

Application of Remote Sensing and GIS to the Study of Land Use/Cover Change and Urbanization Expansion in Basrah Province, Southern Iraq

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Abstract In recent years, land use/cover dynamic change has become a key subject that needs to be dealt with in the study of global environmental change. In this paper, remote sensing and geographic information systems (GIS) are integrated to monitor, map, and quantify the land use/cover change in the southern part of Iraq (Basrah Province was taken as a case) by using a 1:250 000 mapping scale. Remote sensing and GIS software were used to classify Landsat TM in 1990 and Landsat ETM+ in 2003 imagery into five land use and land cover (LULC) classes: vegetation, sand, urban area, unused land, and water bodies. Supervised classification and normalized difference build-up index (NDBI) were used respectively to retrieve its urban boundary. An accuracy assessment was performed on the 2003 LULC map to determine the reliability of the map. Finally, GIS software was used to quantify and illustrate the various LULC conversions that took place over the 13-year span of time. Results showed that the urban area had increased by the rate of 1.2% per year, with area expansion from 3 299.1 km² in 1990 to 3 794.9 km² in 2003. Large vegetation area in the north and southeast were converted into urban construction land. The land use/cover changes of Basrah Province were mainly caused by rapid development of the urban economy and population immigration from the countryside. In addition, the former government policy of “returning farmland to transportation and huge expansion in military camps” was the major driving force for vegetation land change. The paper concludes that remote sensing and GIS can be used to create LULC maps. It also notes that the maps generated can be used to delineate the changes that take place over time.

Keywords urbanization; LULC; RS; GIS; classification; NDBI; Al-Basrah; Iraq

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Introduction

Land use/cover change (LUCC) has been an important research field even in the global view, and it was supported as a core project by the International

Geosphere-Biosphere Programme (IGBP) and by the International Human Dimensions Programme on Global Environmental Change (IHDP). LUCC is a very complicated process, affected by natural and human dimensions. The natural environment is a dominant factor in a way, while human dimensions

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are revulsive factors. The research on LUCC is a basic precondition of regional LUCC monitoring, driving factor analysis, and even to LUCC prediction^[1-3]. RS (remote sensing) and GIS (geographic information systems) are believed as the most advanced means to obtain land use information because they are real time, impersonal and has wide coverage^[4-6].

The urbanization process in Basrah Province has been accelerated after the former government put up the strategy of fast development of the urban economy, transportation, and huge expansion in military camps in the south part of Iraq about 20 years ago. This has caused the loss of farmland in the urban periphery area. What's more, urban expansion has also deeply affected the urban periphery ecological environment. Understanding such interaction between urban cities and rural regions is important for sustainable development of these areas. The variation of urban boundary extracted from satellite can more efficiently and quickly reflect dynamic changes of urban expansion compared with traditional statistical data. Many experiments on land use/cover changes in cities or between urban and rural areas had been carried out by researchers from all over the world since the first earth resource satellite was launched in the 1970s in the United States. Land use/cover maps for the urban area of Boston were produced at level III of the Anderson^[7] scheme using large format camera shuttle photographs and national high altitude photographs, and their accuracies were 65% and 70%, respectively^[8]. The potential of SPOT XS images was tested for automatically outlining agricultural near-urban interfaces for an area around Yogyakarta, Central Java, and satisfactory results were obtained which were comparable to those obtained from visual interpretation of 1:100 000 near-infrared aerial photographs^[9]. Eight land covers were mapped at the level of the Anderson scheme on the urban fringe in England from Landsat MSS data^[10]. 10 m resolution of SPOT panchromatic band was used by registering it with the multi-spectral ones to obtain a classification of eight land covers at the urban-rural fringe of Toronto, Canada with an accuracy of 78%^[11]. Three Landsat MSS images were also utilized to monitor the urban expansion of Montreal, Canada^[12]. Five-category classification was obtained in the small urban area of Beaver

Dam, Wisconsin^[13]. Detailed land cover maps were produced at the urban-rural periphery in southern Auckland using SPOT XS data, and reflected the influence on land use at the urban fringe^[14]. Using imagery residential areas were extracted with simple threshold of spectrum structure^[15]. From TM and ETM+ imagery using normalized difference built-up index, the urban land-use map of Wuxi City was achieved^[16]. These researches have done valuable efforts on retrieving urban boundaries, but to obtain efficiently the urban boundary to know more clearly the urban expansion and to analyze its effect on land use/cover change needs to be studied further.

