Assessment of Land Use/Cover Change and Urban Expansion of the Central Part of Jordan Using Remote Sensing and GIS

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Abstract

This paper presents the temporal and spatial patterns of land use/cover change and identifies the process of urbanization for the major cities at the central part of Jordan using multi temporal remotely sensed data from 1987 to 2005. Land use/cover statistics revealed that urban/built up areas have increased by 220 km2 over the study period. The output land use/cover maps showed that urban expansion has been associated with loss of agricultural land and urban sprawl. The urban expansion was mainly attributed to the high growth rate, large number of immigrants from neighboring countries and other socio-economic changes. These results can provide city planners and decision makers with information about the past and current spatial dynamics of land use/cover change and strictly urban expansion towards successful management for better planning and environmental monitoring.

Key words: Urban expansion, Land use/cover change, Remote sensing, GIS, Jordan

1. Introduction

Land use/cover change is a major factor for global change because it can affect ecosystem processes, hydrology, biodiversity, climate, biogeochemical cycles, energy balance, and human activities (Xiao et al., 2006; Pabi, 2007). Therefore, comprehensive studies should be advanced to support land use/cover management and their changes.

The importance of remote sensing for studying land use/cover patterns and their dynamics is well established. Many literatures have been carried out to analyze the importance of mapping land use classes and monitoring their changes using different spatial resolution satellite data, including Landsat Thematic Mapper (Dewan and Yamaguchi, 2008), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (Yüksel et al., 2008), Satellite Pour l’Observation de la Terre (SPOT) (Barnaby and Petri, 2007), Synthetic-aperture radar (SAR) (Liu et al., 2001) and aerial photographs (Al-Bakri et al., 2001). Change detection techniques are useful in many applications that have been effectively employed to identify changes in different land use/cover classes. These techniques range from post classification comparison (Abd El-kawy et al., 2011) and simple image differencing (Green et al.,1994) to principle components analysis (Byrne et al., 1980). On the other hand many methods have been developed for identifying and mapping urban expansion from remote sensing data: e.g. Mundia and Aniya (2005), analyzed the spatial dynamics of land use/cover changes and recognized the urbanization process in Nairobi using multi-temporal and multi-spatial resolutions of Landsat data; Xiao et al.(2006) detected land use/cover change and urbanization trends using annual urban growth rate supported by two scenes of satellite multi-spectral images, Batisani and Yarnal (2009) assessed urban landscape pattern change from 1993 to 2002 using Landsat TM images.

The process of urbanization is a universal phenomenon taking place the world over, where humans dwell (Sudhira et al., 2004), and it is a major trend in recent years (Weber and Puissant, 2003). In the last 10 years, much more attention has been paid to urban land use/cover change because
ecosystems in urban areas are strongly affected by human activities and have close relations with the life of almost half of the world’s population (Xiao et al., 2006).

The process of urbanization has been characterized not only by increasing the built-up areas, but also has witnessed remarkable industrial expansion, economic and social developmental activities, and strongly consumption of natural resources. Therefore, management of any growing urban society involves careful analysis, meticulous planning and timely implementation of different strategic plans, keeping in view the constraints imposed by resources, space and time (Sebastian et al., 1998).

Remote sensing is an attractive source of thematic maps such as those depicting land cover as it provides a map-like representation of the Earth’s surface that is spatially continuous and highly consistent, as well as available at a range of spatial and temporal scales (Giles, 2002). Urban planners frequently make use of remotely sensed imagery, which they can then superimpose on other demographic or geographic information to provide a more detailed and insightful picture of the human landscape (Carlson, 2003).

Jordanian cities have experienced rapid urbanization over the last two decade, mainly resulted from high natural growth rate, and equally important the continuous migration flows from gulf countries after the first and second Gulf Wars in 1991 and 2003, respectively (Al-Bakri et al., 2001; DOS, 2009). Urbanization in Jordan is significantly high: in 1998, about 78% of the kingdom's population were living in urban areas and it is projected to increase in the future which may probably reach more than 85% of the total population by the year 2010 (Jaber and Probert, 2001).

