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Study of Urban Expansion in Jordanian Cities Using GIS and Remoth Sensing

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Abstract: Urban environments are among the most dynamic systems on earth. Rapid urban expansion necessitates proper planning to avoid profound negative environmental and socioeconomic impacts. Geographic Information Systems (GIS) and Remote Sensing (RS) technologies provide very efficient tools to collect and analyze the information necessary to detect changes in urban areas that conventional surveying technology can't deliver in a timely and cost effective manner. GIS and RS techniques were used in this work to locate and estimate the expansion of urban areas in three Jordanian cities: Amman, Ma'daba and Irbid. Rapid urbanization and industrialization have caused not only social problems, but also environmental and socioeconomic problems in most of the Jordanian cities. Aerial photographs and LandSat images were used to identify urbanized areas and to quantify urban expansion in the above-mentioned cities for periods dating from 1918 to 2002. The results show a massive urban expansion in these cities. The urban area of Amman increased from 0.3 km^2 in 1918 to 162.9 km^2 in the year 2002. The city of Ma'daba expanded from 0.3 km^2 to 11.2 km^2 in the span of eighty-four years from 1918 to 2002. Meanwhile, the urban area of Irbid increased from 1.8 km^2 to 38.2 km^2 over a period of almost fifty years from 1953 to 2000. The entrance of war-time refugees and internal migration of Jordanians over the years constitute the reason for this irregular but magnificent urban growth. Additionally, the study shows that urbanization in these three cities has found concentration near major roads and fertile lands.

Keywords: Urban expansion, Remote Sensing, GIS, Urban Change Detection.

1. Introduction

Urbanization is one of the most evident global changes. In the last 200 years, while the world population has increased six fold, urban populations have multiplied to over 100 times there original number [1]. Today, approximately 50% of the world's population lives in urban areas [2]. Urban environment basically consists of built up area, i.e. buildings, roads, industries, business areas, parks etc. and natural features such as vegetation cover, soil and water inside urban activity zone.

Rapid growth of the world's cities has exerted heavy pressure on land and other resources surrounding them and has resulted in serious environmental and social problems.

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The spread of urban areas has also resulted in the loss of natural vegetation, the depletion of open spaces, and a general decline in the spatial extent and connectivity of wetlands and wildlife habitat. Moreover, infrastructures have been pushed to their limits in order to attend to the needs of their increasing populations. As a consequence, the planning and management of growing urban areas has become more and more challenging. A better understanding of the processes of urban growth and its effects is required for more effective urban planning and management [3].

Management of the urban environment involves procedures for monitoring and modeling which require a reliable information database and robust technologies. Remote Sensing and GIS techniques are used for this purpose [4, 5, 6, 7, 8, 9].

Most Jordanian cities are suffering from rapid urban growth which is due to increased immigration from neighboring countries as well as the urban migration of Jordanians from outlying rural areas. Urban expansion in all directions has resulted in the destruction of agricultural lands and natural resources. The objectives of this study are to quantify urban expansion in three Jordanian cities: Amman, Ma'daba and Irbid (see Figure 1), to understand the principles causes of this uncontrolled growth, and to systematically isolate the patterns of this expansion.

