Jordan Journal of Civil Engineering, Volume **4**, No. **3**, **2010**

Mapping the Land Use / Land Cover Changes in the Basalt Area between 1990 and 2005 Using Remote Sensing and GIS

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ABSTRACT

Landsat TM data in combination with the appropriate multispectral bands were used to investigate land cover changes for the periods of 1990–2000 and 2000–2005 in Amman -Zarqa Basin, North East of Jordan. The results indicate that urban areas increased from 21.2 km^2 in 1990 to 37.1 km^2 in 2005 and that the agricultural areas expanded from 40.2 km^2 in 1990 to 57.4 km^2 in 2005. Also, the surface water bodies' areas increased from 1.7 km^2 to 1.9 km^2 over the same period. In contrast, the bare soil and basalt rock outcrops decreased from 761.2 km^2 to 727.9 km^2 in the same time. The rate of urban changes between 1990 and 2005 was calculated. It is indicated in this research that the rate of urban growth was 0.96 km^2 / year from 1990 to 2000 and 1.26 km^2 / year from 2000 to 2005. Despite the fact that the cultivation and urbanization caused significant changes in the study area, there are other factors controlling land cover changes including industrial and agricultural development, livestock and cattle farms.

KEYWORDS: Remote sensing, GIS, Land cover, Land use, Amman-Zarqa basin, Basalt aquifer, Jordan.

INTRODUCTION

Remotely sensed data are predominantly used in changes' detection studies. Change detection implies the application of various image analysis techniques to multi-temporal images, in order to quantify variations in the state and spatial distribution of phenomena and objects (Lu *et al*., 2004). This information should then provide land managers with improved understanding of interactions and relationships between anthropogenic and natural phenomena.

Remote sensing is increasingly being used to aid labor intensive ground-based monitoring techniques. It involves the measurement of variations in the reflected electromagnetic radiation of an object or phenomenon, without being in contact with them (Jensen, 1996). Remote sensing is able to provide cost effective information on the state of landscapes on a regular, continuous and near real-time basis, at various temporal and spatial scales (Zhou *et al*., 1998). Satellites, such as Landsat and its associated sensors the Thematic Mapper (TM), Multispectral Scanner (MSS) or Enhanced Thematic Mapper (ETM+), have been successfully employed in studies that aim to highlight variations in vegetation community characteristics, usually by measuring the relationship between observed reflectance and total plant or change cover. Remote sensing has been used to investigate differences in vegetation structure, cover and species' composition as a result of varying land uses (communal, commercial and conservational) and management strategies, but perhaps

Accepted for Publication on 15/7/2010.

the most popular use of remotely sensed data, in rangeland management, is in measuring the change detection in the urban environments (environmental changes).

STUDY AREA LOCATION

The study area lies on the northeast plateau of Jordan within the Amman-Zarqa basin, between Zarqa and Al-Mafraq governorates (Figure 1). It covers an area of about 824 km^2, between latitudes 32° 1' and 32° 23' N and longitudes 36° 6' and 36° 39' E. The basalt flows form the main aquifer in the investigated area. These are highly porous and are considered a scoriaceous reservoir (Bender, 1974). The basalt plateau in Jordan covers a total area of 11103 km^2. The study area consists of three geological groups: Bishriyya, Rimah and Asfar.

METHODOLOGY

Data Collection

Different data sets were used in this study as shown in Tables (1) and (2). These data were used for further processing as will be discussed later.

Table 1: Primary image data used in the study

Type	Source	Date	Resolution
Landsat TM	Internet	August, 1990	30 m
Landsat ETM	Internet	August, 2000	30 m
Landsat TM	RJGC	July, 2005	30 m

Table 2: Secondary data used in the study

Type	Source	Date
Jordan shape file	Digitized from paper map	2009
Basalt shape file	Digitized from paper map	2009

Data Analysis and Results

In remote sensing, digital image processing has become important due to two principle areas of application. Firstly, the improvement of the spectral information for visual interpretation and secondly, the processing of image data for computer assisted classification. The whole task of digital image processing revolves around increasing spectral separability of the object features in the image (Singh, 1988).