Few studies provided enough consideration to urban expansion and linked directly to its impact on natural resources and community character; however a lack of quality land use/cover maps for successful management and monitoring programmes in Jordan still exists (Alrababah and Alhamad, 2006).

The objective of this study is to detect and evaluate the land use/cover change due to urbanization among 1987, 1999 and 2005, and to analyze the main factors governing urbanization and land use/cover change, to allow the urban planners to know the changing conditions in the study area in order to develop urban planning strategies that can protect the local environment. To perform the objectives of this study, three time series analyses using remotely sensed data in combination with Geographical Information System (GIS) were employed. Specifically, land use/cover classification schemes for three major cities at the central part of Jordan were identified using Landsat Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+) and Advance Space-borne Thermal Emission and Reflection Radiometer (ASTER) visible and near infrared radiometer (VNIR) images.

2. Study Area

The study area, as shown in Figure 1 is located at the central part of Jordan between the range of 35° 46’E- 36° 13’E and 31° 46’N- 32° 13’N, and is composed of the capital Amman, Zarqa and Al-Salt cities. The study area covers about 13 459 km² representing a bout 15% of the total area of Jordan (DOS, 2007).

The climate of the study area, in summer it is hot and dry and temperature ranges from (27-36) °C, while in winter it is cold, and temperature ranges from (1.4-10) °C. The amount of rainfall is low, ranges between (250-350) mm/year (Freiwana and Kadioglu, 2008).

The study area was chosen based on the personal experience where urban expansion is prevalent, since it has approximately 60% of the total population of Jordan (DOS, 2007). During the last 20 years urban expansion was very noticeable driven by high natural growth rate of 2.3% (DOS, 2007), and due to the wars in the region. Specifically, more than 350,000 people returned to Jordan after the first Gulf War in 1991 (Al-Bilbisi and Tateishi, 2003) and about 450,000 Iraqis entered Jordan after the second Gulf War in 2003 (DOS, 2009). Consequently, the population has increased from 3.1 million (Al-Bilbisi and Tateishi, 2003) in 1987 to the current 5.91 million (DOS, 2009).

3. Satellite Images

A Landsat TM image (1987), a Landsat ETM+ image (1999) and an ASTER VNIR image (2005) were used to extract land use/cover change and to map the physical extent of urban areas at the central part of Jordan for three time series during the same season. Table 1 shows the information related to the satellite images used in this study.
Table 1. Information of satellite data used in this study

<table>
<thead>
<tr>
<th>Satellite data</th>
<th>Date</th>
<th>Spatial resolution (m)</th>
<th>Source of data</th>
<th>Preprocessing from the source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat TM</td>
<td>August 14th, 1987</td>
<td>28.5</td>
<td>GLCF</td>
<td>Georeferenced to UTM 3 map projection, zone36N, W GS 84 ellipsoid.</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>August 7th, 1999</td>
<td>28.5</td>
<td>GLCF</td>
<td>Georeferenced to UTM map projection, zone36N, W GS 84 ellipsoid.</td>
</tr>
<tr>
<td>ASTER VNIR</td>
<td>August 16th, 2005</td>
<td>15</td>
<td>ERSDAC^2</td>
<td></td>
</tr>
</tbody>
</table>

1 Global Land Cover Facility
2 Earth Remote Sensing Data Analysis Center
3 Universal Transverse Mercator

4. Methodology

4.1 Image Pre-processing

Geometric rectification is critical for producing spatially corrected maps of land use/cover changes through time. The Landsat TM and ETM+ images were in UTM projection (Zone 36) on WGS84 as shown in Table 1. The Landsat TM image was used as a reference to register ASTER (VNIR) image. Using the image-to-image registration the first-degree polynomial equation was used in image transformation. The nearest neighbor resampling method was used to avoid altering the original pixel values of the image data. Thus, the image of 2005 of the study area was geometrically corrected using 17 control points. The resultant root mean square error (RMSE) was less than 0.5 pixels.

4.2 Image Processing

The color composites for the three images were generated from Landsat TM and ETM+ bands 2, 4, and 7 and ASTER VNIR bands 3, 2 and 1 as illustrated in Figures 2A, 3A and 4A, respectively. These color composites were selected to assist the selection of the training sites of each class and analysis purposes.