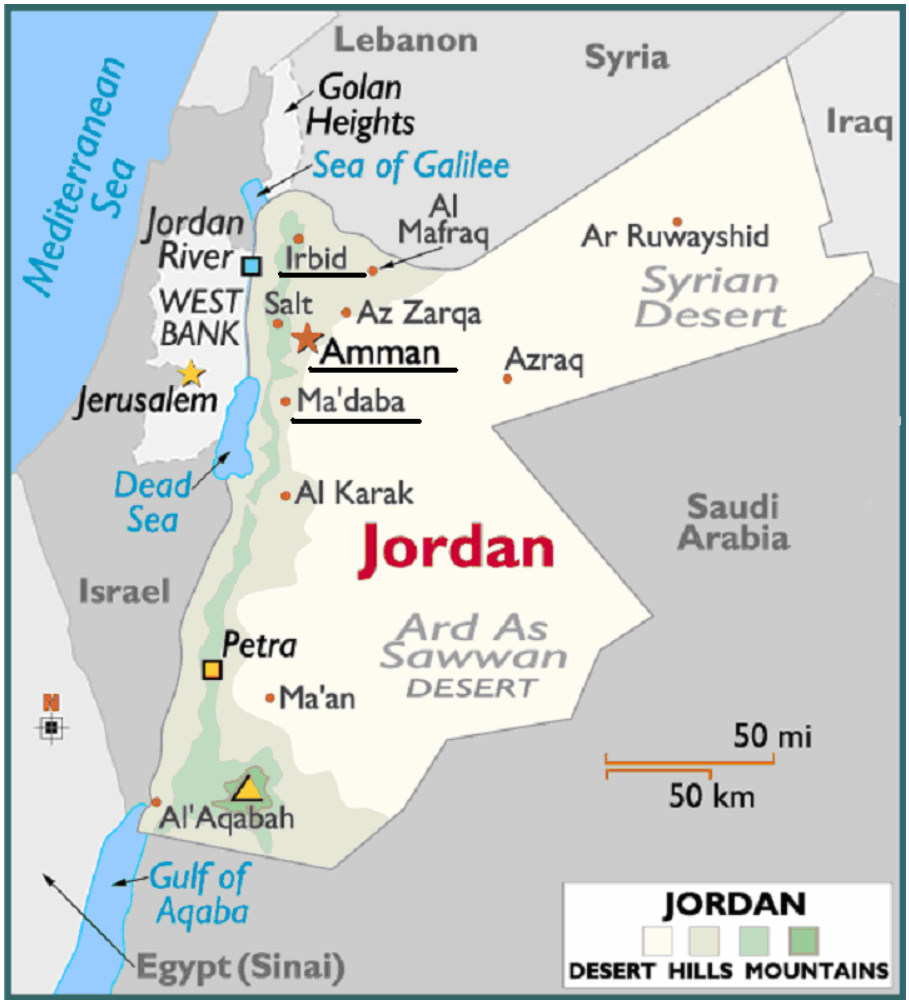

Figure 1. Location map of studied cities.

Remote Sensing and GIS technologies were used in this study for processing data for the years 1918 to 2002 in order to obtain urban changes during this period. These technologies may be used to help planners and decision makers get a global overview of urban changes in Jordanian cities during the past century and to plan effectively for the future.

The three cities in this study are located on mountain plateaus. The highlands of Jordan separate the Jordan Valley and its outlying areas from the plains of the eastern desert. This region extends the entire length of the western part of the country and hosts most of Jordan's main population centers such as Amman, Az-Zarqa, Irbid, Jerash, Karak, and Ma'daba. These areas receive Jordan's highest rainfall totals and are the most richly vegetated regions of the country. The region has been under the domination of the Ammonite, Assyrian, Persian, Greek, Roman, Byzantine, Arab and Ottoman civilizations. Amman is the capital of Jordan and populated by more than two millions inhabitants in 2002. Amman is located at 32° N and 36° E and has a Mediterranean climate; it is situated in the mountain heights plateau of Jordan and limited by the desert from the East and South with an elevation ranging from 400 m to 1000 m above sea level. Before urbanization, the northern and western parts of Amman area were considered as fertile lands suitable for cereals cultivation with a production enough to subsidize the needs of the central part of Jordan. Ma'daba is located at 30 km to the south west of the Amman, at 800 m above sea level. It is populated by more than 135000 inhabitants in 2002. This city is considered as one of the historical and cultural sites in the country due to its ancient monuments. The soil in this area is yellow red and deep red of Mediterranean type, which is suitable for field crops. Irbid is situated in the Northern Region of Jordan; 70 km north of the capital city Amman at 400m above see level. It is the second city of Jordan and counts 250,000 inhabitants in 2002 (Irbid governorate is estimated at one million inhabitants). It lies in the centre of the main agricultural area of Jordan. The soil in this area is deep red and suitable for cereals cultivation.

2. Materials and Methods

The following data was used in this study:

- Multi-date Landsat TM and ETM + images (Figure. 2a and Figure. 2b);
- Multi-date aerial photographs (Figure. 2c);
- SPOT 2002;
- IKONOS 2002; and
- Administration and topographic maps.

Remotely-tracked data and GIS were used to evaluate urban growth in Amman, Ma'daba, and Irbid for the following periods: 1918 - 1953, 1953 - 1983, and 1983 – 2002 and based on:

- Landsat TM (Resolution 30m) for the year 1983;
- Landsat ETM+ (resolution 30m and 15m) for the year 2002; and
- Aerial photographs for the years 1918, 1953, 1983, and 2000.

Ortho-photos were produced from the aerial photographs covering a part of the study area for the dates 1918, 1953, 1983, 2000 using GPS points and RS software. SPOT and IKONOS images were used to validate the obtained results. Spatial and spectral image processing techniques were applied as follows:

- Spectral processing to Landsat TM and ETM+ images;
- Geometric correction of all aerial photographs and Landsat images; and
- Classification:

The aerial photographs are visually interpreted to get classification for the years 1918, 1953, 1983 and 2000. A maximum likelihood classification is performed for Landsat datasets to identify the urban changes in Amman and Ma'daba from 1983 to 2002. The obtained results were examined and modified spectrally and spatially using ground information

and IKONOS and SPOT satellite data. The small spots of vegetation and open areas inside the urban areas were added to urban zones. The class of urban area was extracted for the different dates.

The GIS is used to lay out the roads on the previous images using the road maps and photo interpretation, in order to study the correlation between the urban growth and the location of these roads (Figure 2).

