JJEES

JJEES (2025) 16 (1): 1-10
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Examining Land Use/Land Cover Dynamics in Zarqa Governorate Major Districts: Implications for Urban and Environmental Sustainability

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Received on 13 June 2023; Accepted on 21 June 2023

Abstract

Rapid urbanization has become a serious issue, particularly in developing countries, where cities generally lack adequate planning. Nowadays, the majority of Jordan's population lives in cities. Zarqa governorate is among the most populated governorates in Jordan and is located within the boundaries of a major hydrological basin. Therefore, the objectives of this study were to explore the spatial and temporal varying dynamics in the urban area and agricultural areas over the past two decades (2001-2021) in Zarqa governorate major districts (Zarqa-Qasabah, Russeifa, and Hashemiyah) and map the changes in the land use/land cover (LULC) using remote sensing and GIS techniques. Remotely sensed surface reflectance data derived from Landsat Thematic Mapper (Landsat-5, TM) and Operational Land Imager (Landsat-8, OLI) of the study area dated 2001 and 2021 were downloaded. PCI Geomatics and GIS were used for image preparation and processing. A supervised classification technique was used to classify the images into urban, agricultural and undeveloped land categories. The LULC classification maps showed that rapid urbanization and expansion occur in all directions of existing urban areas. The urban lands increased from around 70 km² in 2001 to 109 km² in 2021, representing a change from 16% to 25% of the total study area land. The overall undeveloped area declined from 354 km² (81%) in 2001 to 317 km² (73%) by 2021 with a small change in the limited agricultural area from 14 km² (3.29%) in 2001 to 11 km² (2.63%) in 2021. Zarqa-Qasabah District showed the biggest urban area change which is 22.4 Km² (9% of the District's total area), while Russeifa showed the highest proportion (15%) of land conversion to urban land, compared to other districts. Hashemiyah occupied the largest agricultural land and the maximum agricultural land recession rate among other districts. Such changes in LULC in the study area are expected to lead to adverse impacts on the natural resources' sustainability if not monitored closely and oriented towards less fragile lands. Management of LULC changes and enhanced greenery can support groundwater recharge quality and quantity and help avoid runoff risks and other potential consequences.

Keywords: *Urban Expansion; Remote Sensing; Zarqa City; Amman Zarqa Basin*

1. Introduction

The natural lands including rangelands (Sawalhah et al., 2021), agricultural lands (Al-Kofahi et al., 2018a), their productivity (Al Qudah et al., 2021), and their intrinsic role (Arora, 2019; Abd-Elmabod et al., 2020) are continuously changing due to anthropogenic effects. There are massive fluctuations in food production at the global level (Arora 2019; Tol 2013). The world's climate is changing and threatening human life, natural resources, and ecosystems (Holechek et al., 2020; Malhi et al., 2021). These impacts have become disastrous due to the rapid increase in industrial activities, rapid population growth and urban sprawl at the expense of agricultural lands (Rimal et al., 2018). Nowadays, agricultural vulnerability due to climate change is one of the greatest challenges facing the sustainability of the global food system (Malhi et al., 2021). According to the Food and Agriculture Organization (FAO 2015), an increase of 60 percent in food production by the year 2050 is needed to satisfy the growing demand, driven by population growth. Developing countries are not an exception where they are more fragile due to climate change impacts, the reduction in food production, and limited availability of productive lands especially in arid lands (Al-Kofahi et al., 2018a).

The unplanned and uncontrolled growth of cities towards their borders might lead to multiple negative consequences on the surrounding environment (Al-Kofahi et al., 2018a; Rosni & Noor 2016; Banai & DePriest 2014), the ecological services (Li et al., 2016; Wang et al., 2017), and the overall quality of life. (Al Tarawneh 2014) reported the adverse effects of urban sprawl on agricultural land, land productivity, microclimate temperatures, pollution levels, and green spaces. (Rosni & Noor 2016) demonstrated that urbanization greatly disrupts the landscape context and has impacts on the built environment sustainability, including the environment's degradation and the community's economic and social well-being. (Tiwari et al., 2018) concluded that rapid urban development has disrupted hydrological systems, diminished groundwater recharge, lowered water supply, and raised the likelihood of natural disasters and dangers. (Fetus et al., 2020) reported that the destruction of rural residents'

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livelihoods in the urban fringe area, land fragmentation, food scarcity, ecological changes, environmental pollution, biodiversity loss, and loss of wildlife habitat are some of the adverse impacts of urban expansion. Overall, unplanned and arbitrary urban development negatively impacts the total environment including plant and animal cycles (Dadashpoor & Salarian 2020), urban living conditions (Wang et al., 2017), groundwater storage, food security (Tiwari et al., 2018; Safa 2020), and population social and economic status (Rosni & Noor 2016).