Image enhancement is utilized to improve the visual interpretability of an image by increasing the apparent distinction between the features. The process of visually interpreting digitally enhanced imagery attempts to optimize the complementary abilities of the human mind and the computer (Shalaby and Tateishi, 2007).

The (PCA) command in ERDAS was used on Landsat TM of 1990, 2000 and 2005. The PCA command undertakes a Principal Component Analysis on a set of image bands and produces a new set of images -components that are uncorrelated with each other and explain progressively less of the variance in the original set of bands (IDRISI, 1998).

The technique is used for data compression since the first two or three components explain 95 to 99 percent of the variance in the original set of bands. In cases like this, the components explaining less than a certain percentage of the variance can be excluded in further processing. It is also useful in the analysis of time series data (IDRISI, 1998). The PCA removes the redundancy between bands and effectively reduces the number of bands within an image without losing overall information contents (Wilkie and Finn, 1996). In PCA, most information will be transformed into the first component and the information content decreases with an increasing number of PCA components (Worawattanamateekul *et al.*, 2000). Worawattanamateekul *et al.* (2000) successfully examined the potential of Principal Components Analysis techniques and satellite remote sensing in estimating irrigated paddy cultivated areas in a test site in Indonesia. Lee *et al.* (2000) used the PCA to reveal some of the temporal – spatial dynamics of land cover change in China from 1982 to 1999.

In order to use the PCA command, it was necessary to define the best combination of bands that could be used to extract the required information. Since this research aimed to investigate land use change, bands TM1, TM3, TM4 and TM5 were selected. This decision was based on recommendations given by Campell (1996), Wilkie and Finn (1996) and Barrett and Curtis (1999).

The first component generated by the PCA command from the Landsat TM of 1990, 2000 and 2005 were selected for further analysis. It was the clearest component that shows a clear boundary between the different land uses.

This component for each year was subjected to on-screen digitizing in order to build the land use map for 1990, 2000 and 2005. Longley *et al*. (2001) argued that digitizing on- screen is the simplest method to create vectors from raster layers. This method is widely used for selective capture of land parcels, buildings and utility assets (Longley *et al*., 2001).

After digitizing, the land maps' uses were exported to ArcGIS 9.3 software, and then the area of each class was calculated. The general change detection was evaluated between 1990 and 2005 using ArcGIS 9.3. Since the images were acquired from the same season, the changes between them reflected the real land cover / land use change between 1990 and 2005. In addition, changes between each two sequent images were detected to reflect the trend. Since all the images were taken at the end of the growing season, changes between them reflected the trend of cultivated and urban land change.

RESULTS AND DISCUSSION

The classification produced three land-use/cover maps from TM 1990, ETM+ 2000 and TM5 2005 Landsat images of the study area. The classification categorized the area into four main land-use/cover types as shown in Table (3). The classified land-use/cover maps of the basalt area are shown in Figure (2).

Table 3: Description of the main land-use/cover types in the study area

Land-use/cover type	Description
Cultivated Area	Fruits and vegetation farms
Water Areas	Surface areas covered with water
Urban Areas	Areas with buildings and factories
Other	Areas such as bare soil and rock

Three land use maps have been prepared using the available satellite images for the years 1990, 2000 and 2005 (Table 4 and Figure 3).

In 1990 (Figure 4), about 92 % of the study area was covered with bare soil and basalt rocks, while the other classes covered (4.87%) cultivated areas, (2.57%) urban areas and (0.2%) water bodies, as described in Table 4.

In 2000 (Figure 5), the cultivated areas, urban, water and bare soil and rocks covered 5.02%, 3.74%, 0.22% and 91.02 %, respectively.

In 2005 (Figure 6), cultivated, urban and water areas increased in their extents and covered 6.96%, 4.50% and 0.23%, respectively, while the bare soil and rock areas were reduced to 88.31%. Based on Table (4), it appears that cultivated, urban and water areas have increased on the expense of bare soil and rock areas.

Table (4) shows that there is a continuous increase in urbanization and agricultural activities in the area between 1990 and 2000.

Based on information collected from the local community and experts from the Natural Resources Authority, this change is a result of:

1- increase in population which led to more urbanization;
2- more investments in the agricultural sector.