Many spectral analyses are applied to determine the main elements of the studied area: road network, built up area, vegetation, etc. This helps in the separation between urban and non urban area. These spectral analyses include the high pass filter, histogram equalization, and vegetation index.

The fertile lands are analyzed based on: soil maps, the geometric type of parcels, color, humidity and the value of vegetation index.

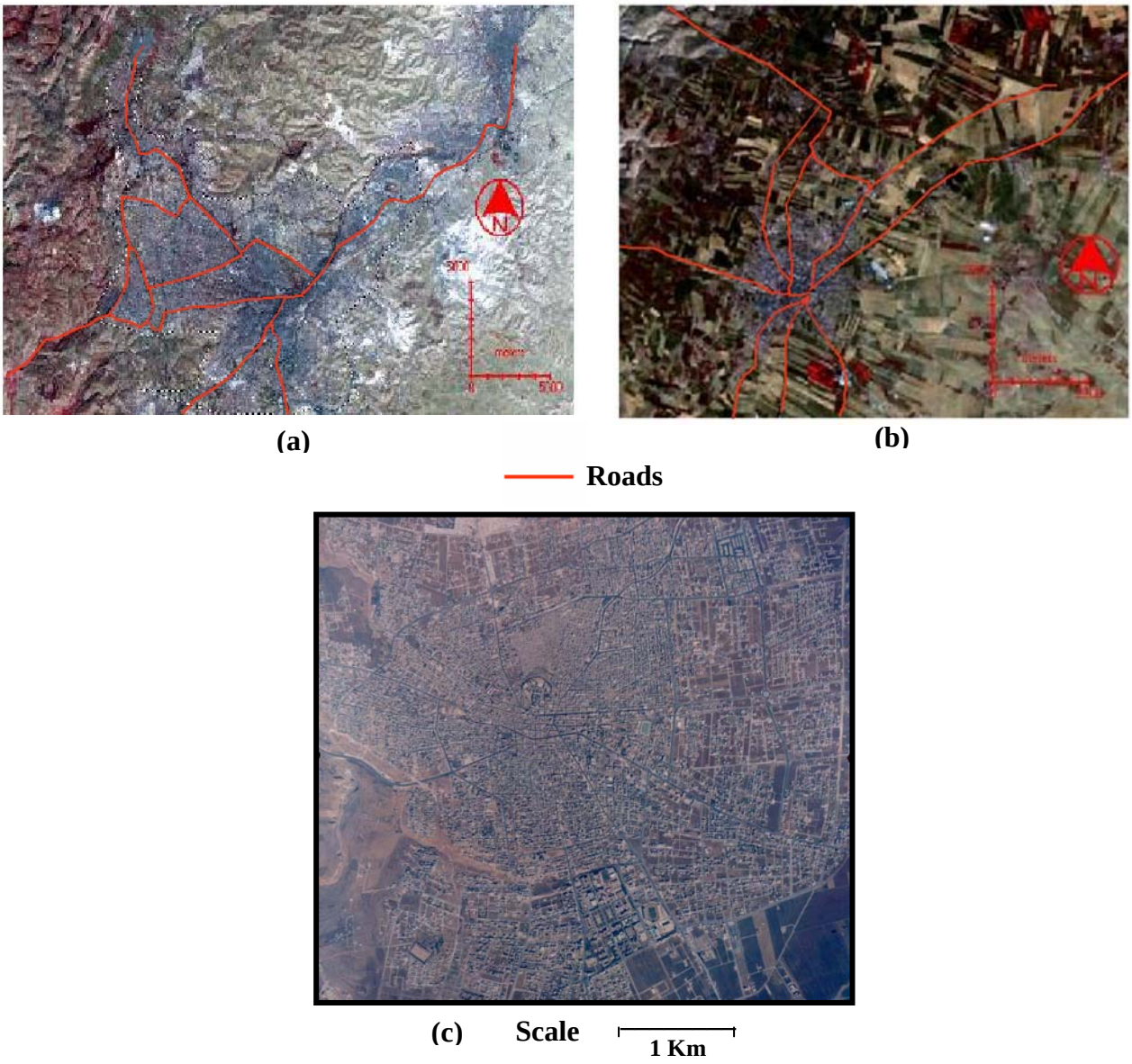

Figure 2. (a) Landsat image of Amman city acquired in 2002. (b) Landsat image of Ma'daba city acquired in 2002. (c) Aerial photograph of Irbid city acquired in 2000.

3. Results

Urban expansion of the city of Amman

The results of the intersection of maximum likelihood classification and aerial photographs interpretation for urban areas are shown in Figure 3 for with their corresponding dates. Using GIS software and different resulting layers, we were able to evaluate urban zones at different dates (see Table 1 and Figure. 4). The urban area for the city of Amman increased from 0.321 km^2 to 162.924 km^2 for the period from 1918 to 2002. Table 2 and Figure 5 illustrate zones of urban expansion during the different periods.