Throughout the world, rapid urbanization has become a serious issue, particularly in developing countries, where cities are typically defined by the absence of adequate planning and infrastructure, excessive immigration rates, and inappropriate settlements pattern (Olajide 2010; Yiran 2020). The buffer zones among cities and natural habitats are fragmented and shrank risking the natural biodiversity and indigenous species (Al-Kofahi et al., 2019; Concepción et al., 2016; Jimenez et al., 2022). Cities are major contributors to the rising amounts of air pollution due to escalating energy use, high rates of waste disposal (Pereira 2014; Zou et al., 2016), and high total carbon emissions from construction, transportation, and industry which are key contributors to pollution (Cheng & Hu 2023).

The unstudied conversion of natural or agricultural land to urban settlements results in irreversible damage (Liu 2018) to forests and open lands and risks food security (Hu et al., 2021). (Al-Amoush et al., 2017) demonstrated that the majority of urban regions are covered with impervious concrete surfaces rather than greenery lands. Thus, the urban land is unable to soak up rain, and this result leads to extra runoff from rain over the surface. Nowadays, urbanization has frequently been reported as a main reason for flooding and poor water quality by moving a lot of sediment and pollutants during floods (Abass et al., 2020). As a result, maintaining groundwater recharge and purity becomes difficult, particularly when aquifer rechange area is the area where new developments are taking place and becomes a source of a variety of surface pollutants (Vahid 2013; Rai et al., 2015; Safa 2020).

Different land cover/land use classification approaches were used to study and monitor the advancement of urban areas towards the surrounding lands and to warn against possible environmental and health impacts (Ghurah et al., 2018; Obeidat et al., 2019; Steurer & Bayr, 2020). Change detection techniques support studying land use/land cover studies (Alqurashi & Kumar, 2013) which can help land use planners and environmentalists observe differences in a phenomenon of interest to support sustainable development while mitigating the possible adverse impacts. Remote sensing and GIS-derived land use/cover maps can be a helpful tool for sustainable land monitoring and management (Gómez al., 2016; Mashagbah, et al., 2022). The use of remote sensing, coupled with GIS, is demonstrated as an efficient effective technique for studying urban areas (Olteanu-Raimond et al., 2020; Goswami et al., 2022) with acceptable accuracy and low cost (Ahmed & Shariff 2016).

Different techniques, procedures, and data types can be employed to investigate and observe changes in cities where the specificity of the land and the availability of data sources might affect researchers' type of data or procedures used. For example, (Alqurashi et al., 2016) used Landsat images to examine the expansion of urban development and changes in land cover in Saudi Arabian cities. The generated land cover maps were classified using an object-oriented approach, Markov chain, and Cellular Automata modeling techniques. (Al-Husban 2019) studied the spatiotemporal dynamics of urban and vegetation areas in Al-Balqa Governorate, Jordan, using Landsat 5 and 8 OLI images using supervised classification and identical technique. (Al-Kofahi et al., 2018a) used Landsat 7 and 8 images along with high-resolution true color orthorectified images to run supervised classification, change detection, and accuracy assessment to investigate the major Jordanian sprawl on agricultural lands. They reported alarming recession rates of agricultural land and conversion into urban and commercial uses in major cities in Jordan.

