REVIEW OF INTERNATIONAL GEOGRAPHICAL EDUCATION

ISSN: 2146-0353 ● © RIGEO ● 11(5), SPRING, 2021

www.rigeo.org

Research Article

Urban Environmental Challenges and Management Facing Amman Growing City

Nour Abdeljawad[1]
Doctoral School of Management and Organizational Science, Faculty of Economic Science, Hungarian University of Agriculture and Life Sciences Kaposvár Campus (MATE)
Nour.Abdeljawad@phd.uni-szie.hu
noor.j@ammancity.gov.jo

Imre Nagy[2]
Full professor, University of Novi Sad, Faculty of Sciences, Department of Geography, Tourism and Hotel Management, Novi Sad, Serbia
Imre.nadj@dgt.uns.ac.rs

Abstract

Environmental degradation and climate change implications on urban areas and cities are a global concern. Urban environment management aims to mitigate the adverse impacts of rapid urbanization. This method identified and measured the effect of a built-in environment. The environmental management of Amman city, considering its exponential urban growth, has witnessed several positive transformations, including urban planning and the establishment of institutions, regulations, laws, mitigation measures, and action plans to absorb the negative impacts. This study documented the existing situation and evaluated the same by reviewing the environmental challenges of urbanization that Amman city is tackling. Particular attention was given to the mitigation measures adopted and the ecological protection expenditure related to overcoming these challenges; these were considered the indicators to measure the efforts taken by public institutions towards environmental development, thereby enhancing city resident's quality of life. Data were collected on the ecological expenditures of the municipalities and other administrative divisions of Jordan. This paper's scope and aim are to present the scholarly literature on urban environmental management in Amman city concerning coping with environmental risks and challenges and the importance of urban planning and initiatives for environmental sustainability and the well-being of citizens. For instance, Amman was the first Arab city to adopt a climate plan to tackle environmental concerns such as inefficient land use and the price of imported energy. Specific suggestions and recommendations are also presented in this study, which can help formulate a successful approach towards a sustainable, resilient and city. One of the essential recommendations that the survey reveals is the need for tools and methods to identify and evaluate the most effective measures to increase the environmental management of Amman's urban city. This report will initially contribute to policy formulation and urban planning works for Amman city. This paper discusses the GAM's environmental problems, potential mitigating strategies, and the effects of population growth and urbanization during the past decade. Traffic congestion and pollution are two additional significant problems in GAM. To address GAM's environmental problems, the study's initial results showed the need to implement specific measures, such as BRT. BRT is supported by policies along the two trunk lines, enabling the city to expand past comprehensive housing projects into more walkable, mixed-use communities with carbon-free electricity and green building standards.

Keywords
Urban planning, environmental challenges, Greater Amman Municipality, greenhouse gas, Bus rapid transit, mitigation measures, environmental expenditure

To cite this article: Abdeljawad, N, and Nagy I. (2021) Urban Environmental Challenges and Management Facing Amman Growing City. *Review of International Geographical Education (RIGEO), 11*(5), 2991-3010. doi: 10.48047/rigeo.11.05.192

Submitted: 14-10-2020 ● **Revised:** 17-12-2020 ● **Accepted:** 18-08-2021

Introduction

Most people live in urban regions that represent the majority of the global population. However, many cities cannot deal with the high population influxes (OECD, 2018). Urban cities also face significant environmental, economic, and social challenges, such as the shortage of shelters, essential services such as waste collection and water supply, and jobs for these new residents, all of which significantly impact the whole city and are related to urban areas development. Urban sprawl plays a driver of these challenges, including greenhouse gas (GHG) emissions, road congestion, and pollution. Cities are significant contributors to climate change since they are responsible for 75%–80% of GHG emissions (Ghaemi & Smith, 2020)

Jordan faces the challenge of rapid urbanization. Jordan is separated into twelve administrative areas with a total population size of 10,234,006 (Worldometers, 2021).

In addition to being Jordan's largest populated city, GAM is also a regional financial powerhouse (GAM; Slideshare.net, 2017). Four million seven thousand five hundred people were living there in 2017. There are 7,579 square kilometers of GAM (Riad et al., 2020). Moreover, 43 percent of Jordan's population lives in GAM (Dar-Mousa & Makhamreh, 2019). Its fast expansion in population and region over the past decade, in any case, had set new and exceptional weights on the city to plan and provide municipal services, especially when refugees in 1948, 1967, and 1991 came to Jordan. In a region defaced by insecurity and struggles, GAM has become a safe and protected shelter for many, which, at the same time, makes city designing and management a seriously complex challenge. There are few extensive open areas and green spots left in GAM after decades of urban growth. An analysis of land cover changes in the western and populous portions of GAM by Khawaldah (2016) found that the urban area increased by 147 percent from 1984 to 2014, with a further 43.9 percent projected from 2014 to 2030. Population growth and immigration from surrounding nations have primarily contributed to the city's fast growth.

