Analyzing the State and Pattern of Urban Growth and City Planning in Amman Using Satellite Images and GIS

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Abstract

Jordan experienced a high rate of urbanization during the last five decades leading to concentration of population in the main cities. This has created high demand for the opening up of huge areas to meet housing, commercial, industrial and other service planning requirements. The objective of this study is to investigate the current pattern of land use and urban servicing and to monitor the trends of urban growth in Amman between 1972 and 2009 using satellite images and GIS. The results showed that the urban core of Amman changed continuously over time with high rates of population growth. Considerable urban expansion was identified with the total settlement areas increasing from 36 km^2 to 250 km^2 at the expense of agricultural land over the time period under study. The Amman city-center has a high population density, and the suburban towns absorbed the potential development, and exhibited an expansionary pattern of urban development. It concentrated along major transportation routes, resulting in different pattern of urban development between the east and west parts of the city. Combination of remote sensing and GIS are useful for understanding the complexities of relationships between urbanization, urban services and agricultural landscape changes.

Keywords: Urbanization, Urban Planning, Amman, Remote Sensing, GIS

1. Introduction

Urbanization is a complex process of change of rural lifestyles into urban ones. It can be defined as the changes that occur in the territorial and socioeconomic progress of an area, including the general transformation of land use categories from being non-developed to developed (Weber 2001). This process is intimately related to the introduction of new modes of technology and transportation, in particular those that allow mobility of the masses (Champion 2001; Pacione 2001; Antrop 2000). Accessibility became the most important factor in landscape change and even in the remote countryside, urbanization processes can be noticed when a region is supported with a good transportation infrastructure.

Urbanization is a major trend in recent years all around the world. Currently, almost half of the world's population live in urban areas and the prospect is that 60% of the world's population will be urban by 2030 and the number of mega cities will reach 100 by 2025 (Avelar, Zah, and Tavares-Corrêa 2009). The population of the Arab world is on the verge of shifting from being predominantly rural to urban. As of 2010, more than half of the Arab world's human population has resided in urban areas,

and by 2050, urban inhabitants will account for approximately 75% of the Arab world's population (Mirkin 2010).

Several decades of population explosion and accelerated urban growth have had profound environmental and socioeconomic impacts felt in both developing and developed countries alike (Wu et al. 2011; Chen et al. 2011). Understanding the environmental and social impacts brought on by urbanization is critical to those who study urban dynamics and those who must manage resources and provide services in these rapidly changing environments (Su et al. 2011; Yeh and Huang 2009).

Urbanization is a complex process of converting rural land uses to urban land uses and has caused various impacts on ecosystem structure, function, and dynamics (Antrop and Van Eetvelde 2000; Pickett et al. 2001; Luck and Wu 2002). One of the major problems for most urbanized countries and regions is the conversion of agricultural land into developed land uses, which is a direct result of urbanization (Batisani and Yarnal 2009; OECD 2001). High population density in urban areas has resulted in a large-scale modification of the landscape and environment. As a city grows, the increasing concentration of population and economic activities demands more land to be developed for public infrastructure (e.g. roads, water facilities, and utilities), housing, and industrial and commercial uses.

Planning and managing urban spaces depends on the knowledge of the underlying driving forces, combined with the chronology and impacts of urbanization (Klosterman 1999). City planners, economists and resource managers therefore need advanced methods and a comprehensive knowledge of the cities under their jurisdiction to make the informed decisions necessary to guide sustainable development in rapidly changing urban environments (Pham et al. 2011). However, urban landscapes are dynamic and continuously changing as a city grows, satellite images can also be used to detect the spatial characteristics of landscape pattern through time (Herold et al. 2003; Dietzel et al. 2005).

Remote sensing provides spatially consistent coverage of large areas with both high spatial detail and temporal frequency, which is useful for examining historical time series (Jensen and Cowen 1999). Moreover, remote sensing data is effective to monitor the land use change, especially where information on land use is inconsistent and insufficient. Therefore, with increased availability and improved multi-spatial and multi-temporal resolution, remote sensing can be applied to monitor and analyze urban expansion and land use changes in a timely and cost-effective manner.

The combination of remote sensing and Geographic Information System (GIS) can provide spatially consistent and detailed information about urban service structure, permitting more accurate representation and understanding of urban growth processes (Deng et al. 2009). They have been recognized as powerful and effective tools for detecting the spatiotemporal dynamics of landscapes changes at various scales (Geri, Amici, and Rocchini 2010; Serra, Pons, and Saurì 2008). Landscape ecology offers theories and methods that can contribute to the formulation of sustainability strategies through a better understanding of landscape transformation processes (Ribeiro and Lovett 2009).

The exponential increase in population has fueled a significant demographic shift in Jordan so more than 80% of the Jordanian population is living in urban areas (DOS 2010). While this population growth is significant in its magnitude, the social and ecological footprint of natural resource consumption and use required to sustain urban populations is even greater. The land use and cover changes accompanying urbanization impacts natural ecosystems at multiple spatial scales.