Three large urban expansions were observed during the periods dating from 1918 to 1953, 1953 to 1983, and from 1983 to 2002. The first expansion is estimated at 4.123 km^2, which represents an increase of 1,284% over the period of thirty-five years from 1918 to 1953.

The second expansion is estimated at 101 km^2, which represents an increase of 2,277% for the years dating from 1953 to 1983. The third urban expansion is estimated at 57 km^2, which represents a growth of 54% over the period from 1983 to 2002.

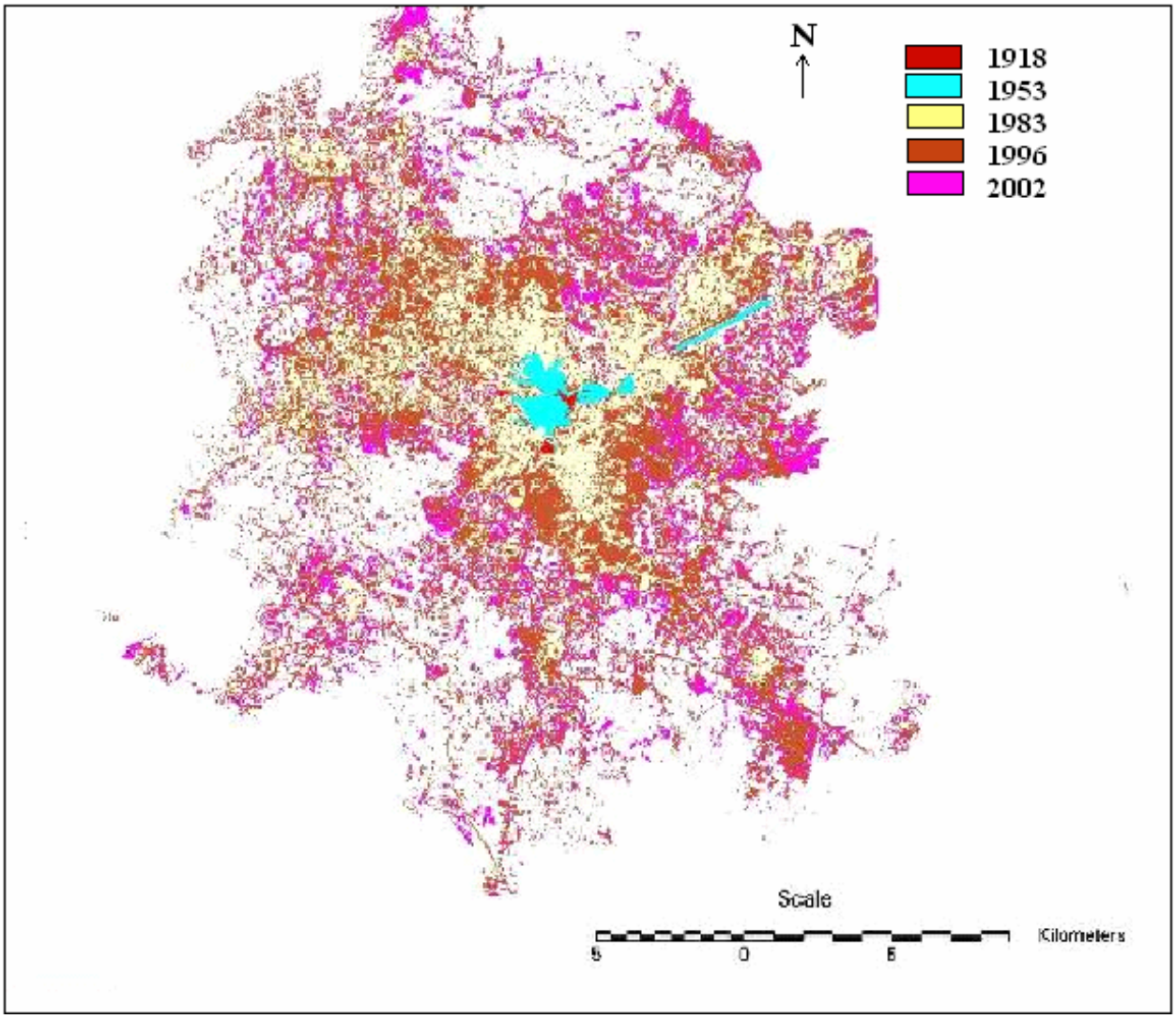

Figure 3. Urban area expansion in Amman from 1918 to 2002

Table 1. Areas (in km^2) of urban zones in Amman over the period dating from 1918 to 2002

Date	1918	1953	1983	1996	2002
Urban area (in km^2)	0.321	4.444	105.675	150.764	162.924

Table 2. Area and percentage of urban expansion in Amman for various periods

Period	1918 - 1953	1953 - 1983	1983 - 2002
Urban change in km^2	+ 4.123	+ 101.231	+ 57.249
Percentage of urban change	+ 1,284%	+ 2,277%	54%