The GAM urban land-use plan enables the conversion from a mono-centric to a multi-centric capital city. Molle et al. (2017) concluded that significant roads connecting significant cities shaped the expansion. The urban growth during the 1918–2002 period was analyzed, and its impacts on the GAM environment were evaluated and compared with similar surveys. Findings indicated that GAM has a higher urban expansion annual rate than Bangkok and Istanbul (Molle et al., 2017). Due to the city's sprawl in all directions, there has been a decrease in agricultural land damage around the city. Construction of new infrastructure has deteriorated land cover, forming a third of the study area by 2043 (50 km 60 km), according to (Khawaldah, 2016).

The combination of urbanization with forced immigration, instability within the region, and rapid economic growth with the over-exploitation of natural resources in GAM specifically led to water resources depletion, poor air quality, land degradation, desertification, loss of biodiversity, climate change, insufficient infrastructure and public carriage, and increased road traffic among others (Dosweb, 2018).

Despite governmental efforts to decentralize economic activities, GAM remains the leading financial center of Jordan. More than 80% of all services in the industrial located towards Zarqa, the northeast region. Economic growth is one of the key contributors to environmental pollution. As long as economic development occurs, natural resources use production capacity, increasing waste levels and GHG emissions. The Urban population growth and increased energy consumption upsurge CO2 emissions. Global cities account for over two-thirds of energy use, causing 70% of energy-related CO2 releases (Tsiouri, Kakosimos, & Kumar, 2015).

This study explores the leading environmental challenges that GAM faces and the mitigation measures to address them, enhancing the residents' quality of life. The remainder of the report's structure addresses the research topic, while the third is dedicated to the method. A significant environmental issue is addressed in part 4, while sections 5 and 6 concentrate on the city's poor urban planning and infrastructure. Section7 presents some of the mitigation measures adopted to respond to these challenges. The public environmental protection expenditures (PEPE) focusing on GAM Expenditure are also discussed in this section. Finally, in Section 8, the main conclusions and recommendations of the study are drawn.

Study area

According to this study, the study's aim is that most environmental issues and their related mitigation measures were handled by local authorities (particularly the GAM, in conjunction with another national and international organized study. In order to address the city's numerous environmental problems and move toward being a resilient, sustainable metropolis, these projects are designed to improve GAM's overall condition. Unleaded gasoline is used in Jordan instead of lead fuel, despite urbanization placing more significant pressure on the environment in cities. There are 1680 square kilometers of GAM in the middle of Jordan. Latitude 31°45′00″ and longitudes 35°44′00″ & 36°14′00″ E make up the area. There are 918 mountains around GAM, 750 meters above sea level and 750 meters above sea level. Modern architecture distinguishes GAM as the business and financial center of Jordan. In all, it covers 758.85 km2. GAM's districts are shown in Figures 1 and 2.

Figure 1: GAM view

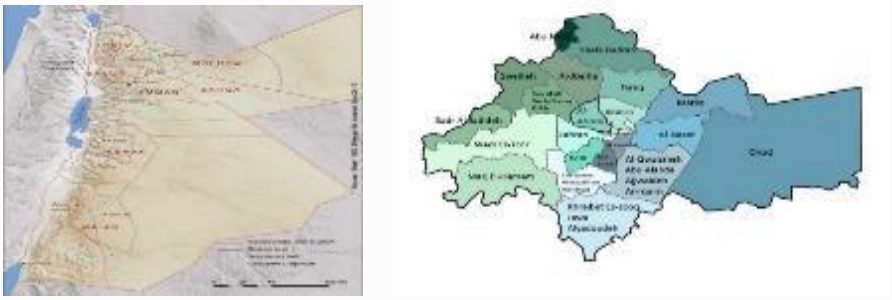

Figure 2: Maps of Jordan map and GAM's 22 administrative districts

Climate

GAM has a diverse geography and climate. Winter weather is expected in the western and northern parts of the city due to steady microclimate conditions. The east tends to be wet, whereas the south-east tends to be hot and humid.

Materials and methods

An attempt was made to investigate and determine the environmental challenges faced by GAM's growing city area from 2000 to 2019. This survey is based on a review of relevant literature, including empirical studies and international conferences. Qualitative methods were employed to meet the research aims. These factual secondary data were collected from various sources related to urban management, environment, water and wastewater, transportation, and energy. A manual literature search of electronic databases (Google Scholar) was performed using unique keywords to obtain the relevant literature.