Table 4: Land use types of the basalt catchment's area in 1990, 2000 and 2005

Land cover/Landuse type (Class)	1990 (%)	2000 (%)	2005 (%)
Cultivated areas	4.87	5.02	6.96
Urban	2.57	3.74	4.50
Water	0.20	0.22	0.23
Bare soil and rocks	92.36	91.02	88.31
Total	**100**	**100**	**100**

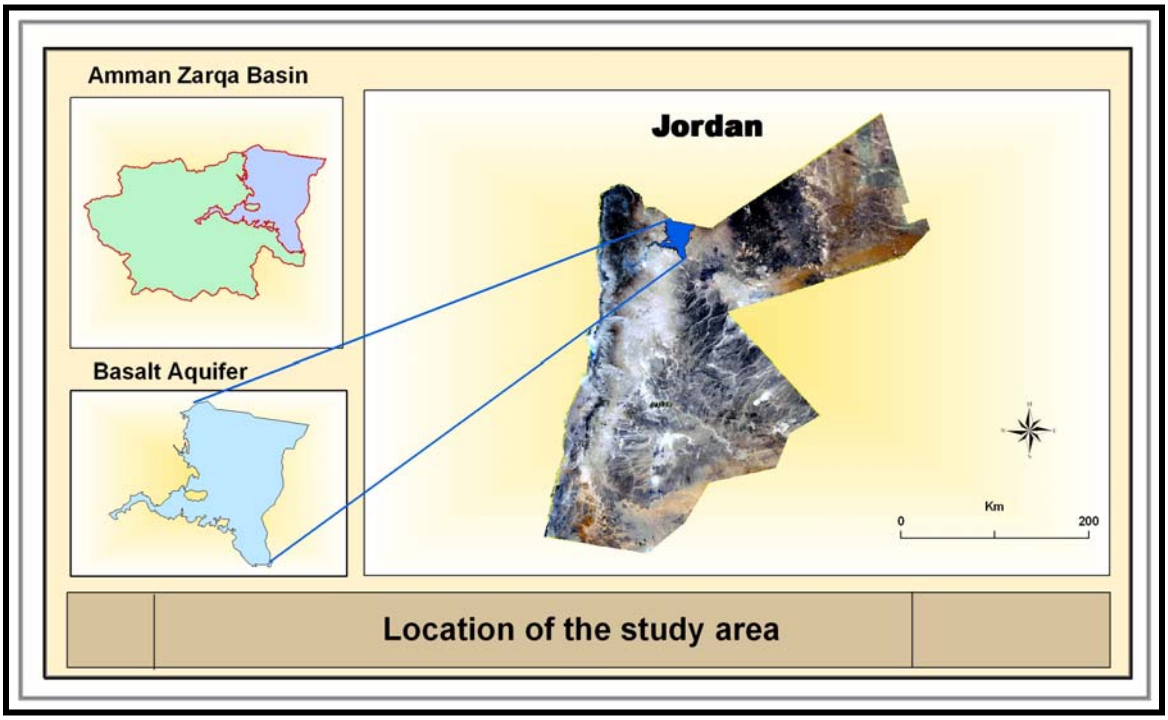

Figure 1: Location of the Study Area

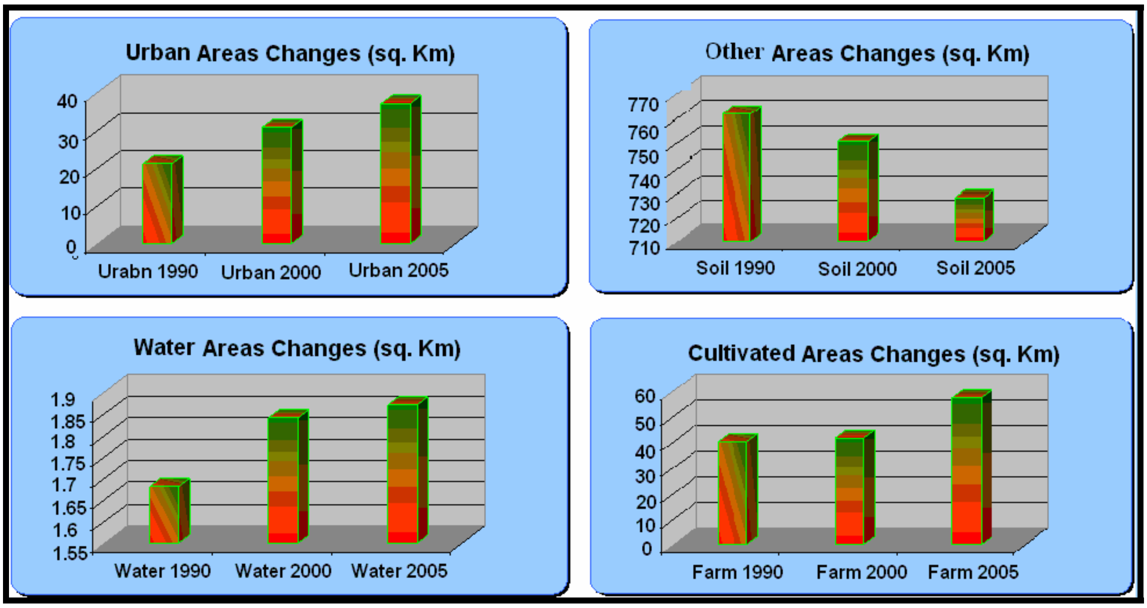

Figure 2: Water, Urban, Cultivated and Other Area Changes between 1990 and 2005

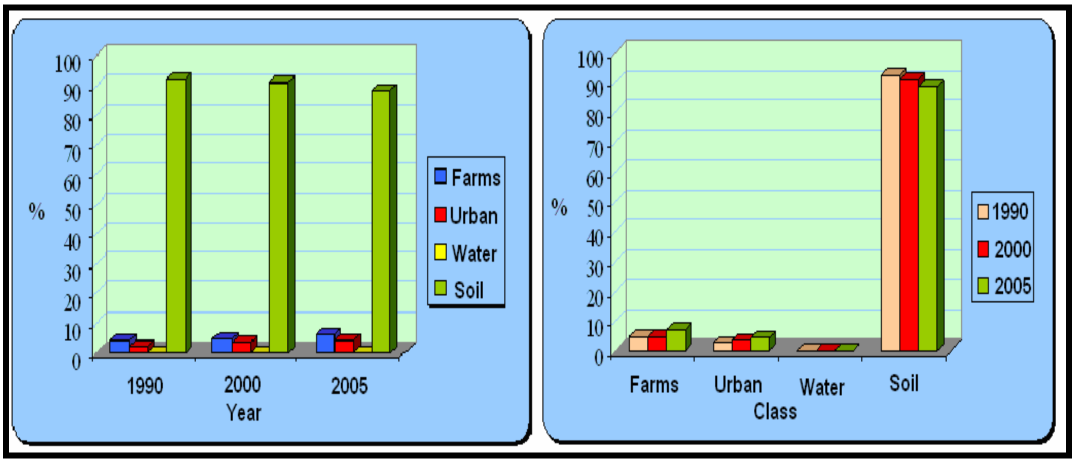

Figure 3: Land Use Types in the Study Area in 1990, 2000 and 2005

Table 5: Land use changes in 1990-2000 and 2000-2005 periods

Land cover/ Land use \ Class	1990-2000 period		2000-2005 period	
	km^2	%	km^2	%
Cultivated areas	+ 1.20	+ 2.99	16.0	+ 38.7
Urban areas	+ 9.59	+ 45.2	6.31	+ 20.49
Water areas	+ 0.16	+ 9.45	0.04	+ 1.97
Soil areas	-10.94	-1.44	-22.35	-2.98

Table (5) provides a summary of land cover/ land use changes between 1990 and 2000 and between 2000 and 2005**.** It shows that the overall increase in urbanization and agricultural activities in the study area between 1990 and 2005 is approximately 33.1 km^2.

SUMMARY AND CONCLUSIONS

Based on the results of this research, there is a strong evidence that tremendous changes in the land use/cover occurred in the study area during the past two decades.