The impacts of high recession rates in agriculture become more serious in arid and semi-arid lands due to the increasing temperatures, limited water resources, and fluctuation of precipitation rates. Jordan is a typical example where the country is classified as arid to semi-arid region with high vulnerability to climate change impacts and reduction in agricultural lands and land productivity (Al-Kofahi et al., 2018a). According to the World Food Programme (WFP), 53% of Jordanians are food insecure (Anera 2021). So, it's now considered one of the food-deficit countries and a country with limited available agricultural lands. The situation becomes alarming when food insecurity is coupled with the escalating demand for water along with growing population, inflow of refugees and increased industrial activities. Recently, Jordan has been ranked as the second poorest country in the world in terms of water scarcity, with an annual water supply of less than 100 m^3 per person (MWI 2020), which is below the threshold of the international water poverty line of 500 m^3 per year (MWI 2009). This puts more pressure on the limited land resources and calls for implementing sustainable development approaches on a country level and in all sectors (Al-Bakri et al., 2013).

Jordanian cities experienced rapid urbanization, resulting in a loss of balance between the built-up area, green spaces, and open lands (Al-Kofahi et al., 2018b). Nowadays, Jordan is considered one of the most urbanized countries where in 2020, more than 91% of the country's population lives in cities compared to 78% in 2000 (DOS 2023). As a result, urban sprawl and land use/land cover (LULC) changes have been noticed in different governorates, especially in Amman (Al-Mahasneh et al., 2012; Albattah 2015; Khawaldah 2016; Abdeljawad & Nagy 2021), Mafraq (Al Mashagbah et al., 2012; Sqour et al., 2016; Alhusban et al., 2019), Irbid (Al-Kofahi et al., 2018, Jawarneh 2021; Mashagbah, et al., (2022), and Zarqa (Al Mashagbah 2016; Othman et al., 2020; Jamhawi et al., 2020).

Zarqa governorate is currently ranked as the third most populous metropolis in Jordan (DOS 2023) where the city's population has risen quickly because of multiple factors including natural population growth, rural-urban migration, the influx of migrant workers, Palestinian settlement, and the recent refugees' flux from Iraq and Syria due to political turbulences. Zarqa is known as a major industrial area where Al Hussein Thermal Power Plant, oil refinery, mining activities, petrochemical industries, and many other industries exist. Surface and groundwater pollution is thought to be primarily caused by these activities. Zarqa governorate land is situated within the Amman-Zarqa Basin (AZB) boundaries, the most significant hydrologic region in Jordan (Kuisi & Abdel-Fattah 2010). Zarqa City planners and officials must comprehend, monitor, and foresee future development because urban sprawl and extension have a variety of effects on the city's ecological, economic, and aesthetic components. Therefore, the objectives of this study were to explore the spatial and temporal changes in the urban area and agricultural areas during the past two decades (2001-2021) in Zarqa Governorate and map the changes in the land use/land cover to delineate the rate of urban area growth using remote sensing and GIS techniques.

2. Methodology

2.1 Study area

Zarqa Governorate is located at 32-32.15º N and 35.5-36.2º E. It connects all Jordan governorates together due to its central position among governorates. It is located around 25 kilometers northeast of Amman, the capital city of Jordan. Zarqa Governorate is the third most populated (14.3% of Jordan's total population), (DOS 2023) and the second largest governorate in terms of economic activities (Jamhawi et al., 2020). The governorate consists of six districts, the most populated districts were Zarqa-Qasabah, Russeifa, and Hashemiyah (Figure 1). These three areas occupy 89% of Zarqa governorate's population (DOS 2023). The governorate includes numerous industries and serves as the country's industrial hub and connects neighboring countries through international roads for commercial and noncommercial purposes.

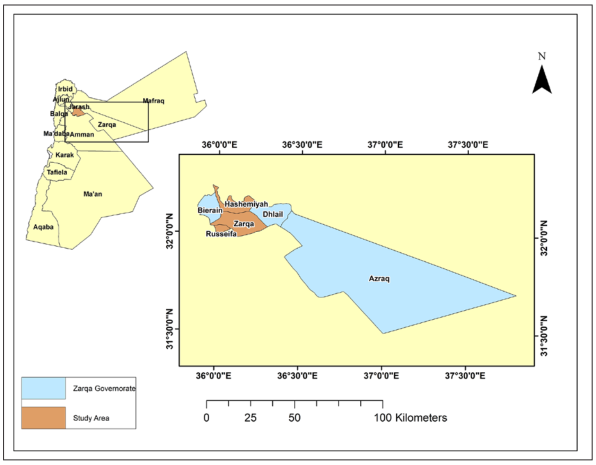

Figure 1. Study location map, Zarqa Governorate and districts, Jordan.