Environmental challenges and opportunities facing GAM city

Several issues are surrounding our environment; however, seven major ones affect GAM urban city overall, which is the following:

- Population-density challenges
- Air pollution
- Transportation
- Waste management
- Wastewater

- Climate-related difficulties
- Energy and water scarcity

Population-density challenges

Population growth is a significant risk to Jordan having maintained stability within a region affected by turmoil and conflict. GAM and its surrounding areas account for over 50% of its population, 80% of its industrial sector, and 55% of its employment sector. Around 80% of industrial manufacture is located within the cosmopolitan area (Tarawneh, Hadadin, & Tarawneh, 2020), adding extra pressure on natural resources allocation, land use, and infrastructure. Population density is more concentrated within GAM. In 2019, it reached 13,600 inhabitants per km^2. It makes up four million on 293 km^2 of the built-up area but went down to 4,987 inhabitants per km^2 for the entire municipality (802 km^2) (Mehrotra et al. 2020), as shown in **Table 1, 2 and Figure 3.**

However, this density is uneven, with some districts reaching more than 20,000 inhabitants per km^2(Mehrotra et al., 2020). The highly densely populated areas as seen in al-Hussein and Whidat refugee camps contribute to an increase in the incidence of respiratory diseases, social problems, and poor neighbourhoods.

Table 1:
Demographics of Amman Governorate Al-Sayaydeh (2020) PopulationEstimates.pdf (dos.gov.jo), 2020)

Demographics of Amman Governorate	2004 Census	2015 Census	2020 Census
Urban population	94%	96%	97.2%
Rural population	6%	4%	2.8%
Total population	1,942,066	4,007,000	4,536,500

By 2002, urban expansion had reached 162,924 km2 (Tarawneh et al., 2020), but by 2018 it had increased to 803 km2 and covered 22 districts. Some areas have a higher population density, putting more strain on infrastructure and services (Mujahed, 2020). The quick urban expansion was caused by several factors, the most notable of which was: The first was the government's decision in 2007 to add five more zones to the GAM, bringing the total area of the GAM to 1,680 km2. The second was the forced evacuation of Iraqis in 2003. The current influx of Syrian refugees is the third cause. According to Alnsour (2016), 1.4 million Iraqis reside in GAM. According to Alnsour (2016), Jordan has around 1.4 million Syrian refugees.

Table 2:
Area (in km^2) of urban zones in Amman during the 1918–2017 period (Al Rawashdeh & Saleh, 2006; Cox, 2021; Saleh & Al Rawashdeh, 2007).

Year	1918	1953	1983	1987	1996	2002	2017	2019
Urban area in km^2	0.321	4.444	105.675	149.08	150.764	162.924	237.86	293

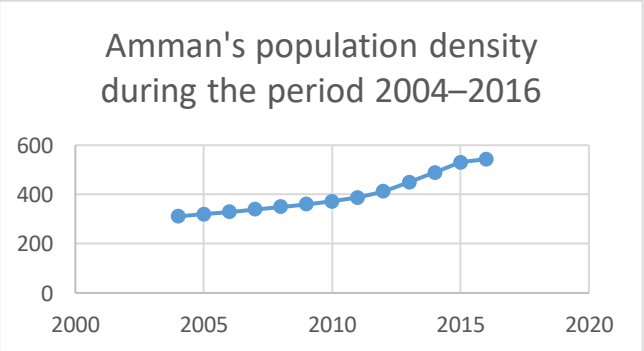

Figure 3: GAM'S population density during the period 2004–2016 Source: (dos.gov.jo)

Air pollution

Air pollution in urban areas is a significant environmental problem and one of the critical disease causes in the Middle East (Tsiouri et al., 2015). The potential sources of PM 2.5 in the Middle East are energy generation, industrial activity, transportation, and construction (Tsiouri et al., 2015). Industrial and service sectors development in Jordan and migration increase pollutants.
Stationary energy and transportation are the two sectors in GAM that contribute the most to emissions (64% and 31%, respectively) (Mehrotra et al., 2020). More specifically, the most important subsectors of emissions were electricity in buildings and on-road transport. Suburban energy consumption in Jordan grew at 8.5% percent from 2004 to 2014, as the growth rate was 6.4%. Energy demand nationally rose 2.4% between 2005 and 2015; however, this was considerably less than the GDP growth, which increased at a rate of 4.4% per year. To achieve the 2050 Vision, the country is already attaining economic development and energy consumption efficiency in name of Greater Amman, 2019.
Amman's C40 emission inventory measured CO2 emissions in GAM in 2014 at 7.4 million tonnes. Without action, the releases are projected to double by 2030, reaching nearly 40 million tonnes by 2050 (Mehrotra et al., 2020). GAM's climate action plan (a vision for 2050) will classify cross-sector and urban planning actions that GAM can employ to achieve its vision, as shown in Figure 4.