In the basalt aquifer area, land cover/ land use types can be grouped into four major groups; namely agriculture (tree farms and vegetable farms), urban (buildings, infrastructure and factories), water bodies and bare soil and basalt rocks. The percent of changes in land use is determined for the total of the study area as follows:

- Increase in cultivated cover area (tree farms and vegetable farms) by 2.99 % from 1990-2000 and by 38.7 % from 2000-2005.
- Increase in urban cover area (buildings, infrastructure and factories) by 45.2 % from 1990-2000 and by 20.49 % from 2000-2005.
- Increase in water body areas by 9.45 % from 1990-2000 and by 1.97 % from 2000-2005.
- Decrease in bare soil and rock areas.

This research showed that remote sensing, mainly satellite imagery and GIS techniques, are able to assess land use / land cover changes in terms of pattern and quantity in a fast and economic way than the traditional procedures of land surveys.

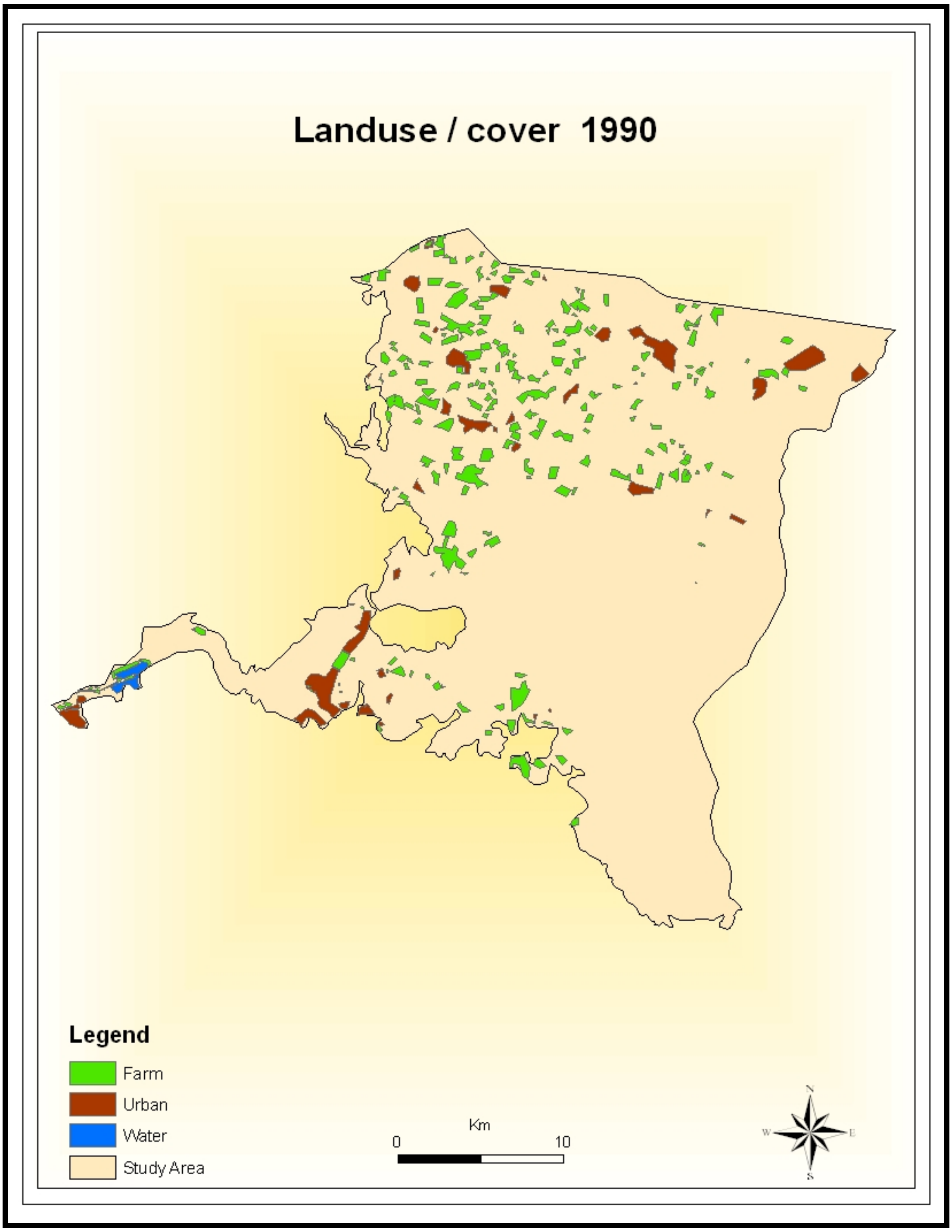

Figure 4: Land Uses in the Study Area (1990)