2.2 Images acquisition and preprocessing

Two landsat images that cover the study area were downloaded from USGS website: Landsat-8 (OLI) and Landsat-5 (TM). The images' acquired dates were 29th May, 2021 (LC08L1TP174038202105232021052901T1.tar) and 26th Jul, 2001 (LT05L1TP174038200107192018072601T1). Images preparation for classification was done using Geomatica tools. The images were clipped/subset to ensure their coverage of the study area (Figure 1). The "Dark-Pixel Substation" function was used to remove the atmospheric effects present in both images; the resulting images were exported as TIFF format images for classification using GIS.

Image Processing and Classification

The supervised image classification technique/GIS was applied (Figure 2) to both images. The maximum likelihood classification algorithm was used to classify the study area into three classes (undeveloped areas, agricultural areas, and urban areas). The classes were defined according to Al-Kofahi et al. (2018a) where urban areas represent any built-up structure for domestic, economic, or industrial uses, while agricultural lands were defined as any cultivated, planted, orchards, or forest lands. The undeveloped areas represent uncultivated, non-built-up, abandoned mountainous, or rugged lands.

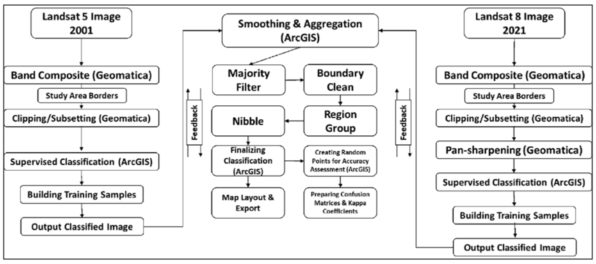

Figure 2. Workflow for image processing and classification using PCI Geomatica and ArcGIS software.

The classification training samples were built up for each of the classification categories. Training samples depended on the spatial matching of well-known identified objects for each category with the help of ArcGIS base-maps and Google Earth images and the available true color aerial images. The output classified images were then compared to the existing cover as seen in Google Earth images, true color images and GIS base-maps to visually assess the classification accuracy. The points, used to test the classification accuracy, are new points other than those used for classification training samples. The feedback process was applied when necessary (when there is a noticeable difference between the actual category and the classified category) till an acceptable result was observed. Smoothing and aggregation processes were employed including Majority Filter, Boundary Clean, Region Group, and Nibble tools (Figure 2). The areas of the classified categories were calculated based on the number of pixels in each category and pixel size and recorded separately. The output files of the classification process were used to assess the accuracy assessment.

2.3 Accuracy Assessment

The classification accuracy was determined by comparing the classified images with another confident data source that was thought to be accurate, such as field-collected ground truth point, and high-resolution and historical Google Earth images. A randomly chosen ground truth points were gathered. Following Jensen's (2005) rule of thumb, 210 points were utilized to evaluate the classification accuracy. A total of 70 points per class were used. The results were used to build a confusion matrix for each classified image where accuracy assessment components, included the Kappa coefficient, overall accuracy, and user's and producer's accuracy.

3. Results and Discussion

3.1 Accuracy Assessment

A confusion matrix for each classified image was developed, overall classification accuracy of the classified images was between 89-92%, while users' accuracy was varying from 79% to 96%. The producer's accuracy ranged from 83-93% (Table 1). The lowest user's and producer's accuracies were in the 2001 image (Landsat 5 TM) classified image due to confusion between the undeveloped lands and each of agricultural and urban areas. Landsat 5 TM images were expected to yield lower classification accuracy compared to Landsat 8 OLI images because of the limited number of spectral bands in TM, which leads to spectral mixing and, thus, some confusion among classes. These findings were also reported by Poursanidis et al. (2015) who compared the performance of both TM and OLI images in classification of urban and peri-urban land cover. However, using TM images given the classification accuracy limitation is tolerable due to the unavailability freely downloadable historical images other than TM images serving the purpose of this study.