The focus grows, out of the concern that unlike other variations in agricultural land availability, it is unlikely that agricultural land converted to developed uses will ever become available again for agricultural production (Thompson and Prokopy 2009). Therefore, the high visibility of agricultural land conversion to developed uses has motivated many policy makers, communities, and farmers to call for action to address this alarming issue. However, few studies has been concerned with development of urban growth and development of Amman city (Oroud and Rousan 2004; Al-Rawashdeh and Saleh 2006).

The main objective of this study is to investigate the dynamics of urban landscapes in response to rapid urbanization and service allocation, for Amman city, one of the most populated and fastest growing cities in Jordan and in the Middle East. More specifically, our objectives are to: (1)

characterize intra-level urban landscape transformations in Amman between 1972 and 2009; and (2) quantify relationships between landscape transformations, urbanization patterns and services.

2. Study Area and Input Data

2.1. Study Area - Amman

Jordan is a small country, whose population is concentrated predominantly along the Mediterranean climate, in close proximity to its major cities Amman, Zarqa, Madaba, Salt and Irbid. The population of these cities and their immediate hinterland amounts to some 75% of the Jordan residents as indicated in figure (1). The study focuses on Amman city and its surrounding suburbs with an area of around 900 km^2, which is part of greater Amman-area. Amman represents the main economic centre of the country, with over 80% of all industrial and service activities located in the capital city together with the industrial suburbs and peri-urban zone toward Zarqa.

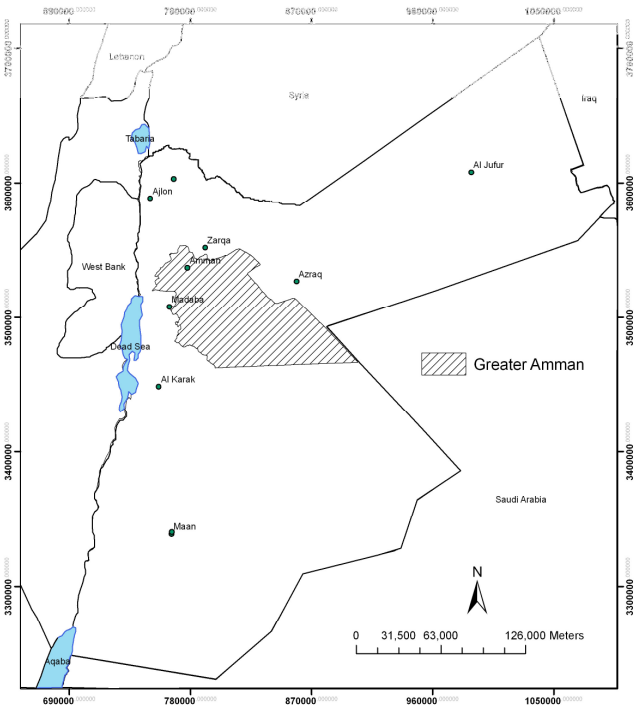
2.2. Data Sources

Sets of multi-spectral and multi-temporal satellite data for Amman were obtained for the years 1972–2009 from the USGS, USA. Cloud cover was less than 10% in all images, and the images were rectified geometrically to a common Universal Transverse Mercator coordinate system. The demographic analysis of the population characteristics in Amman was based on the population census and Household survey in Amman carried out by department of statistics at different survey periods.

3. Methodology

The assessment of the evolution trends of the Amman has been carried out. The methodological approach includes two main steps: first is to define the current land use pattern, locate the spatial distribution of urban services, and second is to investigate the trend of urban growth during the period from 1972 to 2009.

Figure 1: Location of Greater Amman Municipilities.



3.1. Demographic Analysis and Urban Services

This step includes performing the demographic analysis of the population characteristics in Amman based on the published population census and household survey. The population census was used in order to calculate the growth rate, density distribution and household characteristics of the Amman population. The GIS facilities was used to perform the spatial analysis of urban services in Amman such as roads, different types of education and health centers, etc. Finally, the urban growth pattern and service distribution were used to analyze urban growth within the context of urban planning.

3.2. Land Cover Classification

This study used mid-resolution Landsat images for land cover classification and urban growth monitoring. The surface land cover maps of the city were generated from satellite images using the supervised maximum-likelihood classification method (Pham and Yamaguchi 2007). The results of this classification method were validated against the reference data sources such as published land use maps. The accuracy of the classification is around 84% in 1972 and 89% in 2009. The online interpretation was used for delination of urban classes in the study raea in the monitoring peroid. The land cover categories are then integrated in a GIS environment to calculate the land use types and their rate of change.