The present paper analyzed urban expansion impacts on land use/cover change in Basrah Province from the years of 1990 to 2003, with the following objectives: (1) to retrieve the two phases of the urban boundary of Basrah Province in 1990 and 2003 using supervised classification and NDBI respectively followed by comparison of the result derived from these two different methods; (2) to map urban land use/cover of Basrah Province in 1990 and 2003, thus to find the factors causing land use/cover changes during the past 13 years; and (3) to propose some suggestions for the city's development, while protecting limited farmland resources and ecological environment.

1 Materials and methods

1.1 Materials

The study area located in the southern parts of Iraq, lies within longitude 46° 60' to 48° 60' E and latitude 29° 13' to 31° 29' N with a total area of 19 070 km² (Fig. 1). To study the land use/cover change, the districts of Basrah, Abu Al-Khaseeb, Fao, Al Midaina, Al-Qurna, Al-Zubair, and Shatt Al-Arab were selected as study areas. The districts are situated in the southern parts of Iraq. The average population growth was estimated at 3.6% in the period 1990~2003. The soil of Iraq is considered as sedimentary soil, especially in the central and southern parts. The annual humidity is less than 50% and remains less than 30% during the daytime. The average evaporation exceeds 2 450 mm/a with average annual rainfall less than 100 mm. The desert plants are adapted to these varia-

tions of meteorological factors, and represent 66% of the total cover; these plants begin to grow immediately after rainfall, and complete their life cycle by the end of the rainy period, soon after the temperature begins to rise. In recent years, along with the increase of population, economic development, and improvement of the investment environment, Basrah Province has witnessed a rapid urbanization, which has deeply affected the ecological environment in the urban and rural regions. In this study, a Landsat 5 TM image of Feb. 1990 and a Landsat 7 ETM+ image of March 2003 were required. The orbit data of the eight images are 165/39, 166/38, 166/39, and 166/40, and their spatial resolutions are 30 m. All the thematic layers were generated in GIS environment at a scale of 1:250 000. The software packages used for this study were ERDAS and Arc/Info.

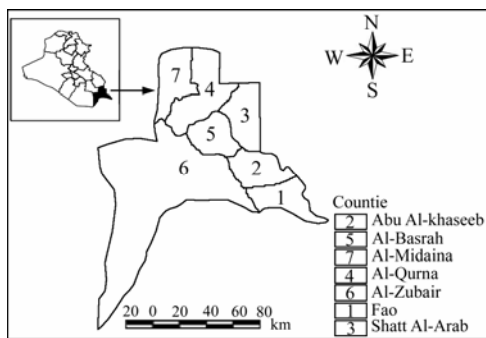


Fig.1 General location of the study area

1.2 Methods

The basic idea of this research was to retrieve the urban boundary of different image phases using Landsat TM/ETM+ data, and then to analyze the impacts of urban expansion on land use/cover change (Fig.2). The detailed illustration of data processing was as follows:

Imagery pre-processing. To retrieve urban boundary efficiently, the pre-processing included geometric correction in which ground control points were chosen referencing to a topographic map of 1:250 000.

Imagery post-processing. In this research, two methods were used to retrieve the urban boundary, namely supervised classification and normalized difference build-up index (NDBI). By comparing the results derived from these two methods, the more precise one was confirmed as the urban boundary.

Statistical analysis. Analyzing the impacts of urban

expansion on land use/cover change using the statistical data of Basrah Province in recent years, the effect of urban expansion on land use/cover change was analyzed.

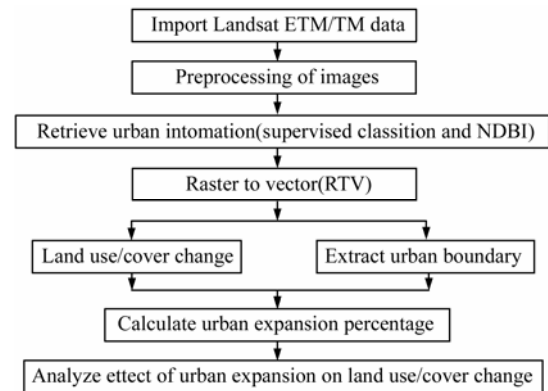


Fig.2 Flowchart of analyzing driving force of urban expansion

2 Results and discussion

2.1 Retrieval of urban boundary

In order to retrieve the urban boundary, the supervised classification and normalized different built-up Index (NDBI) were used.