4.3 Classification System

Supervised classification has been widely used in remote sensing applications. A supervised classification system using maximum likelihood algorithm was consequently applied for land use/cover mapping from the three images. To map changes that had occurred in the central part of Jordan from 1987 to 2005, six non-thermal bands of both Landsat TM and ETM+ images were individually used as input for maximum likelihood classification system. In addition to that for the same purpose, three VNIR bands of ASTER data were utilized. After land use/cover classification system has been chosen, training sites were carefully selected in sufficient homogeneity to maximize the accuracy of classification in the image. This step is probably the most important part of supervised classification, for it’s the spectral signatures extracted from these sites that will determine the overall classification accuracy, and thus the utility of the final thematic map. Therefore should be taken in selecting training sites that represent typical examples of each land cover class and avoiding heterogeneous areas.

A modified version of the Anderson land use/cover classification system (Anderson et al., 1976) was used in this study. Although the classification system was originally developed for the USA, it is the widely used land use/cover classification system across the world (Dewan and Yamaguchi, 2008). The system determined that land use/cover classification of level I classes can be mapped over large areas from Landsat data or from high-altitude imagery. So, land use/cover classification system of level I was chosen and referred for the classification system in this study. Classification scheme and detailed descriptions were given in Table 2.

A median convolution filter, Kernel size $3 \times 3$ was used to smoothen the images and to reduce the number of misclassified pixels. In addition to that visual interpretation was performed because it allows an integrated use of spectral and spatial contents as well as human wisdom and local knowledge.

Figures 2B, 3B and 4B show the classified images for Landsat TM, Landsat ETM+ and ASTER VNIR, respectively.
Table 2. Land use/cover classes used in this study and their definitions

<table>
<thead>
<tr>
<th>Classes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/ built up areas</td>
<td>Residential, industrial and commercial complexes, transportation, communication and utilities.</td>
</tr>
<tr>
<td>Water</td>
<td>All areas of open water, including streams, lakes and reservoirs.</td>
</tr>
<tr>
<td>Bare land</td>
<td>Area of thin soil, sand, or rock, almost has no vegetation.</td>
</tr>
<tr>
<td>Natural vegetation</td>
<td>Herbaceous, shrub and brush rangeland and areas of sparse vegetation cover.</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>Crop fields, vegetable lands and cultivated areas (irrigated and non-irrigated vegetation).</td>
</tr>
<tr>
<td>Forestland</td>
<td>Deciduous, evergreen and mixed forest (natural and man made forests).</td>
</tr>
</tbody>
</table>

Figure 2. (A) Color composite image of Landsat TM 1987 bands (2, 4, and 7) exposed through red, green and blue filter, respectively
(B) Land use/cover classification map of the central part of Jordan based on analysis of Landsat TM 1987

Figure 3. (A) Color composite image of Landsat ETM+ 1999 bands (2, 4, and 7) exposed through red, green and blue filter, respectively
(B) Land use/cover classification map of the central part of Jordan based on analysis of Landsat ETM+ 1999

4.4 Accuracy Assessment

Accuracy assessment determines the quality of the information derived from remotely sensed data (Shaikh and Gotoh 2006). The accuracy of the three land use/cover classification maps was determined using random sampling design. Stratified random sampling design, where the points were stratified according to the distribution of land use/cover classes, was adopted. By allowing the reference pixels to be selected at random, the possibility of bias is lessened (Mundia and Aniya 2005).

For both Landsat TM and ETM+, a total of 450 points were
selected, while a total of 400 points were selected for ASTER VNIR. These pixels were checked against 1:50 000 topographic map and with an interpretation of in situ check. The overall accuracies were 90%, 92% and 95% for TM, ETM+ and ASTER VNIR, respectively as shown in table 3.

A comparison of table 3(A), (B) and (C) reveals that the 2005 land use/cover map based on ASTER VNIR yielded slightly better accuracy than that of the 1987 and 1999 land use/cover map based on Landsat TM and ETM+, respectively. This could be the result of better spatial, and spectral resolution of the ASTER VNIR data. However, the 1987 and 1999 land use/cover map based on Landsat data is compatible in accuracy in every respect to the 2005 land use/cover map based on ASTER VNIR.