Table 1. Confusion matrix for the land use classification results of the study area images for the period 2001 and 2021.

Reference Data						
2001 Image						
	Class	Undeveloped	Agriculture	Urban	Totals	Users' accuracy
Classified data	Undeveloped	68	9	9	86	0.79
	Agriculture	2	58	0	60	0.96
	Urban area	0	3	61	64	0.95
Totals		70	70	70	210	
Producers' accuracy		0.97	0.83	0.87		
Overall accuracy						0.89
2021 Image						
Classified data	Undeveloped	65	2	2	30	0.93
	Agriculture	2	63	2	29	0.94
	Urban	2	5	65	31	0.90
Totals		70	70	70	210	
Producers' accuracy		0.93	0.90	0.93		
Overall accuracy						0.92

3.2 Spatio-temporal urban and undeveloped lands' change

The LULC classification maps showed that rapid urbanization had taken place over the last two decades in all directions mainly towards southwestern parts of the study area (Figure 3). It can be observed that urban and built environment had increased from around 70 km² (16%) in 2001 to 109 km² (25%) of total study area land by 2021, while undeveloped area was declined from 354 km² (81%) in 2001 to 317 km² (73%) by 2021 (Figure 4). Zarqa, as the second-largest industrial city in Jordan next to the capital Amman (Yousef 2012; Jamhawi et al., 2020) has experienced increased urbanization causing a change in the city's LULC. The newly constructed areas for residential or commercial purposes are increasing, which is expected to lead to negative impacts on environmental services. The special location of Zarqa governorate among other governorates, the international road network, industrial activities, the increase in population, and the influx of refugees and migration of people from surrounding countries of political conflicts specifically the Syrian crisis (Sawalhah et al., 2021; Al-Kofahi et al., 2018a) are the main potential causes of these changes in a metropolitan area. The Department of Statistics in Jordan reported that over the last two decades, Zarqa governorate's population increased from 0.8 million (DOS 2001) to 1.6 million per capita (DOS 2023).

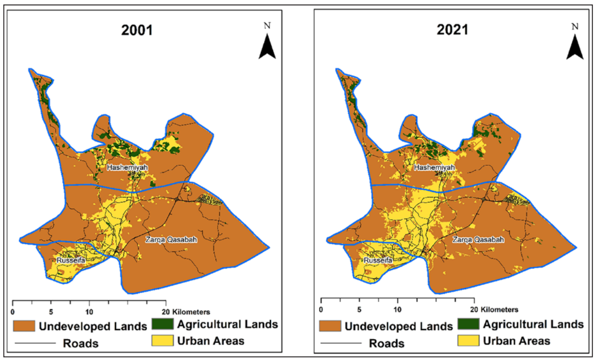

Figure 3. The spatial distribution of different LULC categories of Zarqa Governorate major districts (2001-2021)

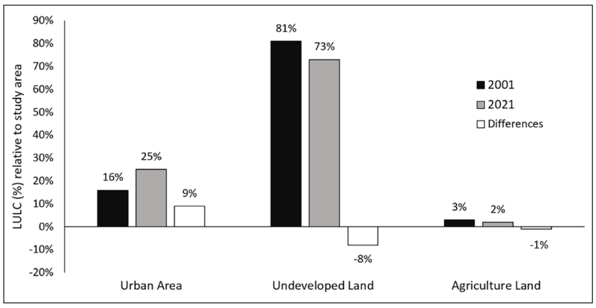

Figure 4. The relative proportion of LULC changes of Zarqa governorate's study area (2001-2021)

Among the driving factors that made Zarqa Governorate a population-attracting center is the high possibility of people recruitment. The Ministry of Planning and International Cooperation reported the presence of 23856 economical facilities in Zarqa Governorate that represent around 15% of all economic facilities in the country, therefore this governorate is considered as Jordan's industrial hub. Zarqa Governorate is a home for 52% of the country's industries, including plastic, rubber, leather, chemical, food, agricultural, information technology, packaging, and paper cardboard industries (Ministry of Planning 2017). The availability of such industries leads to adverse pollution impacts on surrounding environment (Yousef, 2012) besides the expected anthropogenic sources of pollution in the Governorate. The major industrial and commercial activities are Petroleum Refinery Company, Al-Hussein Thermal Station, iron industries, animal farms, quarries, etc. Nowadays, Zarqa Governorate, especially Hashemiyah District is considered a pollution hotspot (MOI 2022). However, the limited freshwater resources (Al-Qinna et al., 2011; Hadadin 2015), low and irregular rainfall, high evaporation rate (Al-Kilani et al., 2021), and over pumping of groundwater (Al-Qinna et al., 2011; Bajjali et al., 2017) further complicate the environmental quality sustainability in this governorate.

