Assessing land cover/use changes in Karbala city (Iraq) using GIS techniques and remote sensing data

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Abstract. In this research, land cover changes between 2000 to 2017 were studied in Karbala city (Iraq) using geographic information system techniques and remote sensing data. Satellite imagery data -Landsat7 (2000) and Landsat 8 (2017) - were processed using the supervised maximum likelihood algorithm, and the post-classification comparison method in QGIS 2.14. Four land cover categories, namely, built-up, vegetation, water, and soil have been specified to produce land cover maps for each acquisition date. The overall accuracies were 99.99% (2000), and 99.98% (2017) with Kappa statistics of 0.99, and 0.99. The evaluation of land cover changes shows that built-up, vegetation and soil have been increased by 1.9% (93.5 km²), 0.4% (20.8 km²) and 4.4% (221.3 km²) while water land has a shrink by 6.7% (335.6 km²) respectively. These changes conclude a serious threat to water land which it affects on population growth, human activities and agricultural activities in the study area.

Keywords: Remote sensing, Karbala, Maximum Likelihood, Post-classification ,Land use, Land cover, GIS.

1. Introduction

Effective analysis and monitoring of land cover/use changes are necessary for environmental sustainability. Several factors have triggered rapid unplanned and uncontrolled changes to earth’s land cover over the last two decades such as population growth, urban expansion, cropland loss, climate variability, and etc. These changes have resulted in deforestation, degradation, biodiversity loss, mismanagement of agricultural, natural disasters, and increase global warming[1],[2]. In the recent years, there has been an increasing interest in studying the land cover status at regional and global scales, as well as the assessment of land cover changes is fundamental for a sustainable management of natural resources [3,2,4,5,6,7].

Land cover/use change detection is necessary for better understanding variations in the nature of a phenomenon by studying it during a known period of time. Land cover/use change is a common process, essentially induced by anthropogenic activities and natural phenomena, which in turn make changes that would affect natural ecosystem [8]. The study of land cover change detection is a major subject in remote sensing applications because of its adverse effect on the ecology of the area and vegetation. So, good planning and management of land cover change play a significant role in climate change mitigation, moderation of extreme events and land degradation [9]. Understanding landscape patterns, changes, and interactions between natural phenomenon and human activities are necessary for good land management and decision improvement. Currently, earth resource satellites data are very useful and applicable for land cover/use change detection studies [6].
Change analysis of features of earth’s surface is necessary for better understanding of relationships and interactions between natural phenomena and human activities. This understanding is necessary for improved resource management and improved decision making. Change detection involves applying multi-temporal remote sensing information to analyze the historical effects of an occurrence quantitatively and thus helps in determining the changes associated with land cover and land use properties with reference to the multi-temporal datasets. The monitoring of land cover/use change dynamics can be applied by comparing a land cover/use map at present with the conditions in prior years as multi temporal [10,11,3].

In recent years, Geographic information system (GIS) and remote sensing technologies have progressed significantly because these technologies provide information to study and monitor the dynamics of natural resources for sustainable development and environmental management. Now the land cover/use change can be assessed or modeled using these technologies by analyzing multi temporal remotely sensed data to identify, detect, monitor, and map differences in LU/LC patterns over time [6]. The availability of historic spatiotemporal data and high-resolution satellite images from many satellites such as MODIS, CBERS, TM and ETM Landsat are necessary for decision makers and planners to get accurate information about land covers’ changes [1].

The primary purpose of this study was to locate the range of changes occurred in Karbala-Iraq over 17 years’ time period. However, the specific purposes included (1) to delineate various main land cover/use categories in Karbala city from 2000 to 2017 (2) to test the possibility of combining GIS with remote sensing in analyzing the spatial distribution of various land cover/use changes (3) to determine and quantify the variation in land cover/use categories through spatial comparison of the land cover/use maps generated.

2. Study Area
Karbala city is placed in the middle of Iraq about 110Km south-west Baghdad. It is located between latitude 32N to latitude 33N and longitude 43E to longitude 44E, its area about 5.034 km². The Karbala city includes three provinces which are the center of Karbala, Hindiyah, and Ean-tamer. In the last two decades, Karbala has witnessed a great incensement in urbanization as a result of the annual growth in people and migration to it. The selected area could be recognized in figure (1), which illustrates the Iraq map with a selected window represents the study area. The lands of Karbala are urbanization and agriculture. Agricultural areas include the cultivation of date palms, barley, wheat, fruit trees and summer crops. Urban areas include industrial plants, educational facilities, and residential units.

![Figure 1](image_url)

Figure 1 Iraq map with a selected window represents Karbala city.