In spite of the differences in spatial and radiometric resolution of the satellite data, compatible land use/cover maps were produced using same image processing procedure (Jay and Yansui, 2008)

5. Results and Discussion

5.1 Post Classification Comparison

The post-classification comparison approach is very advantageous when using data from different sensors with different spatial and spectral resolutions (Alboody et al., 2008). It was employed for detection of land use/cover changes, by comparing independently produced classified land use/cover maps. The main advantage of this method is its capability to provide descriptive information on the nature of changes that occurs (Mundia and Aniya, 2005). It is important to note that this method depends on the results of the classification of all images and data stored in GIS database. The GIS capabilities allowed the post-classification comparisons, and facilitated qualitative assessment of the factors influencing urban expansion. There is six land use/cover classes of interest in central part of Jordan: Urban/ built up areas, Water, Bare land, Natural vegetation, Agricultural land, Forestland. The spatial distributions of these classes were extracted from each of the land use/cover maps by using of GIS spatial analysis. The statistic land use/cover distribution for the three time series (1987, 1999 and 2005) as derived from the maps are presented in table 4.

The urban/built-up area class increased from 9% in 1987 to 13% in 1999, and then to 20% in 2005. Agricultural land class, however, decreased significantly from 11% in 1987 to 6% in 1999 and remained with slight changes in 2005. Bare land class decreased about 5% during the 18 years of the study period. On the other hand natural vegetation and forestland classes that existed in 1987 remained with minor changes in 2005 in all sites. In contrast water class took up the least percentage with just 2% in the total classes of the three time series. That percentage reflects the climate of the study area that lies in arid environment. The spatial distributions of the six classes were extracted from each land use/cover maps of 1987, 1999 and 2005 as shown in Figures 2B, 3B and 4B.

Among the six land use/cover classes, it is clearly visible that there are three main classes of interest in the study area: urban/built-up areas, agricultural land and bare land, because of their significant changes in the last 18 years of the study period. The trends of the three classes are illustrated in Figure 5.

The results indicated that the urban/built-up area class increased from 174 km² in 1987 to 260 km² in 1999, and then to 394 km² in 2005, showing an expansion of urban/built up areas of 220 km² from 1987 to 2005. In contrast, agricultural land occupied a bout 205 km² in 1987, decreased to 115 km² in 1999 and then to 106 km² in 2005, indicating a decrease of 99 km² from 1987 to 2005. On the other hand, bare land slightly increased from 1394 km² in 1987 to 1411 km² in 1999 and then decreased to 1292 km² in 2005, a record loss of 102 km² during the 18 years.
Table 3. Error matrix of land use/cover maps (1987, 1999 and 2005)

<table>
<thead>
<tr>
<th>Class name</th>
<th>1987</th>
<th>1999</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/Built up areas</td>
<td>174.2</td>
<td>259.9</td>
<td>394.3</td>
</tr>
<tr>
<td>Natural vegetation</td>
<td>118.1</td>
<td>115.8</td>
<td>109.4</td>
</tr>
<tr>
<td>Water</td>
<td>2.75</td>
<td>3.57</td>
<td>4.21</td>
</tr>
<tr>
<td>Bare land</td>
<td>1393.6</td>
<td>1410.9</td>
<td>1292.2</td>
</tr>
<tr>
<td>Forestland</td>
<td>44.0</td>
<td>31.8</td>
<td>31.3</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>204.6</td>
<td>115.1</td>
<td>105.7</td>
</tr>
<tr>
<td>Total</td>
<td>1937.2</td>
<td>1937.1</td>
<td>1937.1</td>
</tr>
</tbody>
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Table 4. Results of land use/cover classification statistics for 1987, 1999 and 2005

<table>
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<th>Class name</th>
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<td>1937.1</td>
</tr>
</tbody>
</table>