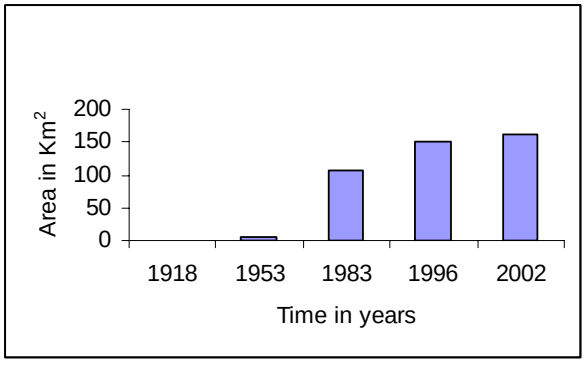

Figure 4. Histogram of the urban areas of Amman for various years

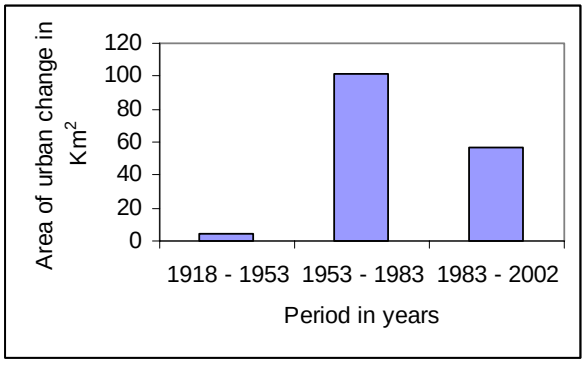

Figure 5. Histogram of urban changes over various periods in the city of Amman.

We found that urbanization in Amman followed four major axes: (I) the first axis is oriented toward the north-east direction and follows the road to Zarqa. (II) The second axis is oriented toward the north-west direction and follows the road to the cities of Jerash and Irbid. (III) The third axis is oriented in the westerly direction. A new urban area, Biader Wadi Al-Sir, stretched out over fertile lands to create an industrial and commercial area of the city. (IV) The fourth axis is oriented in the south-easterly direction and follows the new Airport Road. Once again, fertile lands were taken in order to provide a new haven for single family housing areas and university campuses.

Urban expansion of the city of Ma'daba

The results of the intersection of maximum likelihood classification and the interpretation of aerial photographs for the urban areas of Ma'daba are shown in Figure 6 with their corresponding dates. The obtained results were examined and modified spectrally and spatially using ground information and SPOT satellite data. The small spots of vegetation and open areas inside the urban areas were

added to urban zones according to the definition of urban area in the Introduction.