The whole studied area showed changes in LULC categories from low to high with respect to other categories in the studied districts. The LULC maps of Hashemiyah District, for example, showed that new urban developments are directed towards the Eastern part of the district, where numerous new avenues were observed in the direction of urban growth. These avenues are connecting the Hashemiyah District with the Hashemite University, Zarqa-Mafraq highway and Zarqa Free Zone. The urban growth is usually driven by accessibility to transportation and road networks which is widely recognized as one of the key factors influencing urban architecture (Kasraian et al., 2019; Pratama et al., 2022). Similarly, Rai and Saha (2015) reported that changes in land use around cities follow highways. This type of expansion is known as edge expansion where the new developments go radially from the urban edge outward (Forman 1995). Therefore, a sizable residential urban expansion and newly established bodies such as Steel factories and the National Electricity Company followed the recently constructed avenues. The proximity of Zarqa-Mafraq highway road, low land prices and tribal zone lands in that direction contributed to such a change. This also contributed to outlying expansion to the east of Hashemiyah districts where the Army Condominium Complexes were established western the Hashemite University and Zarqa-Mafraq highway.

The Hashemiyah District witnessed extension towards the Western side of the District. The infilling expansion was also observed and prevailed in the center of Hashemiyah Village. New outlaying developments and edge expansion in the Western parts of the district towards Jerash Governorate were noticed along with northward and eastward extensions to the Zarqa River and the southward movement to Masoum area (the boundary of the Zarqa-Qasabah District). Migration from the villages to the city center for economic and job opportunities, together with the City's natural population growth, has caused a fast increase in residential and commercial areas as well as the development of essential infrastructural networks. Similar reasons were reported to explain the urban expansion in Irbid City (Mashagbah et al., 2022) and Amman (Al-Kofahi et al., 2018a), Jordan. The settlement of Palestinian refugees in the Sukhnah Refugee Camp, the proximity of roads connecting the Governorate with Mafraq, Jerash, and Zarqa-Qasabah District, tribal zone and the lower lands prices in these areas compared with that within and surrounding the city center are possible causes for these multi directional expansion.

Zarqa-Qasabah is the most populated district of the governorate and represented around 50% of the governorate population with a population density of around 3000 capita/km^2 (MOI 2022). Younes et al. (2013) stated that the city's expansion has accelerated in recent years because of a significant change in population, commercial centers, and industrial activities. Al-Mashaqbeh et al. (2014) reported that the development of public infrastructure, such as roads, water facilities, housing, and industrial and commercial activities are among the elements leading to the emergence of urbanized regions. The presence of Hashemite University, Zarqa University, and other colleges and educational centers also contribute to the urban expansion of this district towards the east direction of the city. The observable urban change in Zarqa-Qasabah was concentric, infilling around the city center. A similar type of expansion was observed in other Jordanian cities such as Irbid and Amman (Al-Kofahi et al., 2018a). Edge-type expansion is observed in the eastern portions of Zarqa where various military camps are spread and the establishment of King Abdullah bin Abdulaziz City as a new residential development with an area of 250 hectares, benefiting from multiple regional highways (Amman-Zarqa Highway, Zarqa-Mafraq Road, and Zarqa Road), connecting the Kingdom to Saudi Arabia, Iraqi, and Syrian borders and other mega industrial and governmental bodies such as Al-Musfah and Zarqa Free Zones. However, outlying types of sprawls exist in several locations to the eastern portion of the district such as Princess Salma Suburb, New Zarqa Governmental Hospital, Princess Iman Residence Suburb, and Military Centers. These findings are consistent with Al Mashagbah (2016), who reported that the development of the urban area is a result of the city's infrastructure upgrades and population growth. Thus, municipalities and city planners, to a certain extent, can control or govern the new urban developments by establishment of governmental bodies or mega projects towards allocating more green spaces that would yield less environmental or ecological impacts.