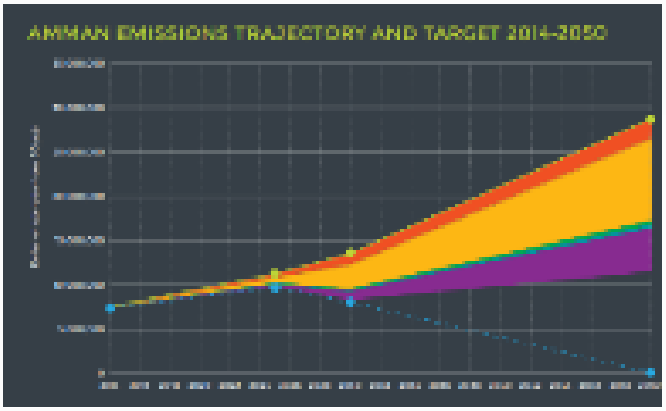

Figure 4: GAM emissions trajectory and target for 2014–2050

Jordan's nationally determined contribution to the Paris Agreement commits to reducing GHG releases by 14% than a business-as-usual situation by 2030. Jordan's planned emission reduction actions are primarily focused on the energy sector. Supported Climate Action for Urban Sustainability (CURB) projections, the emissions scenario shows GAM at roughly 11 million tonnes of CO2 in 2020, less than a third of nation-wide emissions. GAM has adopted several measures to reduce its energy consumption. For example, in 2020, solar panels were installed on some of the rooftops of GAM buildings, and LED lights were installed along the main arteries (120,000 were established in 2018) and in all GAM buildings. The municipality has bought 100 electric cars, and in 2018 a Germany-based business, E-Charge, signed a contract to install 10,000 electric charging stations across the country, several of which are located in GAM. However, regarding ongoing discussions concerning the 150 buses of the bus rapid transit (BRT) project, GAM is concerned that the operator would not invest in such facilities, while the European Union (EU) and the Agence Francis de Development (AFD) are pushing for electric buses.
It was found that there was an association between the number of vehicles and air pollution in GAM by Alnawaiseh, Hashim, and Isa (2012) and co-workers in 2015. In addition to the effect of temperature, the study found that high concentrations of suspended particles (TSP) and PM10 were induced by traffic volume in areas with high traffic counts. Traffic-heavy regions have high levels of PM10 and TSP. A lower mean PM10 concentration was found in low-pollution areas (90.9 34.4 g/m3) than high-pollution areas (164.9 58.7%), exceeding Jordan's PM10 standard of 120 g/m3. However, according to Jordanian Air Quality Standards, the observed annual mean of PM2.5 was three times greater than its allowed value and breached the WHO's air quality guideline(Li et al., 2020).
Air pollution from transportation is a significant issue in the Greater Amman Metropolitan Area

(GAM). There is a routine violation of whom air quality standards for total suspended particulate matter, sulfur dioxide (SO2), carbon monoxide (CO), and nitrogen oxides (NO). Particulate matter (PM10) has an annual average concentration of 130 g/m3 in Ghana and 69 g/m3 in Jordan, but the WHO recommends a 20 g/m3 annual average. In 2006, new guidelines were put in place to limit industrial leakage. As part of a climate change mitigation strategy, the government limits industrial and automobile pollutant emissions and develops two types of non-leaded gasoline (90 and 95 octanes) (Mehrotra et al., 2020).

In addition, the air quality is impacted by the industrial cities around GAM (such as Sahab south of Amman, Zarqa, and Irbid). Jordan's heavy industries are located in Zarqa, including Jordan Petroleum Refinery, Al-Hussein Thermal Power Station, the As-Samra Wastewater Treatment Plant, and steel and pipe companies. Fifteen kilometers from Amman, the cement factory in Fuhais is one of the most destructive industries around GAM. Many pollutants are emitted from cement production, including soot and sulfur compounds, hydrocarbons, nitrogen oxides, carbon dioxide (5 percent of global CO2), and 0.07 kg of dust for every kilogram of cement produced. The dust contains high levels of metals. As a result of Jordan's dry climate and frequent winds, dust cannot settle and spread. The Ministry of Environment launched a program to measure pollution levels in the air in 2014. Environmental monitoring stations were built in the kingdom's densely populated industrial areas (Gov't to monitor air pollution levels, Jordan times Journal, 2016) and electronically linked to the Environment Ministry for testing. GAM district Al-Madeenah includes central Amman. Located in Amman's busiest area, the Al-Hussein station was selected to benchmark the city's maximum PM10 concentration (Croitoru & Sarraf, 2010). MOH assessed the PM10 levels in Al-Huseini from 2002 to 2007 and calculated a 124 g/m3 year-to-year average.