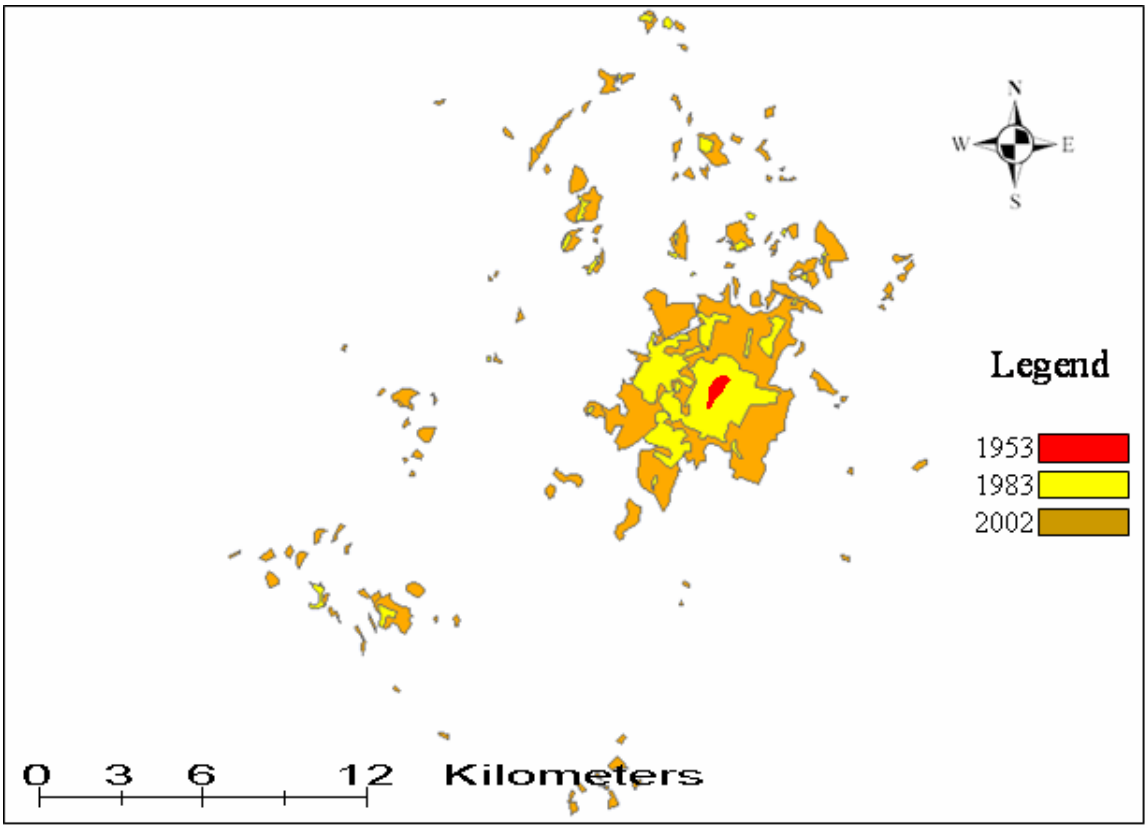

Figure 6. Urban area expansion in Ma'daba over the period dating from 1953 to 2002

Ma'daba's urban area increased from 0.231 km^2 to 11.151 km^2 for the period dating from 1918 to 2002. Table 3 and Figure 7 show great variations in the urban growth of the city over time. Moreover, GIS was used to evaluate the change in urban area for the following periods: 1918 - 1953, 1953 – 1983, and 1983 - 2002. Table 4 and Figure 8 illustrate the geographic areas of urban expansion in Ma'daba.

Two large urban expansions were observed during the periods from 1953 to 1983 and 1983 to 2002. The first expansion is estimated at 3.309 km^2, which represents an increase of 1,099% over the period from 1953 to 1983. The second expansion is estimated at 7.541 km^2, which represents a growth of 209% over the period dating from 1983 to 2002.

Ma'daba's urbanization follows two major axes: (I) the first axis is oriented northeasterly and follows a major road connecting Ma'daba with Airport Highway. (II) The second axis is oriented towards the north and follows a major road which connects the city with Amman. Both roads pass through Ma'daba's most fertile lands.

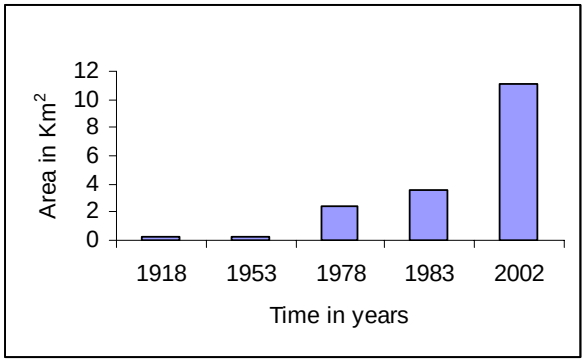

Figure 7. Histogram of the urban areas of Ma'daba for various years

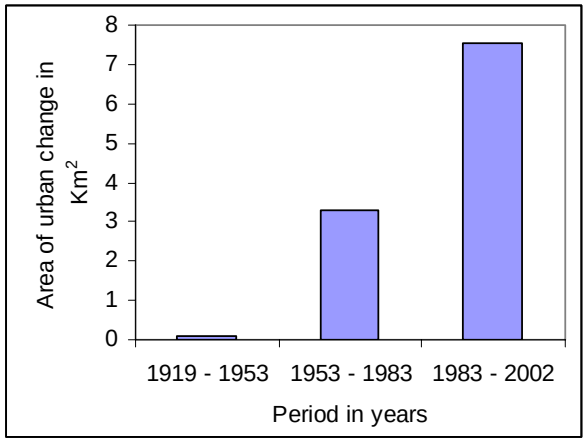

Figure 8. Histogram of Ma'daba's urban growth during varying periods

Table 3. Area (in km^2) of Ma'daba's urban zone over a period dating from 1918 to 2002

Date	1918	1953	1978	1983	2002
Urban area in km^2	0.231	0.301	2.446	3.610	11.151

Table 4. Area and percentage of urban expansion in Ma'daba for various periods

Period	1919 - 1953	1953 - 1983	1983 - 2002
Urban change in km^2	0.070	3.309	7.541
Percentage of urban change	0.3%	1099%	209%

Urban Expansion of the City of Irbid

The results of urban expansion based on interpretation of aerial photographs from the years 1953, 1983, and 2000 are shown in Figure 9. The urban area of Irbid increased from 1.847 km2 to 38.222 km2 for the period dating 1953 to 2000 (see Table 5 and Figure. 10). The area and percentage of urban expansion over the periods from 1953 to 1983 and 1983 to 2000 are given in Table 6 and illustrated in Figure 11.

Two large urban expansions were observed from 1953 to 1983 and from 1983 to 2000. The first expansion is estimated at 8.061 km^2 and represents an increase of 436% over the period dating from 1953 to 1983. The second expansion is estimated at 28.314 km^2 and represents a growth of 285% over the period dating from 1983 to 2000.