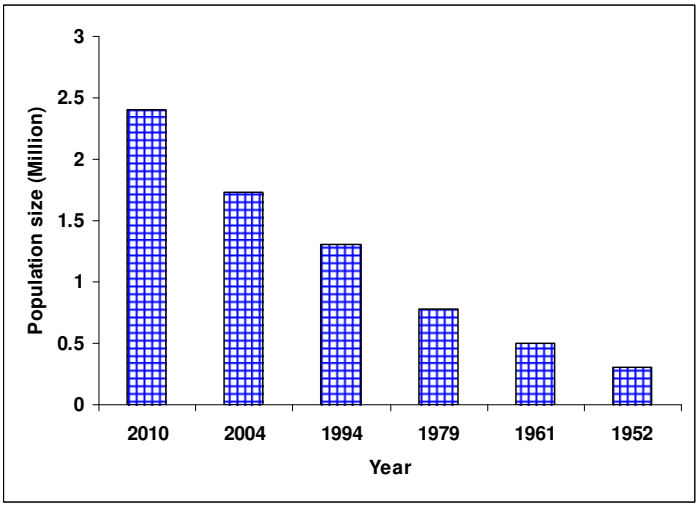
4. Result and Discussion

4.1. Trends of Demographic Growth

The Urbanization in Jordan is the result of a rapid population growth caused by high natural growth and a flow of refugees. This essentially unplanned and therefore uncontrolled process results in the destruction of natural landscape and ecological footprint. Historically, urban immigration in Amman has increased at rates that have exceeded those of infrastructure development in the destination cities, resulting in concentration of population and increasing of population density. Continuous migration flows have largely contributed to an increase of the population density and built-up areas, one of the main effects of such a situation is the transformation of settlement structures and urban services.

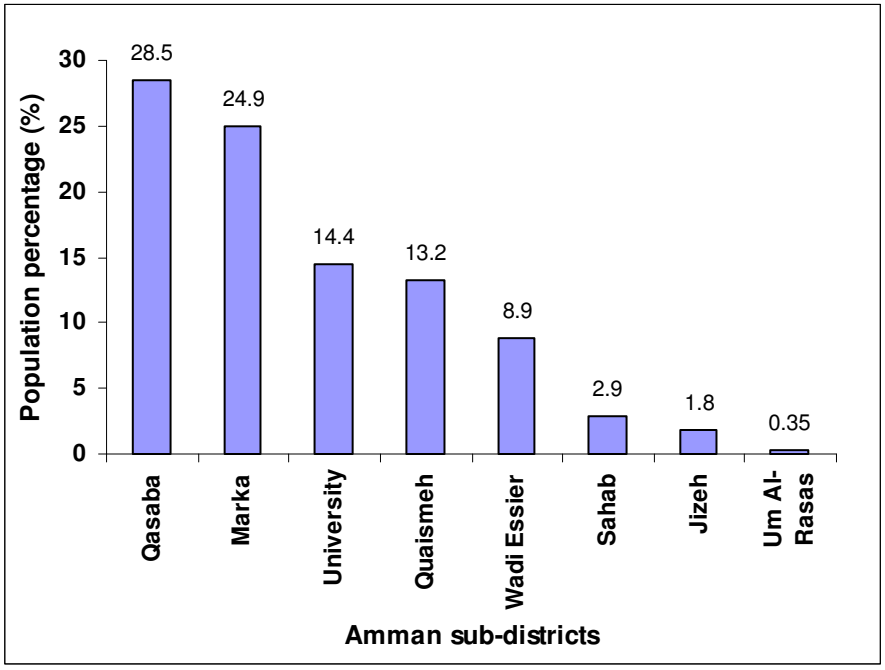
The population growth of Amman since the second half of the 20th century has been phenomenal, in terms of its population, density, and socio-economic characteristics. This has transformed Amman from small town in the early 1920s of little more than 3000 people to a major city with a population of 2.4 million people as shown in figure 2 (DOS 2010).

Figure 2: Development of Amman population in the period from 1950s to 2010.



Through the period from 1920s to the first Arab-Israeli war Amman experienced a gradual spatial expansion. Its population was estimated at 11 thousand in early 1930s and 45 thousand in the early 1940s. Population size was dramatically increased and reaches around 350 thousand in 1952 shortly after the first Arab-Israeli conflict in 1948. By 1979 the population of Amman city had reached about 778 thousand inhabitants, representing 52.6% that of Amman Governorate and virtually 30% of the country. In 1994 the population had reached 1.3 million inhabitants representing an increase of 54.6%. The last census in 2004 after the creation of the geographically wider Greater Amman Municipality, the population of Amman Governorate had increased to some 1.73 million inhabitants. Thus, at this stage, the population of Amman amounted to approximately 32.7% of the Kingdom's total of 5.3 in 2004. But with the war in Iraq, the population is currently continuing to grow at a phenomenal rate and in 2010 the department of statistics gave the population of Amman as 2.4 million out of 6.1 million for Jordan as a whole, which equals almost 40% of the national population. Figure (3) represents the distribution of Amman population in terms of population percentage on a sub-districts basis. The analysis show that more than 53% of the population concentrated in the city center of Amman e.g. Qasaba Amman and Marka sub districts, while 47% of the population distributed on the other parts of Greater Amman Municipilities.