Air quality monitoring stations for the Ministry of the Environment include seven in GAM. Graph No. 5: The Jordanian Air Quality Monitoring Department measured the TSP and PM10 levels in ambient air and reported the results to the Ministry of Environment. On the other hand, large amounts of PM10 and TSP were discovered in areas with high traffic. High-pollution areas had a significantly higher average PM10 concentration (164.9 58.7 g/m3) than low-pollution areas (90.9 34.4 g/m3), above the Jordanian PM10 threshold of 120 g/m3. However, according to Jordanian Air Quality Standards, a three-fold increase in PM2.5 levels was recorded compared to a decrease in PM10. However, both exceeded WHO air quality standards (Alnawaiseh et al., 2012).

Figure 5: One of Amman's monitoring stations

The Jordanian Air Quality Monitoring Department also conducted frequent monitoring tests at Abdullah II Ibn Al-Hussein Industrial Estate (AIE), located within Sahab and is considered the most significant industrial city in Jordan. Sahab comprises the biggest cemetery in GAM. The study's preliminary results were that SO2 and CO levels increased at Sahab during this study period compared to the previous study period. During this study period, nitrogen dioxide (NO2) and PM2.5 levels exceeded the hourly and daily limits stated in JS 1140/2006. The prevailing wind direction at the Sahab site was calm wind with 89.7%, followed by south-western wind with 5.2%. The PM2.5 annual averages at the Sahab monitoring site exceeded the yearly limit stated in JS 1140/2006 during this study period, as shown in

Table 3.

Table 3: Annual air pollutant rate for the year 2018 (Source: Ministry of Environment)

The year 2018	Annual rate (ppm)	The maximum permissible limits for ambient air pollutants monitored in the study (Technical Rule No. 1140/2006)
SO2	0.002	0.04
NO2	0.028	0.05
NO	0.011	There is no limit in the specification
Nox	0.039	There is no limit in the specification
CO	1.742	There is no limit in the specification
PM2.5	27 µg/m³	15 µg/m³

Transportation

One of the significant environmental, economic, and social challenges facing GAM includes its flawed transportation system, and only 30% of Jordanians use public transport (Hadjidimoulas, 2018). One of the biggest challenges for mobility in GAM relates to behavioral and cultural issues. GAM hosts about 69% of all Jordanian vehicles, which represents a significant source of air pollution. Most people prefer to use their private cars or taxis, which is why in 2017, there were 655,323 motor vehicles registered in GAM (according to CEIC) (*Jordan | Number of Vehicles: Amman | Economic Indicators*.2015), serving 1,966,000 people in the same period, meaning, one car per three persons. The current infrastructure of roads leads to significant congestions and immense amounts of exhaust from the vehicles,

Figure 6. Additionally, most vehicles are old, which is the main factor in the emission of pollutants (GAM, 2019).

Figure 6: Traffic congestion issues in Amman

BRT is one of GAM's infrastructure projects that aim to tackle the air pollution problem, especially concerning CO2 Emissions, and improve mass public transportation by reducing the traffic congestion in the city (C40, 2020). It is expected to be finished and begin operating at the end of 2021 and is expected to upsurge the share of open transport usage from 14% to 40% by 2025, as shown in

Figure 7.

Figure 7: Amman's BRT project

Poor waste management

Municipal solid waste disposed of in a landfill causes soil, water, air, and aesthetic pollution and increases landfill gas emissions (LFG) (Ahmadi et al., 2020). In May 2003, the GAM moved the disposal system to a recently built sanitary landfill at Alghabawi and closed the Russaifah landfill. The new dump is a well-engineered facility with leachate and gas collection systems. It is the largest and the only lined sanitary landfill in Jordan, serving five municipalities. Located 32 kilometers away from Amman city, Al Ghabawi is the first municipal carbon finance partnership in the Middle East. The landfill receives around 4,300 tonnes of solid waste (1.15 million tonnes in 2017 and 1.5 million tonnes in 2018). However, the waste collected in GAM was being disposed of at the Al Ghabawi landfill without any regular treatment or recycling. Scavengers, NGOs, or private recycling companies recovered less than 3% of recyclable materials (C40: Clean Cities through Better Waste Management Systems, 2021). As shown in **Table 4**, the per capita waste in GAM was 747.6 grams/day in 2017, whereas the municipal waste collected in 2019 at GAM was 1456074 tonnes, which represents 33.8% of the total waste collected in Jordan.

Table 4:
Per capita waste collection of Amman governorate compared with the whole kingdom in 2019 (Jordan in Figure 2018 – Department of Statistics, 2018; Hadjidimoulas, 2018).