The Russeifa District is 15 kilometers northeast of Amman. The District stretches from the western boundaries of the capital city, Amman, to the eastern boundaries of Zarqa-Qasabah District, and from the southern boundaries of Amman Zarqa highway to the northern boundaries of Zarqa-Qasabah District. This district serves as a transit point between the capital city, Amman, and Mafraq and northern cities. According to the DOS data, Russeifa population was duplicated in the last two decades (DOS 2004; DOS 2023). The district witnessed rapid natural population growth with a recorded population density of 6792 per capita/km^2 (MOI 2022). An infilling type of sprawl in the center of the district is observed with remarkable expansion to the west direction towards Amman, where a newly developed residential area called Al-Karamah neighborhood was established.

3.3 Spatio-Temporal Changes on Agricultural Lands

The LULC maps showed that the identified agricultural areas in 2001 and 2021 are concentrated around the north border of the Hashemiyah District. The temporal changes in the agricultural land proportion (-1%) between the studied years were very low in the study area, while the spatial changes in the agricultural areas' locations are observable (Figure 3). Considerable portions of the identified agricultural lands were on both sides of the Zarqa River (not identified on the maps as no flow exists at the images' dates), as well as in the nearby regions around the As-Samra Wastewater Treatment Plant (WWTP). As-Samra WWTP is located at the northeastern parts of the Hashemiyah Village. Zarqa River floodplain is irrigated using the wastewater from WWTP (Al-Bakri et al., 2013). However, the study's findings revealed that the overall agricultural lands of the study area slightly declined from 14.4 km^2 (3.29%) in 2001 to 11.5 km^2 (2.63%) in 2021 (Figure 4). The possible reasons behind the spatial and temporal changes in agricultural land are the fluctuation in rainfall amount and distribution in the last two decades. Additionally, the projects of upgrading As-Samra WWTP, meant to handle the rising volumes of wastewater from the growing population in the source governorates (Amman and Zarqa) (Al Omari et al., 2013) during the study period, exploited the surrounding lands of WWTP where some of them were agricultural lands in 2001. The expansion plans for As-Samra WWTP have resulted in a reduction of agricultural farms in the southeast and southwest direction of the WWTP, with observable changes in land use in these spots from agricultural to urban areas. The project of As-Samra upgrades is expected to continue to 2025 and may possibly lead to further reduction in the agricultural lands there until project completion (SPC 2012). The northeastern area of As-Samra WWTP showed large agricultural areas in 2021 that were not observed in 2001, while there was a kind of shift or change in exploitation of different lands depending on the availability of lands and water sources. The field visits of these farms upstream area cultivated with annual and forage crops and irrigated from wells.

3.4 Spatio-Temporal LULC Changes among Districts

The three districts showed major changes in the urban areas. Zarqa-Qasabah District showed a fundamental change in terms of urbanized area where the overall urban area increased 22.4 Km^2 (9% of the District's total area) in 20 years; this represents a net annual increase in the urban area of around 1.2 Km^2 and an equivalent reduction in the undeveloped lands (Figure 5). Such new urban areas in Zarqa-Qasabah District, compared to the other districts, is due to its industrial position among other districts and cities. It has a major role in the country's industrial sector (Yousef 2012; Jamhawi et al., 2020; Ministry of Planning 2017). The urban area of the Hashemiyah District, similarly, showed an increment of 6.45 Km^2 (5% of district's total area) and reduction in the overall district agricultural area of around 2 Km^2. The major recession area in agricultural land among the studied districts was observed for the Hashemiyah District. This is because it originally had the largest overall agricultural area due to the presence of WWTP within the district borders. The presence of WWTP contributed to the development of agricultural lands in Hashemiyah (Al-Bakri et al., 2013). Russeifa District showed the smallest increment in urban area, relative to other districts while representing the largest proportion (15%). It is also relative to the district total area which is the smallest size district of the three. It can be observed that the net agricultural area reduction in Zarqa-Qasabah and Russeifa Districts was negligible (≤0.5 Km^2).