Figure 3: Distribution of population percentage within the Amman sub-districts in 2006

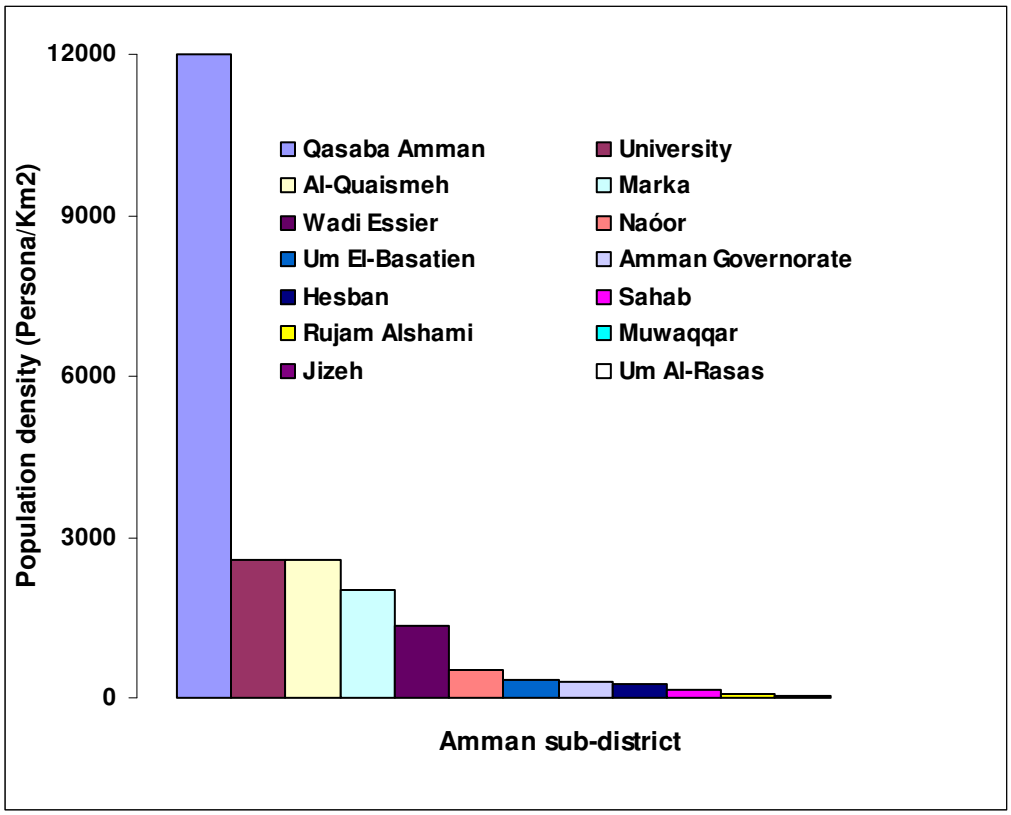


Another important population indicator is the population density, which characterized the population growth both in Jordan and Amman governorates because its affect on the development process and its geographical distribution. Figure (4) represents the Amman population properties in terms of population density on a sub-districts basis. Currently, the population density in Jordan is about 62 person/km^2 while in Amman is 286.7 person/km^2. However, analysis of the population characteristics on a sub-districts level give detailed overview of the demographic differences within the Amman governorate itself.

It is obvious that, the highest population density are occupied by Qasaba Amman, with high difference from the other parts, and then followed by Al-Quaismeh, University and Marka sub-districts with about 81% of the total population of Amman. They also have the highest population density in Amman and Jordan. In contrary, the new expansion area's in Amman governorates toward the eastern and southern parts (Sahab, Jizeh, and Naóor) have the lowest population percentage and density among

the Amman governorates with about 5.8% of population, while the other expansion area (Um Al-Rasas, Mowaqqar, Rujam Alshami, Um El-Basatien and Hesban) have less than of 1% of population percentage in Amman governorate.

Figure 4: Distribution of population density within the Amman sub-districts in 2006.