Governorate	Per capita (grams/day)	Population	Municipal waste collected (tonnes)
Amman	747.6	4,226,700	1,153,400
The whole kingdom	929.0	10,053,000	3,408,918

In response to GAM's critical need for investment in solid waste management, the European Bank for Reconstruction and Development (EBRD) provided GAM up to €7.4 million to fund LFG recovery system expansion. This mega-project started generating 4.8 megawatts per hour in May 2019 by burning the methane gas collected from waste. It is collected and burned to avoid releasing it into the air while also using the collected biogas to generate electricity. Methane gas is captured and used to generate clean energy at the Al Ghabawi landfill using a modern LFG recovery system. Gas turbines with a capacity of up to 4.8 MW are used to link the energy produced to the national grid, decreasing CO2 emissions by around 2.6 million tonnes (Zgheib, 2018).
GAM and other municipalities seek to reduce the number of waste dumps from 23 landfills to 10 environmentally friendly landfills by 2034 to collect waste in specific areas and increase the amount of gas extracted from them for energy production. To make GAM a sustainable city, specific actions need to be taken, including proper waste management, litter prevention, environmental innovation, and collaborations between the community, government, and industry to protect ecological resources and promote water conservation, reuse initiatives, and energy innovation.

Wastewater

Wastewater volume grows as the population increases. Only 93 percent of Jordanians have improved sanitation, and only 63 percent have it through the network. The rest get it through other means (MWI, 2016). In Jordan, the As-Samra Wastewater Treatment Plant handles 99 percent of GAM's wastewater and 71 percent of Jordan's (MWI, 2016). Treatment wastewater flows into the Zarqa River, which King Talal Dam dams. It is mixed with fresh floodwater and finally discharged for irrigation use in the Jordan Valley, of which 90% is recycled for agricultural uses (MWI, 2016). The first wastewater treatment plant in GAM was the Ain Ghazal plant, which opened in 1968. A pre-treatment facility for As-Samra is now located here. The Ain-Ghazal/As-Samra system, which handles and treats wastewater in the Amman-Zarqa region, is a significant source of concern (Helmer & Hespanhol, 1997; MWI, 2021).
About 65% of the wastewater discharged to the As-Samra Treatment Plant is collected by the sewerage system and discharged via Ain Ghazal. The sewerage system covers the GAM districts, Jubeiha, Tela'a Al Ali, Khilda, Umm El Soumaq, Marj El Hammam, Abu Alanda, Quweismeh, parts of Wadi Essir, and parts of Sweileh. The sewage is released by a siphon (DN 1200, 38 km) to As Samra.

Industries that are not linked to the municipal sewerage structure and disposing of their wastewater using exhaust freighters reported a considerable problem, **Table 5**. According to the USAID finance survey, it has suggested that industrial wastewater that is not recycled should be transported to sites in Jordan that receive industrial wastewater, such as the Ain Ghazal pre-treatment premises located on the border of Amman and Zarqa.

Table 5: Overview of the most important industrial estates in Amman

Name	No. of enterprises	Location	Water consumption (m3/year)	Treatment	Discharged/ Reused
Abdullah II bin Al-Hussein Industrial Estate (AIE)	340	Sahab – Amman	700,000	Yes	Irrigation
Al Tajamout Industrial City	50	Sahab	n.a	n.a	n.a

The Russia-West Zarqa Sewer System area contributes about 28% of the sewage discharged to the As-Samra Plant. The north-eastern part of Amman (Tariq and Marka districts) and the community of Russifa and West-Zarqa belong to this sewerage system.

The plant is overloaded by a wastewater flow, which exceeds the design flow by about 150%. It has no nitrogen removal capability. Additionally, the existing treatment plant lacks basic facilities for sludge management. The sludge in the anaerobic ponds is removed only once in 15 years. The exposed deficiencies of the treatment plant result in effluents of poor quality. Formerly existing odor problems are partly reduced by measures of deodorization at the inlet structure. Nevertheless, significant improvements are required to overcome the existing deficiencies at the site. The effluent of the plant (> 100 mg BOD5/l) is quite unsatisfactory; it is discharged to the Wadi Dhuleil, which joins the Wadi Zarqa, the major tributary to the King Tala Reservoir. The effluent does not meet the requirements according to the relevant Jordanian Standard 893/1995 for discharge to wadis and catchment areas. Severe environmental negative impacts downstream of the treatment plant due to the remaining pollution load of the treated wastewater. The effluent can be reused only for restricted irrigation due to the high faecal coliform counts (> 100,000 per 100 ml),

Figure 8.

Figure 8: Treated wastewater from the Amman-Zarqa area flows through the Zarqa River to the *Jordan Valley, where it is indirectly reused for irrigation*

The water authority of Jordan Laboratories is responsible for monitoring and controlling wastewater, both domestic and industrial, to protect water resources, the environment, and public health. The water discharged from the purification plants is monitored to ensure that the treated water quality conforms to the standard specification of "reclaimed domestic wastewater" according to No. 893/2006, and the quality of the water discharged into the wastewater network is monitored and evaluated according to the instructions for non-domestic wastewater disposal for the year 2019. There are assisting establishments that implement these instructions by disposing of their wastewater through public sewage networks, and 2837 samples were collected and subjected to 14,239 tests for the GAM during the year 2019 in wastewater laboratories.