2.1.1 Classification method

The supervised classification is the most common method in obtaining land use/cover information. In this research, after data pre-processing, a training sample was selected according to spectrum features. Unlike the conventional classifications of land use/cover, in this study, only two classifications of land cover were chosen, which were urban regions and non-urban regions. This could separate the urban areas from extra classes. Then, the maximum likelihood classification was used to map the land use/cover of Basrah Province counties. Fig.3 and Fig.4 are

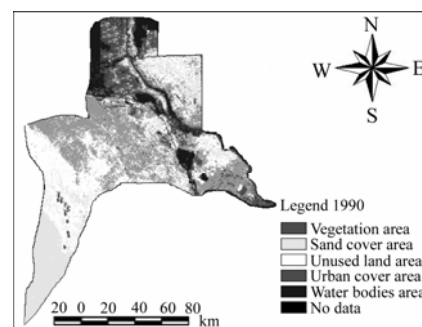


Fig.3 Land class boundary of Basrah in 1990 under maximum likelihood classification based on Landsat TM

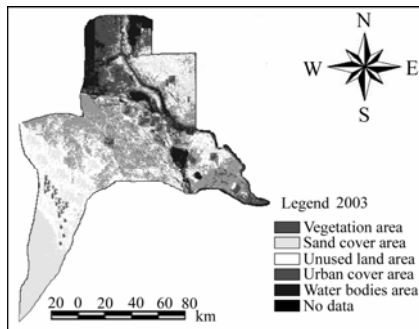


Fig.4 Land class boundary of Basrah Province in 2003 under maximum likelihood classification based on Landsat ETM

the results of the classification. It can be seen from the study provided by the ERDAS software that the overall accuracies of classifications of 1990 and 2003

reached 97.89 and 95.93, respectively. From the classification image, it is clear that non-homogeneous urban area was influenced by green land, sandy land, and water bodies. In order to convert raster data into vector map, the classified result was filtered by a window of 5×5, then the aggregation was carried out. That is to say, the non-urban part within the city was merged into urban area and the urban part outside the city was aggregated into non-urban part, then in turn, urban profiles were obtained. Based on this, urban boundaries of Basrah Province in 1990 and 2003 were extracted by converting raster to vector. Table 1 shows the results.

Table 1 Calculated (LULC) classes totals monitored from satellite image for the study area during the period from 1990 to 2003

(LULC) classes	Area /(km ²)		Amount of change		Percentage growth	
	1990	(%)	2003	(%)		
Vegetation land	5 110.8	26.8	4 595.9	24.1	-514.9	-10.1
Sand land	4 119.1	21.6	4 557.7	23.9	438.6	10.6
Urban area	3 299.1	17.3	3 794.9	19.9	495.8	15.1
Unused land	3 356.3	17.6	3 146.5	16.5	-209.7	-6.2
Water bodies	3 184.7	16.7	2 955.9	15.5	-228.9	-7.2

2.1.2 Normalized different built-up index method

To ensure the authenticity of the urban boundary, in this study, another method, NDBI was used to extract the urban boundary of Basrah Province counties on the RS images of 1990 and 2003. NDBI takes advantage of the unique spectral response of built-up areas and the other land covers. Built-up areas are effectively mapped through arithmetic manipulation of recoded NDVI (normalized different vegetation index)^[15]. Like NDBI, NDWI (normalized different water index) and NDSI (normalized different snow index) were also developed to map water bodies and glaciers^[16].

From the spectrum feature of the ground, band 4 (0.76~0.90 μm) of TM/ETM+ is the near infrared waveband which reflects vegetation information. Thus, this band is very sensitive in detecting vegetation, while the reflectance of residential areas in this band is low. ETM/TM5 (1.55~1.75 μm), the short-wave infrared waveband, can reflect the information of moisture content in different land use types. For example, in band 5 the reflectance of forest and farmland with high moisture content is low, but for resi-

dential areas that have low moisture content, the reflectance is high. Researchers indicated that on Landsat TM/ETM+ images, except urban and barren areas, the digital numbers of other landscapes in band 4 are lower than that of band 5. NDBI is the result of calculation of (band 5-band 4)/(band 5+band 4) (Fig.5 and Fig.6). The value of NDBI in Basrah Province counties ranges from -0.49 to 0.20. Then mask processing was done to the binary image, thus the urban area of Basrah Province counties was extracted by converting raster to vector. The comparison between the two values was obtained in 1990 and 2003 (Table 2).