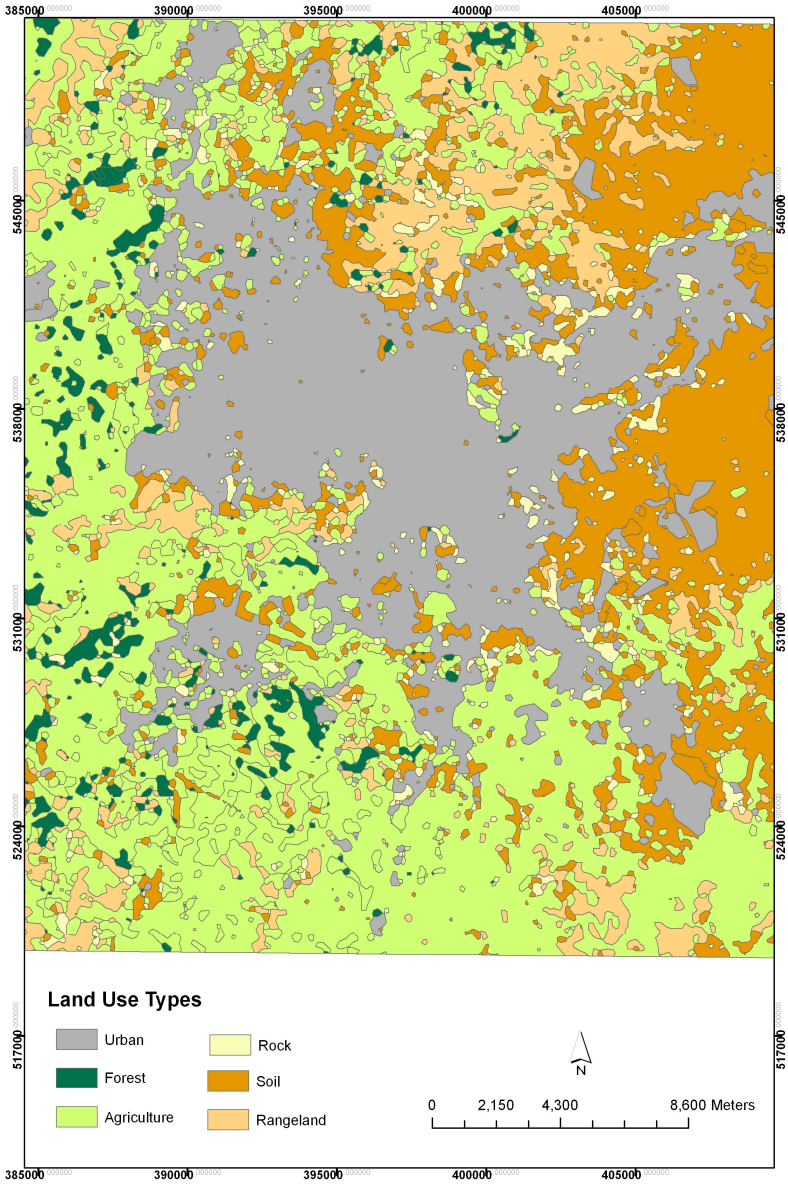


The socio-economic and demographic characteristics of the households of Amman show that, the main difference between the household's characteristics was in their respective average income levels, and household size (Potter et al. 2009). The general levels of prosperity and incomes are higher in the capital. According to the Household Expenditure and Income Survey (DOS 2003). The average annual income of Amman's households was 6533 JD, while the national figure was 5590 JD. Also, there are distinct differences between two levels in terms of average house size, this is 345 m^2 for the high income households and considerably lowers at 82 m^2 for the low-income households (DOS 2008). Thus, while 76% of low-income households live in houses comprising 100 m^2 or less, some 20% of high-income households live in houses with 401 m^2 or more of living space. These differences were also reflected on the pattern and structure of urban facilities in the city.

4.2. Current Land Covers and Urban Services

The urban land use plan for Amman was designed to transform the city from being mono-centric to a multi-centric metropolis in order to decentralize the population and economic activities. As reported by Amman city council, the new satellite towns have been aggregated to the Amman Municipal district since 2008 so that the suburbs will absorb the development potential of the new population of Amman. As can be seen, the satellite towns of Amman have had a significant impact on the pattern of development of urban growth and urbanization in the city. Figure 5 shows the current land cover classification of Amman in 2009.

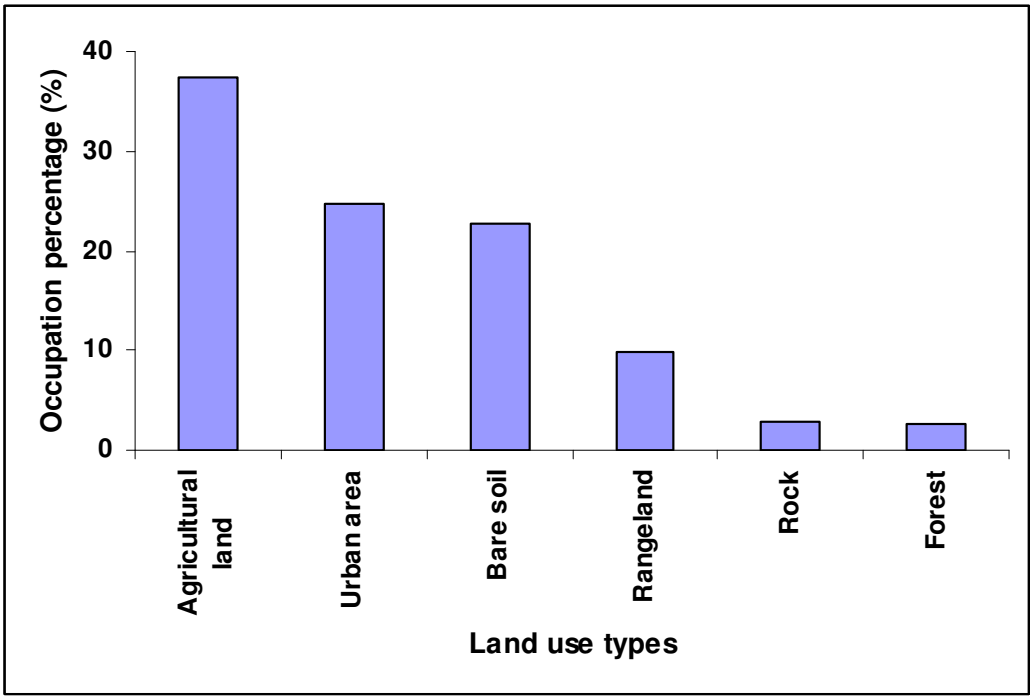
Figure 5: Land cover classification of Amman in 2009.