Climate-related challenges: flash floods, hazardous blizzards, and rockslides

GAM is vulnerable to earthquakes, flash floods, drought, heat and dust waves, and blizzards. For instance, weighty rains usually lead to flooding in lower-lying parts. Even snowstorms paralyze GAM, affecting the power grid, schools, and transportation,
Table **6**.
Countries are rapidly expanding their metropolitan regions with little forethought. Many of these newly urbanized regions have inadequate contemporary sewage systems, which exacerbates the problem. As a result, land that could previously absorb rainfall and store it as groundwater can no longer discharge significant amounts of water. Property destruction, pollution, and landslides are all expected side consequences of flash floods. In Jordan, the main reasons for flash floods include rapid and unplanned urbanization, inadequate drainage systems capacities, and climate change implications. Although GAM is characterized by water scarcity and drought, it suffers from occasional flash floods due to high-intensity, short-duration rainfall events. GAM has contrasting seasons; the wet season falls between November and April. The topography of GAM consists of steep hills and narrow valleys, which exacerbate the quick run-off on the dry landscape in flash floods. In 2015, several people in low-lying areas of GAM died during a horrible flooding event.

In 2018, flash floods caused loss of lives and damage to properties. According to the flood hazard map for Jordan for June 2019, GAM was among the most susceptible to flash floods and epidemics due to the high population, increasing the pressure on the water, sanitation, and drainage services, as shown in **figure 9 and table 6.** In partnership with the GAM, UN-Habitat Jordan is working on a project to address these urgent risks and strengthen the resilience of exposed Jordanian and Syrian communities in Amman as a mitigation measure.

Figure 9: Flash flooded on February 28 in Amman downtown in 2019

Table 6: Flash floods in Amman downtown in 2019 (Tarawneh et al., 2020).

Date (Location)	Damage due to the flash flood	Notes
28/2/2019 Amman	Two thousand accidents, houses flooding, vehicles being swept away, and 279 downtown traders affected. Estimated damage cost = $15 million	Heavy rainfall: 68 mm in 24 hours (nearly 20% of the whole rainy season)

Lack of natural resources (water and energy)

Water scarcity

Water scarcity is among Jordan's most important problems. The country is characterized by a particularly arid climate, with a bit of amount of arable land. Since the 1960s, GAM has derived water from the Azraq aquifer and in 2013 from the fossil Disi aquifer from Water supply,2021. About half of GAM's water comes from the Jordan Valley, according to the company. From 225 meters below ground in the Jordan Valley, water is pumped into Zai, treated at a sophisticated facility. Other water sources include the Al-Mafraq well, the Azraq aquifer, and the Qatnana, Swaqa, and Wala aquifer systems Water consumption is managed by delivering water to citizens and businesses only once to0020twice a week; moreover, the water is stored in tanks by each

household as part of the norm. The growing demands of people uprooted by the Syrian civil conflict are driving up water consumption. Currently, the population gets much less than the WHO's guideline requirement of 120 liters per person per day. By 2022, the Red Sea-Dead Sea Conveyance will be operational, assisting in forming a long-term balance between existing water supplies and demand. In 2015, 42.0 percent of GAM's total water supply was received. Furthermore, water consumption in GAM has reached 300,000 cm per day, exceeding the maximum possible daily levels by 90,000 cm and resulting in a 35 MCM water deficit each (Dar-Mousa & Makhamreh, 2019).

Groundwater is a vital natural resource for economic development and a reliable supply of safe drinking water. In 1990, for example, boreholes in the Amman-Zarqa watershed region revealed high TDS, Na, Cl, and NO3 pollution. Aquifers with limited potential are Jordan's alternative water sources, such as the almost drained Azraq Oasis. According to a study by the Al-Zyoud et al. (2015), Amman-Zarqa, the country's most significant renewable groundwater aquifer, is currently overexploited. While the safe yield is 87.5 million m3, actual pumping is 156.3 million m^3 or more than 178 percent of the safe yield. Meanwhile, water extraction from the Azraq basin totals 58.2 million m^3, or more than 240 percent of the safe production, and is deemed overuse Resource protection issues are a frequent occurrence. In the consuming regions, the expenses of water extraction and transport are considered. As a result, pollution of surface water and groundwater sources should be avoided. In the Amman, Zarqa, and Dhuleil regions, groundwater contamination from organic and industrial pollutants is widespread in surface water pollution in King Talal Dam and King Abdullah Canal. GAM started receiving 100 × 106 m^3 water from the Disi aquifer in 2013 to satisfy the growing water demand (Al-Zu'bi, 2017 and Jordan Water Company Miyahuna, 2018), as shown **in Table 7 and Table 8 Lack of energy resources**

Jordan *is* one of the world's most energy-dependent countries. Around 10 percent of the country's GDP is devoted to energy, with 94 percent from imports (Sandri et al., 2020). With 98 percent of GAM's energy coming from Middle Eastern nations, hydrocarbons are GAM's primary energy source (GAM document in Slideshare,2019). Cities with significant population and economic growth driven by regional immigration, and cities with energy insecurity, according to Sandri (2020), have two main features related to energy problems (Sandri,2020).