The urbanization in Irbid city from 1953 to 1983 follows two major axes: (I) The first

axis proceeds in a north-easterly direction and follows the roads connecting Irbid with the city of Ramtha and other outlying villages; and (II) the second axis flows toward the south and down the road which leads to Amman. These axes pass through the most fertile lands in the area. Urbanization continued from 1983 to 2000 around the new urban area of 1983 and in the direction of key cities such as Ramtha, Ajloun, Mafraq, Jerash, and Shouneh.

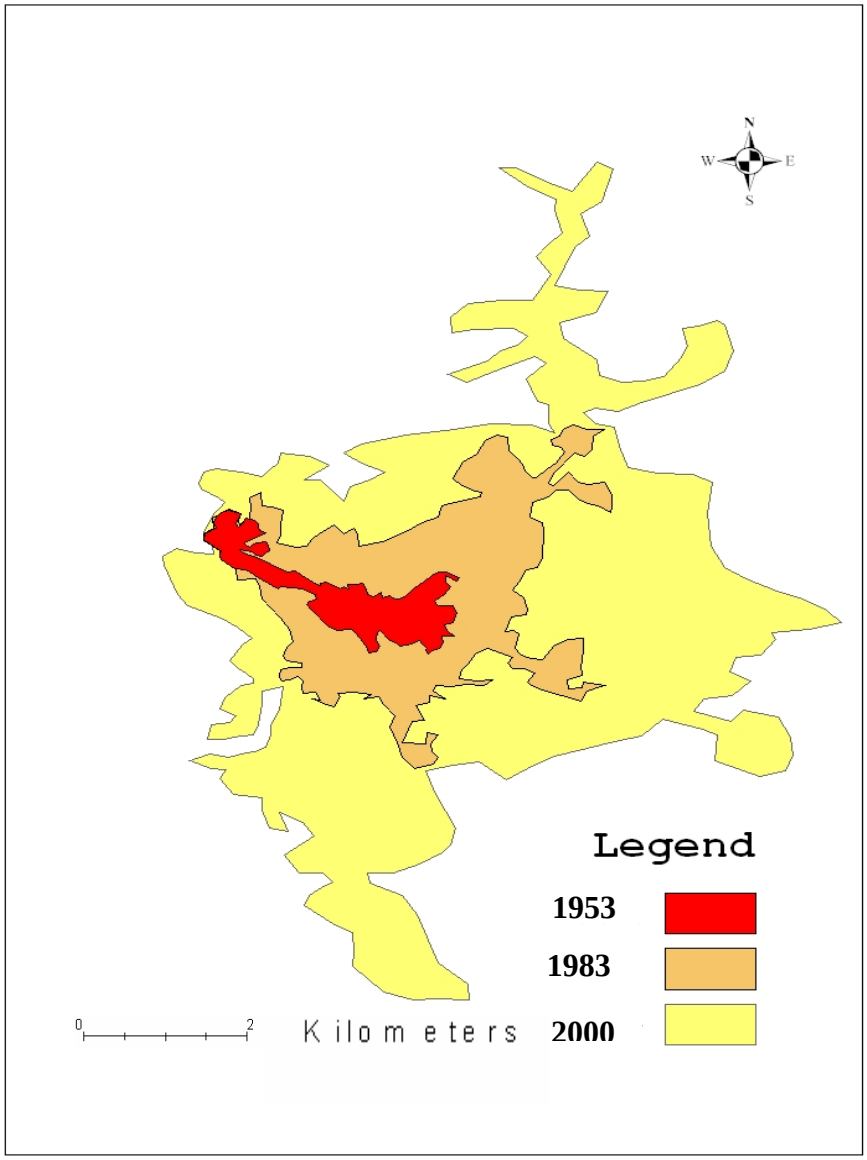

Figure 9. Urban area expansion of Irbid from 1953 to 2000.

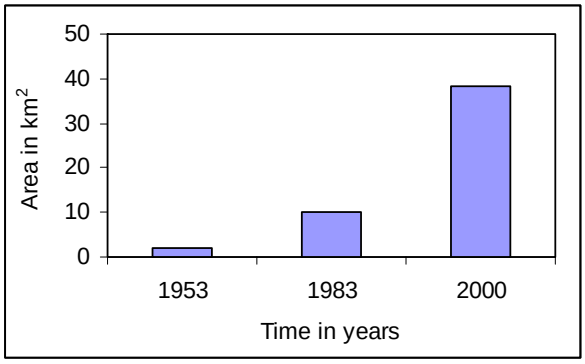

Figure 10. Histogram of the urban areas of Irbid for various years.