5.2 Analysis of Land Use Changes and Dynamics of Urban Expansion

A GIS has been used to integrate urban/built up areas class for the three time series and generate a thematic map to examine dynamics of urban expansion as presented in Figure 6. During the period (1987-1999), it was clear that the encroachment of urban/built up areas occurred to the directions of northwest and southeast of Amman (Potter et al., 2008) and continued toward Zarqa city. On the other hand, the rate of the encroachment of urban/built up areas during the period (1999-2005) expanded much more extensively in the same direction of the former period besides the expansion toward Al-Salt city. Looking at the urban expansion during the period (1987-1999), it is found that the encroachment of urban/built up areas occurred extensively over agricultural lands which decreased by 90 km² and caused land degradations and a loss of natural resources. However, during the period (1999-2005), the expansion of urban/built up areas increased toward bare lands more than
agricultural lands. Furthermore, there is a rapid urban sprawl occurred around Amman, Zarqa and Al-Salt cities, since the sprawl normally takes place in radial direction around the city center or in linear direction along the highways (Sudhira et al., 2004). Consequently, the existence of transportation routes within the study area encouraged the urban sprawl to be happened, where transport in the cities is as socially polarized as the structure of the cities themselves (Potter et al., 2008).

These changes have pointed toward that the spatial pattern of urban expansion; has not occurred consistently in all direction but has taken place much faster in certain directions.

The increase of urban/built-up areas without comprehensive planning has a negative impact on local environment; especially, on water resources which Jordan has already a serious environmental problem in this sector. One study considered urban areas as ‘hazards’, which can affect the groundwater quality and increase its pollution risk (Al-Hanbali and Kondoh, 2008). Another study showed that some housing settlements have been established on water basin, such as Baq’a basin to the north of Amman, giving rise to serious environmental problems (Al-Bilbisi and Tateishi, 2003). On the other hand, there are many "informal" houses, which were built without planning permits in urban areas and comprise more than half of the urban building stock, i.e. where the poorest are located (Jaber and Probert, 2001). The informal houses are considered a serious problem to the environment due to improper planning system. Moreover, Amman city remains the main economic center of Jordan (Potter et al., 2008), which offers plenty services, sufficient employment, job and business opportunities. Therefore, the flowe of a big number of immigrants from the neighboring countries; after 1990 and 2003 into Amman city (DOS, 2009), caused an urgent need to urban planning studies, to determine the magnitude of encroachment resulted from the urban expansion centered mostly at the central part of Jordan.

6. Conclusion

Information about land use/cover patterns change over time is necessary not only for urban planning purposes, but also to improve the management of the use of land resources.

This study has demonstrated the importance of using satellite
remote sensing and digital image processing together with GIS technique in producing accurate land use/cover maps and change statistics for the central part of Jordan, which is valuable to monitor urban expansion effectively over a time.

The change detection results of the study area show that urban/built-up areas covered 174.2 km² (9%) in 1987, 259.9 km² (13.4%) in 1999 and 394.3 km² (20.4%) in 2005. This represents a net increased of 220 km², which is mainly attributed to the fast increase population due to large rural-urban migration, representing loss of agricultural lands by 99 km² over the period from 1987-2005. In particular, during the period of 1987 to 1999 a high percentage of agricultural lands were converted to urban areas, while from 1999 to 2005 the urban expansion increase toward bare lands. However, urban sprawl was increased during the same period, which is considered as a key indicator that urban planning strategy should be given more attention.

The preprocessing stage, such as the geometric corrections of multi-temporal satellite images as well as using the same classification scheme, is very important to enhance the accuracy of the results. In this study, the accuracy of the maps was satisfactory; it confirms that the image processing procedures were effective in producing land use/cover maps from the ASTER image, which are fairly compatible to those, produced from the Landsat data.

The study took the advantage of remote sensing and GIS techniques that are indispensable for dealing with the dynamics of land use/cover change in the central part of Jordan over the last 18 years of the study period. Therefore, it is highly recommended that urban planners and decision makers can use remote sensing and GIS techniques for effective monitoring of urbanization trends. Thus, it will improve their predictions toward the amount of urbanization changes and the location of future built-up areas, and enhance the existing urban strategies for better sustainable land management.

References