The land cover classifications allow for the identification of six major lands cover categories in the study area. The major categories are urban area (settlements, road, quarries etc.), agriculture land (field crops, tree crops and vegetables), bare soil, rangeland, forestland mainly scattered forest, and rocks. Figure 6 show the relative importance and percentages of major land use types in the study area. The most dominant land use types are agricultural land, urban area and bare soil with about 85% of the total area.

On the other hand, the distribution of urban services in Amman as shown in figure 7, show that the route accessibility and land tenure characteristics are the most important factors influencing rate and direction of urban development, while the distribution of other facilities e.g. education and health services are playing a minor role. This observation suggests that, the mass transport lines that were constructed to link the satellite suburbs to the urban core may have been a key factor contributing to the unplanned expansion of the urban areas in the region.

Figure 6: Relative importance and percentages of major land use types in the study area.



Currently, the spatial characteristics of the urban areas of Amman had become increasingly complex. The peak in the population number indicated an increase in the fragmentation of the urban areas, and decreases the existence of open spaces inside the urbanized areas.

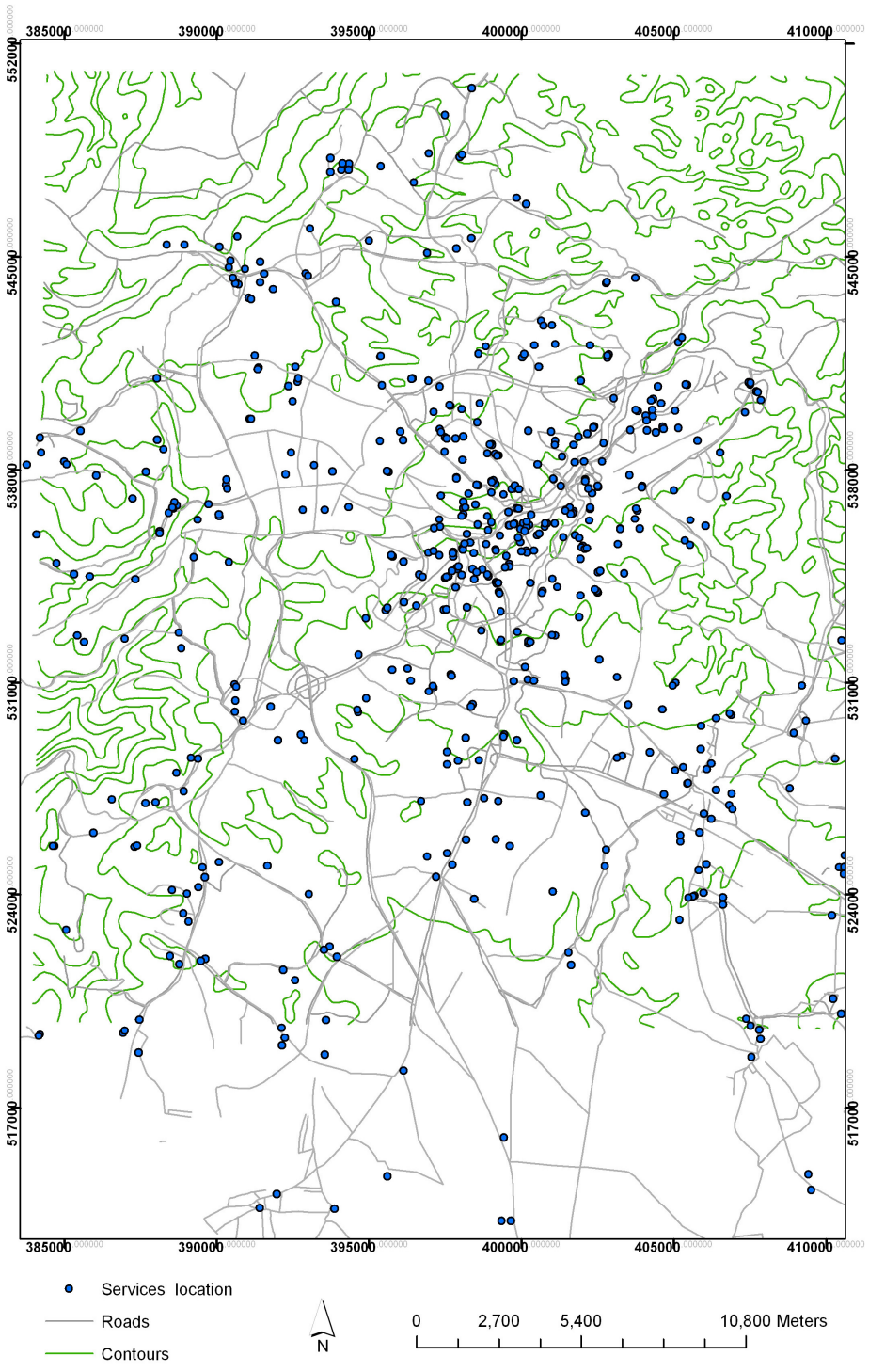
In examining the location of educational and health services in the urban area of Amman, it was observed that the services seemed to be randomly distributed in a way that did not correspond with the actual population distribution. This result confirms the findings of Al-Hunatie (1996), who studied the distribution of services in south of Amman. He found that the pattern of service distribution and provision did not ensure the principles of efficiency or equality in terms of access to services.