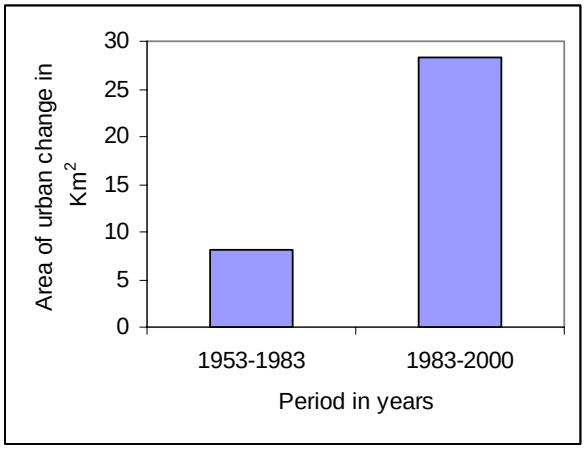

Figure 11. Histogram of Irbid's urban growth during varying periods.

Table 5. Area (in km²) of Irbid's urban zone over the period dating from 1953 to 2000

Date	1953	1983	2000
Urban area in km^2	1.847	9.908	38.222

Table 6. Area and percentage of urban changes in Irbid for various periods

Period	1953-1983	1983-2000
Urban change in km^2	8.061	28.314
Percentage of urban change	436%	285%

4. Discussion

The image and its corresponding classification are geographically linked together using ERDAS software. The obtained classifications were verified by image interpretation based on our experience in image-interpretation. Some features are identified and compared with the obtained classification. This comparison proved that the classifications are accurate. Moreover, soil maps, SPOT and IKONOS images acquired in 2002 and field works demonstrate the accuracy of the classification.

The previous results show different urban expansions in the three given cities over the period dating from 1918 to 2002. It should be noted that these results far exceed natural urban expansion rates due as a result of births

and internal migration. The first urban expansion in Amman occurred during the period dating from 1918 to 1953. The urban area of Amman expanded at a rate of 4 km^2 for this period and represents an increase of 1,284%. The immigration of Palestinians to Jordan during and after the Israeli-Arab War in 1948 and the adoption of Amman as the capital of Jordan are the main reasons for this expansion. The second urban expansion occurred from 1953 to 1983 in the three studied Jordanian cities. Urban expansions in Amman, Ma'daba and Irbid are estimated at 101.2 km^2, 3.3 km^2, and 8.1 km^2 respectively. This extraordinary urban expansion is due to a second immigration of Palestinians to Jordan which was caused by the Israeli-Arab War of 1967. The third urban expansion occurred during the period dating from 1983 to 2002. Urban sprawl in Amman, Ma'daba, and Irbid are estimated at 57.2, 7.5, and 28.3 km^2 respectively. This expansion is a result of the Gulf War which began in 1991. A lot of refugees from Jordanian and Palestinian descent returned from Kuwait and Iraq and settled in the three cities.

This study shows that urbanization in the three cities follows major roads and fertile lands; naturally because of easier transportation and lower land prices. The cities have been planned and built by a diversified group of public departments and private enterprise companies. In general, each of these groups is primarily focused on performing a specific function, offering specialized services, and responding to local political priorities. These decisions are generally based on initial capital costs, rarely on lifecycle costs, and almost never with a consideration of the costs to future generations. Therefore, some refugee's camps and industrial zones were installed on agricultural lands of low prices situated on the suburbs of the cities. Many houses were built around these zones on the fertile lands to use the road network and other infrastructures, which have been built to serve these areas.

According to Chin model [10], the current stage of urban growth in Jordanian cities would fit better in the "suburbanization" phase. The fastest growth is happening just outside of the city core. Technological and economic progress creates greater fluidity in the population with changes in transport and technology allowing the outward dispersal of manufacturing, retail, trade and housing. Moreover, the increase in the standard of living raises the spatial demands of city dwellers.

There is a strong and parallel relationship between land development and transportation infrastructure in the three Jordanian cities. The effect of transportation infrastructure on the development of land has been studied and analyzed by many planners [11, 12, and 13]. Transportation services must be available to provide access before land can be developed, but the demand for development also creates a demand for access, which in turn, is usually responsible for the ultimate provision of a transportation infrastructure [14].

Before urbanization, Amman, Madaba and Irbid areas were considered as fertile lands suitable for cereals cultivation with a production enough to subsidize the needs of Jordan. The population of each city was around few thousands inhabitants before 1918 and has increased hundreds of times in less than a century. The huge increase in population created many planning and environmental problems. Consequently planed and unplanned housing is increasing while green areas are decreasing.

We recommend that urbanization planning in cities take place in conjunction with the protection of the precious fertile lands surrounding them. We recommend, as well, that other lands be improved in order to make them suitable for urbanization while keeping in mind important economical factors. This type of analysis could be applied to all cities in Jordan with the goal of ascertaining their respective patterns of urbanization. We desperately need such studies for better decision-making and planning. This will help, as well, to avoid expanding in the wrong directions, to keep from building in hazardous areas, and to

protect precious fertile lands.

5. References

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