3. Material and Methods
3.1. Data Preparation

Multi-temporal Landsat images were obtained from USGS Earth Explorer site[12]. The satellite imagery data for year 2000 was selected from Landsat 7 and for year 2017 was selected from Landsat 8. The satellite data was obtained in the same time period to avoid differences occurred in land cover change after implementing the mosaic process on the classification results. The field surveys were implemented from April to August 2017. Through the field surveys, 300 reference points within the study area were enrolled using global positioning system technology. While old maps the reference points determined from the satellite image taken in 2000.

3.2. Data Pre-Processing and Land Cover Classification

QGIS 2.14 software was used in this study, which is a free and open source geographic information system. The satellite data was imported in QGIS to calculate surface reflectance using DOS1 atmospheric correction tool. The resulted data was clipped to specify the study area. In this study, the supervised maximum likelihood algorithm was applied to implement the land cover/use classification process. This algorithm is popular in processing remotely sensing image data, which its work based on the probabilities of pixels [5,1,6].

Four land cover/use types are specified in the study viz., the delineated types are (i) built-up land, (ii) vegetation land, (iii) water land, (iv) soil land. For each identified land cover/use type, training areas/regions of interest (ROIs) were selected by delimiting polygons over homogeneous areas of the image. The spectral signatures of the land cover/use are calculated according to the pixels values corresponding to these ROIs. Then the spectral signature list was used by the maximum likelihood algorithm to classify the entire satellite image.

Maximum likelihood is one of the most popular classifications and has been implemented in several land use/cover change studies[11,3]. This algorithm supposes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is allocated to the class that has the highest probability. To implement this algorithm, an adequate number of pixels is required for each training area to calculate the covariance matrix.

During work, some indices were calculated to improve the classification results, these indices are illustrated in table (1).

| Eq  | Formula                          | Remarks                                                                 |
|-----|----------------------------------|-------------------------------------------------------------------------|
| 1   | $\text{Normalized difference} \ \text{vegetation index}$ | $\text{NDVI} = \frac{(\text{NIR}_B - \text{R}_B)}{(\text{NIR}_B + \text{R}_B)}$ | $\text{NIR}_B$: near infrared reflectance, $\text{R}_B$: Red light reflectance, where $\text{NIR}_B$ and $\text{R}_B$ in Landsat7 are band4 and band3 while in Landsat8 are band5 and band4 |
| 2   | $\text{Normalized difference} \ \text{built-up index}$ | $\text{NDBI} = \frac{(\text{SWIR}_B - \text{NIR}_B)}{(\text{SWIR}_B + \text{NIR}_B)}$ | $\text{NIR}_B$: near infrared reflectance, $\text{SWIR}_B$: SWIR reflectance, where $\text{SWIR}_B$ and $\text{NIR}_B$ in Landsat7 are band5 and band4 while in Landsat8 are band6 and band5 |
| 3   | $\text{Normalized difference} \ \text{water index}$ | $\text{NDWI} = \frac{(\text{G}_B - \text{NIR}_B)}{(\text{G}_B + \text{NIR}_B)}$ | $\text{NIR}_B$: near infrared reflectance, $\text{G}_B$: Green light reflectance, where $\text{G}_B$ and $\text{NIR}_B$ in Landsat7 are band2 and band4 while in Landsat8 are band3 and band5 |
3.3. Accuracy Assessment
After implementing the land cover/use classification, it is necessary to evaluate the quality of the classified maps and determine the level to which they correspond to real world conditions. The accuracy was evaluated using error matrices.

In this study, the accuracy assessment was based on a stratified random sampling method of a minimum of 20 reference points per category from ground truth data and visual interpretation. For the image of 2000, the ground truth data were generated from the satellite images that are suitable for detecting vegetation, water lands, and etc. For the Image of 2017, the ground truth data were acquired from field surveys as well as satellite images. The accuracy of each product was evaluated using several statistics such as user accuracy, producer accuracy, Kappa hat, and overall accuracy, as used in several land cover and land use studies.

3.4. Land Cover/Use Change Assessment
For assessing land cover/use changes, post classification comparison was implemented in QGIS. Post classification comparison is one of the most common methods for calculating land cover changes. This method works on comparing the land cover maps from different classifications and calculating the number of pixels that alter from one land category to another [13]. The result is a land cover map with a change matrix included a quantitative data of the overall changes in each category between 2000 and 2017.

4. Results and Discussion
Land cover maps resulted from the classification process appear good agreement with the real world as showed by overall accuracies of 99.99% for 2000 and 99.98% for 2017. The corresponding Kappa statistics are 0.99 for both 2000, and 2017.