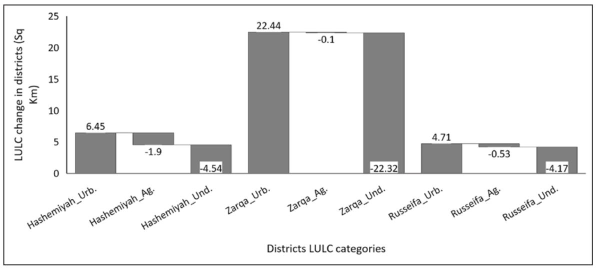

Figure 5. LULC dynamics (Km^2) in different Zarqa Governorate districts between 2001 and 2021.

4. Implications

Such large spatial changes and new urban developments in the three districts are expected to lead to adverse impacts, attained from the needed infrastructure, mobility, waste disposal, air pollution and water resources. One of the major concerns in this governorate is the management of sustainable water resources. It is important to monitor the LULC changes as they affect groundwater recharge and surface runoff (Owuor et al., 2016). Surface runoff, resulting from changes in LULC, were raised by several researchers (Eshtawi et al., 2016; Al-Amoush et al., 2017). In urban catchments, the change in LULC, when combined with climate change, may increase the danger of flooding (Shammout et al., 2021). Alananzah (2022) warned from the expected and observed higher frequency of sudden surface runoff events in Russifa District and recommended removing built-up structures from stream banks to avoid the possible risk of flooding on these structures. Alananzah study suggested installing drainage networks for running water in main and secondary roads. Furthermore, urban runoff is widely regarded as a major transporter of contaminants from and to urban environments and consequently represents a significant contributor to the deterioration of the quality of urban water resources (Björklund et al., 2018; Astuti et al., 2019). These impacts are not restricted to Russifa as it is the District with the largest proportion of land conversion to urban area but also Zarqa-Qasabah District that showed the largest area of changed to urban area.

The growing industry, rapid urbanization, regular population growth, and the rise of civilization are rapidly driving today's freshwater demand. As a result, wastewater is increasingly being used to irrigate agricultural land to attain food security (Mizyed 2013), especially in arid and semi-arid countries where freshwater resources are scarce. Jordan is a country that suffers from scarce water resources, frequent droughts episodes, uneven rainfall distribution, a high rate of evaporation, and a decline in groundwater recharge (Hadadin 2015). As a result, treated wastewater is used as an alternative and an unconventional source of water (Alfarra et al., 2011), and Jordan supports recharging of ground water (Bajjali et al., 2017). Wastewater consists of mainly municipal wastewater, industrial effluents, and storm water runoff. It can transport dangerous substances which affect crops, soil, and groundwater quality. It also contains some pathogens that can harm people (Ashraf et al., 2018). According to (Owuor et al., 2016), improper planning of urban growth will accelerate the runoff which will affect surface water bodies and groundwater quality. Studies on runoff quality improvements are needed to help policy makers implement strategies and plans that could lower pollutant levels in urban runoff. The involvement of effective water harvesting plans potentially will reduce adverse effects on recipient water bodies and better water quality to enrich groundwater.

5. Conclusion

In recent decades, most Jordanian cities have witnessed substantial urban growth. Between 2001 and 2021, the urbanization rate in the Zarqa Governorate increased quickly. The study area witnessed significant changes and advancements in its transportation system, roads, residential complexes, industrial activities, and numerous educational institutions. These are among the factors that are observed to drive the expansion of urban areas. These changes in the natural environment have exacerbated problems associated with natural resources sustainability such as flash floods, environmental pollution, loss of agricultural lands, land degradation and desertification. The study area showed urban advancement in all districts with recession of the limited agricultural lands in Hashemiyah area that depend on wells and treated wastewater. The urban growth is anticipated to continue, which might put further stress on the surrounding environment. Satellite images, remote sensing, GIS, and other software can serve to monitor and direct urban development frequently. Additionally, such tools could help show the future trajectory of urbanization and other land uses which are expected to aid in the development of sustainable environmental policies through cooperative work of decision-makers, environmentalists, and urban planners.

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