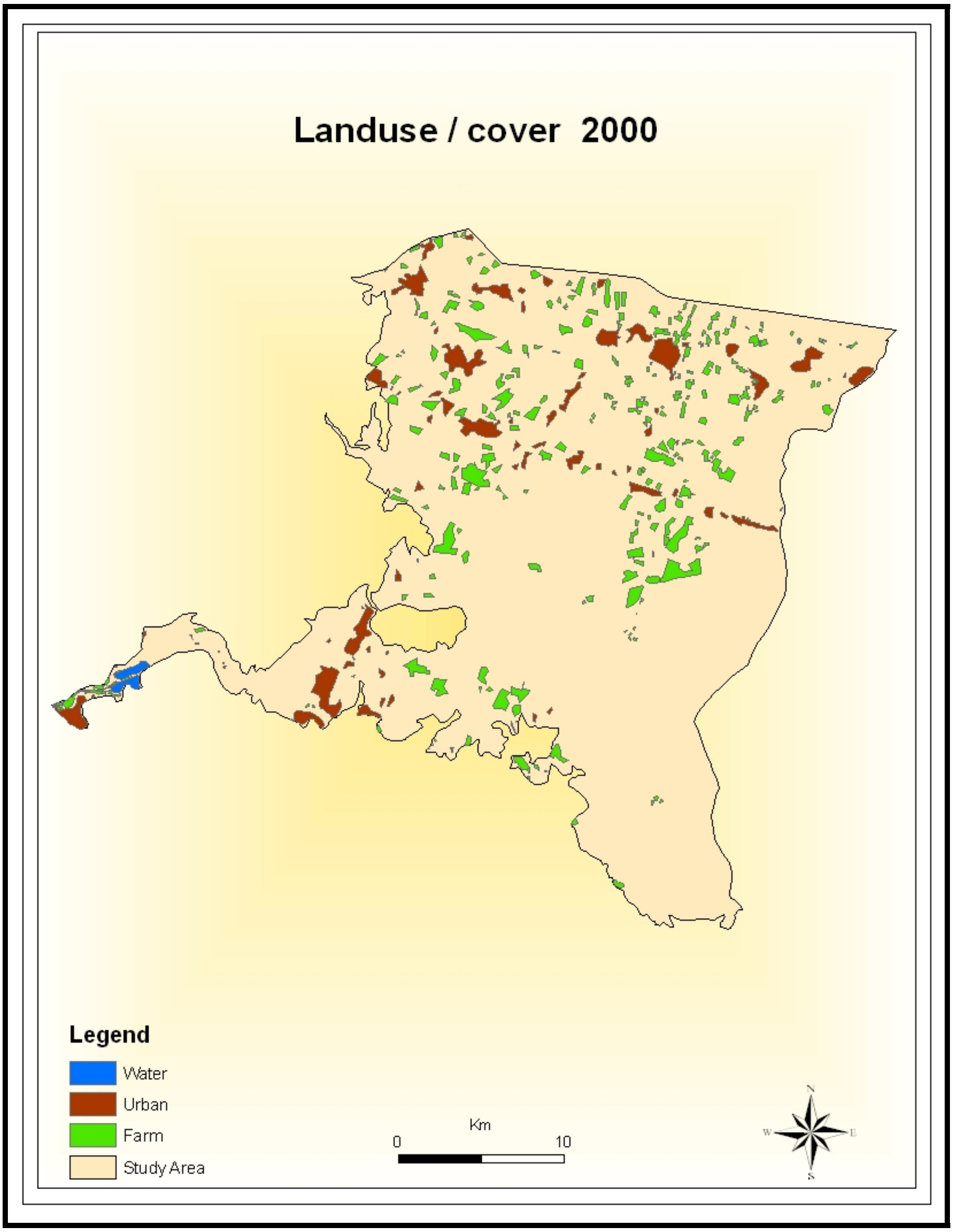

Figure 5: Land Uses in the Study Area (2000)