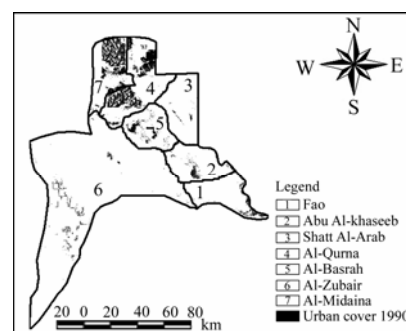
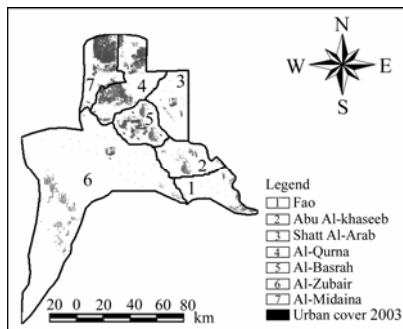


Fig.5 Urban boundary of Basrah Province in 1990 derived from NDBI

Table 2 Calculated Urban areas monitored from satellite image for the study area during the period from 1990 to 2003

Study site	Area /(km ²)	Area/(km ²)				Increase /(km ²)	Percent /(%)	Increase /(%)
		1990	(%)	2003	(%)			
Abu Al-Khaseeb	1 152	161.3	14.0	187.8	16.3	26.5	16.4	1.3
Al Midaina	989	298.7	30.2	321.4	32.5	22.7	7.6	0.6
Al-Qurna	2 612	412.6	15.8	449.3	17.2	36.7	8.9	0.7
Al-Zubair	11 618	859.7	7.4	1 010.7	8.7	151.1	17.5	1.4
Basrah	1 085	342.8	31.6	416.6	38.4	73.7	21.5	1.7
Fao	98	10.1	10.6	12.1	12.3	1.9	19.3	1.5
Shatt Al-Arab	1 516	171.3	11.3	194.1	12.8	22.7	13.2	1.1
Total	19 070	3 280.1	17.2	3 756.8	19.7	476.7	14.5	1.2

**Fig.6** Urban boundary of Basrah Province in 2003 derived from NDBI

2.2 Change analysis

2.2.1 Change analysis via supervised classification

ERDAS Imagine and ESRI ArcView were used to quantify the area of the five LULC classes from the 1990 and 2003 classification maps. The software was also able to quantify the amount and type of change that occurred in each of the LULC classes over the ten-year study period. These numbers were used to create Table 1. Table 1 quantifies the amount of land contained in each LULC class, the percentage of the study area encompassed by the LULC class, and the amount of growth of each of the LULC classes from 1990 to 2003. Table 1 shows and quantifies the LULC class from 1990 to 2003. For example, the table shows that 514.9 km² of land that had been classified as vegetation land in 1990 was classified as sand land and urban area in 2003, and 209.7 km² of land that had been classified as unused land in 1990 was classified as urban or built up in 2003. This can be used to determine the extent of the changes taking place in the LULC over time. By using Table 1, the significant changes in the LULC can be recognized and the type of LULC conversion can be identified. From 1990 to 2003 sand land and urban areas saw a

relatively dramatic increase. The areas that contributed the most to this change were vegetation land. This may suggest logging and development. During the same time span, urban areas also increased in size. The majority of this change came from the development of vegetation land into an urban class. Water bodies saw a decrease of 228.9 km² in size. Some of the marshes were converted to unused land, while some were converted to urban. Vegetation areas also saw a decrease in size. Most of it was converted to sand cover area, while a smaller but significant portion was developed into urban areas.

2.2.2 Change analysis via NDBI

Through band math of the two satellite images, we obtained the land surface built-up percentage distribution map of the study location in 1990 and 2003. Fig.5 shows high built-up percentage area (in black) concentrated in the northeast part, and the NDBI value is decreasing from east to west, which means the build-up of land surface is decreasing in this direction; on the contrary, the sand land is increasing from west to east, coherent with that the land cover type is from crop land to sandy land in this direction. Fig.6 shows a complex distribution of the built-up area patches. There are several big patches of built-up high-content scattered and moved to the southeast direction, illustrating that the land surface in the southeast part has higher built-up area percentage content than 13 years ago. It implies that the land use/cover change is progressing to the east and south directions and the land use/cover change degree continues to turn serious during these 13 years.

