to the target year,
r = Growth rate, which was calculated by subtracting the population in the year after the target year from the population of the year before the target year, then dividing by the population of the past year and multiplying by 100, to be finally divided by the number of years between the past and the future population.

$$r = ((V\,future - V\,past)/V\,past * 100)/N \quad (3.3)$$

N = Number of years between the future and past population.

The growth rate is first calculated from the Eq. (3.3). Next, the result is substituted with the population of the base year in Eq. (3.1) to obtain the annual population growth. This is finally substituted with the base year population and the number of years between the base and the projected years to obtain the estimated population. The results are shown in Table 7.

By comparing (a) and (b) from Fig. 11, it is clear that the trend of the change in the population and of the urban

Table 7 Population of the years same as classified image years

Year	Population
1972	45,622
1990	90,356.6
2000	141,954.7
2010	209,645.2

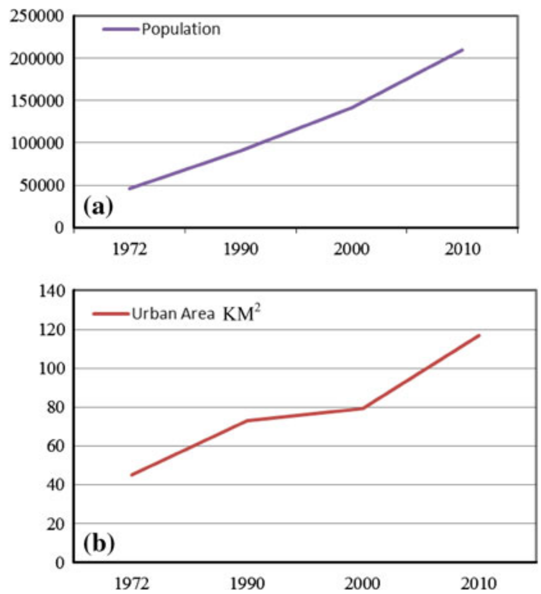

Fig. 11 **a** Tikrit population change through 1972–2010. **b** Change of urban area through the time in km^2 (1972–2010)

area is similar. In other words, the urban area has been growing with the population. There is a small difference though between the two figures: the population trend maintains its slope, while the slope of urban growth in the period 1990–2000 decreases, which means the growth rate decreases. This slight difference is due to the fact that people in that period who were working in Baghdad (and living with their families) were still being accounted as belonging to Tikrit.

8 Conclusion

The study shows that considerable LULC changes have occurred in the study area which largely affects the eco-environment through the last four decades, particularly in the last 20 years, the most obvious aspects of which have been the spatial–temporal decrease in the water areas which heavily affect vegetation, soil properties, surface characteristics, and water resources that are developed by humankind such as irrigation, dam construction, and channeling. In the contrast, there has been an increase in the urban area that leads to decrease green land and marshlands, in addition to increasing desertification phenomenon in the study area.

One of the findings of this research is that the 2003 US invasion of Iraq has affected the demography of the whole country, especially Tikrit. Important conclusions are derived by examining the urban area growth trend, which was small in the period 1990–2000, but increased significantly in the period 2000–2010. In the former period, urban growth in Tikrit was slow with most people working in the capital Baghdad in government security agencies as the urban percentage was 2.85 % in 1990 while in 2000 was 3.10 %. In the latter period, the 2003 war forced people out of their jobs and back to Tikrit, which fed urban area growth significantly as the percentage of urban area in 2000 mentioned earlier increased in higher trend to be 4.57 %. As for vegetation, it decreased dramatically in the last decade as in 2000 its percentage was 8.35 % of the total area while in 2010 it came down to 5.82 % because of the reduction in the amount of rainfall and in the quantity of water bodies in Tikrit. This reduction in the area of vegetation should be controlled to prevent the degradation of the eco-environment. Moreover, the water bodies represented by Tigris River, in general, decreased during the study period as its percentage was 1.03 % in 1972 while it was 0.57 % in 2010, mostly as a result of dams built on the riverbed in the part of Tigris that belongs to Turkey. Regardless of the cause, the decrease contributes greatly to the phenomenon of desertification, directly or indirectly, by reducing the amount of vegetated areas.

Finally, using different remote sensing datasets, satellite imageries, GIS vector maps, and hard copy maps, it is demonstrated that GIS and remote sensing are excellent ways of identifying the changes that take place in land cover and land use because of their ability to provide data for different times with an accuracy that facilitates decision making. Also, these tools are instrumental in modeling future land cover/use.

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