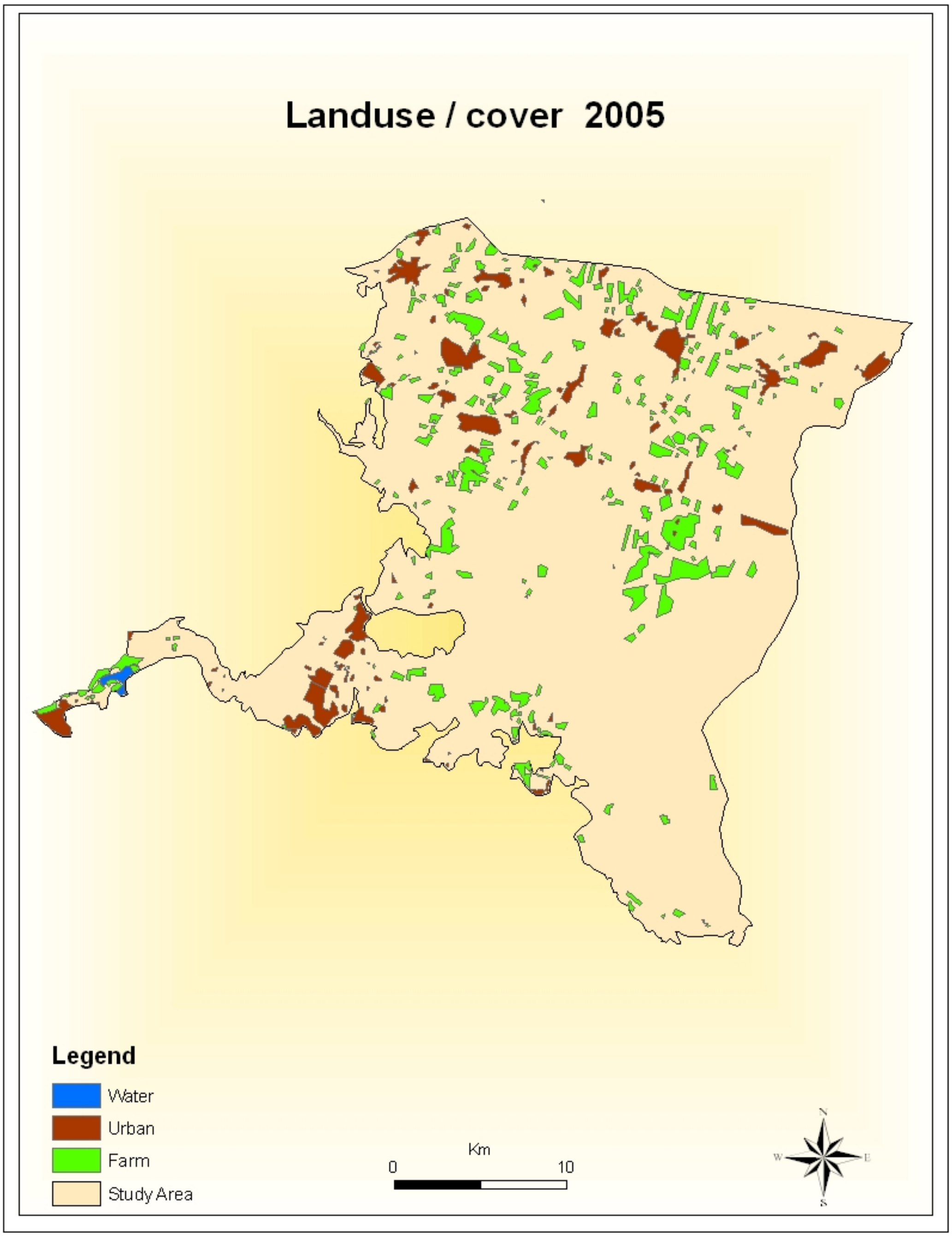

Figure 6: Land Uses in the Study Area (2005)

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