In addition, there are several other factors that play a key role in the geographical location planning of basic services in Jordan in general and Amman in particular. This includes the land tenure type, the borders of sub-districts, the road and transportation network and the topography of lands. The combination of these factors means that, as Al-Tyyif (1985) suggests, increasing the number of services will not necessarily improve access for a large proportion of the population.

Due to the marked difference in socio-economic conditions, the form of urbanization in west Amman is considerably different from that observed in east Amman. The urban growth under the Amman Land Use Master Plan has been influenced by economic development of the country and the city. In the east of Amman, the urban area was small and condensed, which is corroborated by the small size and high density, while in the west Amman, the pattern of urban area is fragmented and population density is lower than the other parts.

The urbanization of Amman has also produced several patterns. The new urban areas were quickly assimilated into the old urban centre by the rapid and unexpected economic growth that followed the privatization reforms, while the areas of east Amman remained relatively less developed. In the newly urbanized areas, the new transportation routes and apartment buildings were planned very close to existing urban areas and are an average of higher development level.

Figure 7: Distribution of the urban services in Amman in 2009.



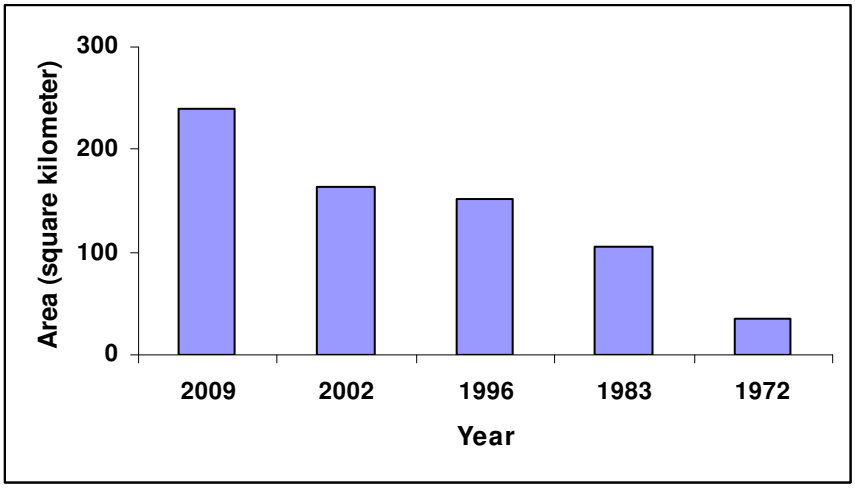
4.3. Pattern of Urbanization

The pattern of urban expansion in Amman during the time period from 1972 to 2009 was investigated and analyzed using Landsat images and GIS.

Amman population size was increased approximately 480 times in less than a century. The huge increase in population and unplanned housing is increasing on the cost of agricultural land, which created many planning and environmental problems. The analysis shows an increase in the urban area from 36 km^2 to 250 km^2 in the time period from 1972 to 2009, which represents an increase of about

595 times in the urban area. Figure (8) shows the changes in urban area in Amman city, which show a trend of increase in the urban area on the cost of the Agricultural lands.

Figure 8: Changes in urban area in Amman city since 1972 (Computed from personal analysis and other published data (Oroud and Rousan 2004; Al-Rawashdeh and Saleh 2006).