In this study, the differences in urban area of seven sites between 1990 and 2003 were analyzed. The

measurements make it possible to notice a significant increase of urbanization with respect to the time interval. The rate of increase ranged from 0.6% to 1.7% (Table 2). The data reveals a significant increase in urban area with time. However, the magnitude of increase depended on the strategical significance of the location. The southern part of Iraq is considered a great economic and administrative center, and the percentage increase in its urban area reached 19.7% compared with its original coverage in 1990. And the counties, Abu Al-Khaseeb, Al-Zubair, Basrah, Fao, and Shatt Al-Arab, experienced very high increase in urbanization, with a percentage of 16.4%, 17.5%, 21.5%, 19.3%, and 13.2%, respectively. It was a clear indication of a great danger to very fertile cultivated land in the southern part of Iraq. This pattern of increase was mostly related to the socio-economic conditions. People tend to live where the administrations are concentrated. Also, the rural life is associated with a distinctive location strategy, as in study location. These trends are always on account of the fertile cultivated land. Hence, the redistribution of administration and work opportunities must be considered in establishing new urban societies. These conditions might have their influence on people's education and mentality, which may help in following a civilized population policy.

2.3 Urbanization expansion assessment

Analyzing the urban boundaries of Basrah Province counties in 1990 and 2003 resulted from supervised classification and NDBI. We can find that during the 13 years, the study location has witnessed a rapid urban expansion. From 1990 to 2003, the urban area has added 476.7 km², from 3 280.1 km² to 3 756.8 km². The average increase rate was 1.2% per year (Table 2). The conspicuous expansion region mainly happened in the center of the city (Basrah District) and the south (Shatt Al-Arab District and Abu Al-Khaseeb District). However, there was little change in the east and west of the city. The causes of urban expansion in the center and the south of Basrah Province were the new and high technological industry zones, Basrah Province economical and technological development zones which are newly located in these two regions. Because of large-scale

construction of development zones, large scale constructions of infrastructures have made urban expansion develop rapidly.

2.4 Causes of land use/cover change

From the analysis on land use/cover changes in the counties of Basrah Province during the past 13 years, it can be found that the area of urban infrastructure construction and sand land increased a lot, while the farmland reduced rapidly. One direct reason for this change was the policy "returning farmland to transportation and huge expansion in military camps", which converted mass farmland to built-up area. Besides this reason, there are still four important ones for this great change.

First, Basrah Province has been developing fast under the environment of rapid development of south Iraq for the sake of the developing economy such as rural development of the Ahwar region (marshland of southern Iraq) and the Safwan-Zubair agriculture near-urban interfaces (south western desert). Thus, the urban area increased rapidly. At the same time, a lot of farmland was converted to urban construction land.

Second, the continuously increasing population and housing demands accelerated the real estate development on the outskirts of Basrah Province districts, converting farmland to residential land.

Third, traffic, water, power, natural gas and other various infrastructures are some other driving forces of urban development and expansion. Large-scale infrastructure construction has been developed because of the needs of rapid urban development, which provided convenience for the development of real estate, industrial and economic development zone at the urban fringe. These constructions resulted in land use change.

In addition, the great demand for increasing farming productivity due to urban expansion was also an important reason. Centralized urban markets need abundant farm production, which can bring considerable economic benefits, therefore driving the adjustment of development of some special farm production and agricultural structures. This is the fundamental cause for internal conversion of different kinds of agriculture land use. In this study area, a lot of farmland was converted to transportation, huge expansion in military camps and unused land by the war during 1980~2003.

3 Conclusion

We can get the following conclusions by analyzing the effect of urban expansion on land use/cover changes that occurred in Basrah Province between 1990 and 2003.

In this study, it is obvious that the average accuracy of supervised classification and NDBI is 89% and 81%, respectively. Therefore, we consider supervised classification as a perfect method in retrieving urban boundary. According to the urban boundaries of 1990 and 2003 in the study location, the urban area of districts increased 476.7 km² during the 13 years and the increase rate was 1.2% per year.

The urban periphery of the study location is the region where land use/cover changed greatly. The primary feature of land cover change was that great amount of farmland was occupied by urban construction. In addition, affected by the strategy of the previous government policy of “returning farmland to transportation and huge expansion in military camps”, a lot of farmland was converted to urban construction area.

The land use/cover change of the study location was driven by many factors; however, human activity was the most important one. Rapid economic development and fast urbanization were the fundamental reason for land cover change from 1990 to 2003. What is more, the investment of social assets, development of the urban economy, construction of infrastructure, such as transportation and internal adjustment of agricultural land use played important roles in the process of land change.

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