Results obtained from the classification process and change detection are graphically explained in figures (2–4) and data are recorded in tables (2-3). Figure (2) describes land / land cover status, figure (3) describes land cover/use change in different land cover categories and figure (4) explains the magnitude of change in different land categories.

The figure (2-a) depicts the spatial distributional pattern of LU/LC of Karbala for the year 2000, while figure (2-b) for the year 2017. These data reveal that in 2000, about 9.36% (466.98km2) the area of Karbala was under vegetation, 75.49% (3764.35km2) under Soil, 3.87% (193.21km2) under built-up land and 11.26% (561.5km2) under water. During 2017, the study area in the land cover categories was found about 9.78% (487.75km2) under vegetation, 79.93% (3985.66 km2) under Soil, 5.75% (286.74km2) under built-up land and 4.53% (225.89km2) under water (table 1).

Data recorded in table (1) and figures (3-4) show both negative and positive shifts that have happened in the land cover/use pattern of Karbala.
In the last two decades, the vegetation in the study area has slightly increased from 466.98 km² in 2000 to 487.76 km² in 2017 which accounts for 0.4% of the total study area. The built-up area has increased from 193.21 km² in 2000 to 286.74 km² in 2017 which accounts for 1.9%. The soil land has been increased from 3764.35 km² in 2000 to 3985.66 km² in 2017 which accounts for 4.4%. The water land of the study area has decreased from 561.5 km² in 2000 to 225.9 km² in 2010 which accounts for 6.7%.

Table 2. The area and the amount of shift in the identified land cover/use categories in Karbala over the last period (2000–2017).

| LU/LC categories | Year 2000 | Year 2017 | Change 2000–2017 |
|------------------|-----------|-----------|-------------------|
|                  | Km²       | %         | Km²               | %        | Km²          | %      |
| Built-up         | 193.217   | 3.875     | 286.74            | 5.75     | 93.523       | 1.9    |
| Vegetation       | 466.985   | 9.366     | 487.76            | 9.78     | 20.775       | 0.4    |
| Water            | 561.504   | 11.261    | 225.9             | 4.53     | -335.604     | -6.7   |
| Soil             | 3764.354  | 75.498    | 3985.66           | 79.94    | 221.306      | 4.4    |
| Total            | 4986.06   | 100       | 4986.06           | 100      | 0            | 0      |

Table (3) includes land cover/use change matrix that shows land crawling for different land classes during the last two periods, which reveals that:

i. About 22.77% the area of built-up has been turned into vegetation, 47.25% into soil and 1.1% in water;

ii. About 10.65% the area of vegetation covered has been turned into built-up, 2.14% area under water area and 22.8% area under soil land;

iii. About 1.4% of the area of soil has been turned into built-up, 2.18% area under vegetation and 8.43% area under water land;

iv. About 1.03% area of water covered has been turned into built-up, 0.36% in vegetation and 4.72% in soil.

Table 3. Land cover/use change matrix showing land crawling (in %) of Karbala.

| LU/LC categories | Year 2000 |
|------------------|-----------|
|                  | Built-up  | Vegetation | Water | Soil |
| Built-up         | 28.88     | 10.65      | 1.03  | 1.4  |
| Vegetation       | 22.77     | 64.41      | 0.36  | 2.18 |
| Water            | 1.1       | 2.14       | 93.89 | 8.43 |
| Soil             | 47.25     | 22.8       | 4.72  | 87.99|
| Class Total      | 100       | 100        | 100   | 100  |
Figure 3. Land cover/use change maps in the identified land categories over the last two decades in Karbala development (2000–2017); (a) water (b) built-up (c) vegetation (d) soil (based on Landsat imagery data).

Figure 4. Land cover/use change in percent over the last two periods (2000–2017) in Karbala.

5. Conclusion
The study conducted in one of the important holiest cities in Iraq advocates that multi temporal satellite imagery and remote sensing together with GIS techniques play a vital role to monitor urban expansion effectively over time by producing accurate Land cover/use maps and change statistics. The study shows that the main land use in the study area is built-up. The area of built-up has increased by
1.9% (93.52 km²) due to expansion during 2000 to 2017. The second main category of land is vegetation which has also increased. During the study period (i.e., 2000–2017), vegetation land has been slightly increased by 0.4% (20.78 km²). The third main category of land is water which was decreased by 6.7% (335.6 km²) due to conversion in vegetation, soil land and built-up land. The area under the fourth category of land, i.e., soil land has increased by 4.4% (221.3 km²) due the decline in the water land in the last two decades. Based on the results achieved by using GIS and Remote Sensing techniques to obtain the specific research aims for dealing with the dynamics of land cover/use change in Karbala, it’s concluded that the land cover/use practices in the study area have altered significantly in 17 years.

6. References

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