The early urban expansion was concentrated around the water resources and main transport routes in the city center. Then it started to take the direction of other parts of the city, towards East, North and then in the South. The routes which are connecting the major cities were of the major roads in Jordan. The first axis is oriented toward the northeast direction and follows the road to Zarqa, and it was growing together to form one bulk city. The other axis is oriented toward the northwest direction and follows the road to Jarash and Ajloun cities. Recently, a new axis of urban expansion is appeared towards the south west direction and connects Amman with Madaba and the south, which was growing over the agricultural lands to create the most prominent developed part of Amman and Jordan.

The area of the inner city transportation infrastructure increased enormously implying that new road construction was a powerful catalyst for the growth of urbanization to outside of city directions. The rate of urban growth varies from one period to another. The rate of urban growth of Amman over the time period being monitored was 5.8 km^2 per year, which is the highest rate among the other cities in the Middle East. The first trend of urbanization since 1950s was mainly oriented toward the unoccupied area, while this urbanization expanded in the last decades toward the agricultural lands. In the eighties amd nineties, the urban expansion is about 45 km^2, which represents a growth of 43% mainly due to the Gulf war in 1991. The new developed area of west Amman was also observed to expand rapidly since the mid eighties.

In order to promote the decentralization of the city centre, numerous new suburbs were constructed since the 2000s mainly in the western part of the city. Taken together, agricultural land were converted to urban use and the urban areas continued to expand along highways to the south and south-west of the city. The urbanization in west Amman after the 2000s was characterized by the outlying pattern with pronounced development on both sides of main streets toward the south direction. Most of this new development activity arose through the conversion of vacant land along the periphery of the city near the major transportation routes and far away from the sub-urban centres. The new developed urban areas subsequently expanded along the major services and transportation routes and a multi centered city was created in Amman.

The study showed that a great urban expansion in Amman area of 214 km^2 had occurred during the past century which led to the destruction of about 98 km^2 of agricultural lands. This is equivalent to the increase in the Built-up areas within and around the cities of Amman with about 6 times in the monitoring time. These results are in accordance with the growth trend that observed by previous

studies conducted on Amman city (Oroud and Rousan 2004; Al-Rawashdeh and Saleh 2006). The expansion was mainly due to the immigration of population from neighboring countries. Demographic, political, economic, and legislative factors interacted to produce this accelerated urban growth. During this period, the population of Jordan increased more than 11 times. Beside that, the low economic return of dry agricultural lands, along with a substantial jump in land prices in and around urban centers, which led to the massive transformation of agricultural lands into urban conglomerates. The absence of laws regulating land use, along with a lack of vision and creativity among decision makers, has been a major factor in the growth of urban areas at the expense of the productive agricultural lands.

A reduction in agricultural lands has vastly consequences on water resources, biological diversity and food production. The fast growing of population and urban areas created new problems to internal structure of the Amman city. It is suffering from deterioration of landscape biodiversity, traffic jams, air pollution, and severe water shortages. However, urbanization is not always a bad thing, rather it is a very useful way for societies to get together and share resources, therefore, it would be better if it were planned growth in conjunction with sustaining environmental biodiversity, which is not the case of Amman city.

5. Conclusion

Urbanization is primarily a complex of functional changes, it occurs near cities as well as in the rural countryside. It is regarded as a diffusion wave of changing life-style mainly controlled by the changing accessibility of places offering new opportunities. The integration of remote sensing and GIS provides a useful method for analyzing urban growth patterns, and for examining the changes in the urban land use over time. The results of this study show the relationship between certain changes of spatial land use pattern and a particular type of city planning policies and services distribution.

The great urban expansion in Amman is represented by a 6 times increase in the build-up areas during the time period being monitored. During this period, the population of Jordan increased more than 11 times. This resulted in the establishment of satellite towns or suburbs around the existing city centre of Amman, which was demonstrated by the rapid development of residential zones in the new suburb of Amman and creation of multi-center cities. The results presented in this study were useful in getting comprehensive information required for making informed land use planning decisions, and contribute to an increased understanding of the urban dynamics and development of future sustainable land use plans, especially in other cities of Jordan. It shows the need for modern master land use plans and promulgating appropriate land legislation policies is thus considered to be vital for the future development of Amman.

As land resources for new development in Jordan rapidly diminish, the development pressure on the Jordanian land resources may intensify. Therefore, if the current trend of urban growth continues into the future, the Amman city will face many environmental and urban planning problems. Besides that, the agricultural activities will inevitably be forced towards the eastern and southern parts, semiarid fringe of the desert. This may result in the intensification of the environmental and social impacts in the country, due to further urbanization process. Therefore, alternative scenarios for sustainable development of Amman and Jordan are required. The most promising alternative scenario propose either full or partial cessation of the urbanization process in the fertile, heavy populated areas, and, introduce urbanization to desert regions, instead of introducing agriculture to deserts.

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