Modern energy production methods are required to build a sustainable low-carbon economy and to improve energy security. Equipping people with ecologically sustainable fuels is just part of the answer (Sandri, 2020). Amman city has a large amount of solar energy potential, with annual average sun irradiation of 5.5 kWh/m2 (Al-Zu'bi, 2017), and there are more than 300 sunny days a year in Jordan due to its location in the world's solar belt. As a result, the country enjoys low humidity and moderate temperatures. Photovoltaic systems are presently cheaper than traditional energy sources (Al-Zu'bi, 2017).

The primary source of GHG emissions in Amman city is electricity consumption in commercial and residential buildings. During 2004–2014, household energy consumption grew at a rate of 8.5% at the national level (GAM, 2019). Some mitigation measures have been introduced, including issuing building licenses and providing occupancy certificates. There is a low application rate of such measures due to incentives misalignments.

Shortage of green space

It is well known that urban green spaces address heat and air pollution. Some areas of GAM, particularly the East of GAM, have little access to green public spaces due to rapid and poorly planned urbanization. In GAM, the green spaces do not exceed 2.5% of the total area (Whitman, 2013). Residents of GAM enjoy 2.5 m2 of park area per capita, while the WHO standard is 9 m2 per capita. Accessing green spaces reduces well-being as global research suggests that physical 2020activity in a natural environment can reduce mental disorders (GAM, 2019).

Expanding the green space has always been on GAM's agenda. For instance, in partnership with EBRD, GAM is developing a Green City Action Plan. In June 2019, GAM identified an innovative vision and prioritized the challenges that Amman is currently facing. The project team has developed a list of over 300 action plans that might be enforced to respond to those prioritized challenges. With its Green City Action Plan, GAM is collaborating with Jordan's National Action Plan for Green Growth 2019–2030 to (i) rethink solutions to economic, environmental, and social challenges and (ii) rethink the environment's role in increasing economic opportunities for

sustainable development (Mehrotra et al.,). City parks reduce overall temperatures. GAM has 11.72 km2 of green area, including parks, recreation, and pavement landscapes (Bazian, 2019). This area includes 143 parks distributed all over the 22 districts. GAM planted around 25,000 trees in 2019, compared with 23,000 in 2018. All the trees that have been planted are authentic species as per the agreements signed with the International Union for Conservation of Nature, the Valley Association, and the GIZ organization and are appropriate for the climatic conditions in these areas, such as acacia trees, ornamental peppers, agendas, conifers, and carobs, GAM planted 25,000 trees in 2019 (GAM, 2020). In 2006, GAM established a specialized Urban Agriculture Unit. Around 110 homes, mainly in the eastern regions. GAM has also been educating urban farmers on using water efficiently.

Table *8*

Table 7: Jordan's population versus per capita water availability

Year	Total annual renewable freshwater available (Mm3)	Population (millions)	Per capita water availability (m3)
1955	1331	1.447	920
1990	906	4.009	226
2020	1236	10.229	120

Lack of energy resources

Jordan is one of the world's most energy-dependent countries. Around 10 percent of the country's GDP is devoted to energy, with 94 percent from imports (Sandri et al., 2020). With 98 percent of GAM's energy coming from Middle Eastern nations, hydrocarbons are GAM's primary energy source (GAM document in Slideshare,2019). Cities with significant population and economic growth driven by regional immigration, and cities with energy insecurity, according to Sandri (2020), have two main features related to energy problems (Sandri,2020).

Modern energy production methods are required to build a sustainable low-carbon economy and to improve energy security. Equipping people with ecologically sustainable fuels is just part of the answer (Sandri, 2020). Amman city has a large amount of solar energy potential, with annual average sun irradiation of 5.5 kWh/m2 (Al-Zu'bi, 2017), and there are more than 300 sunny days a year in Jordan due to its location in the world's solar belt. As a result, the country enjoys low humidity and moderate temperatures. Photovoltaic systems are presently cheaper than traditional energy sources (Al-Zu'bi, 2017).

The primary source of GHG emissions in Amman city is electricity consumption in commercial and residential buildings. During 2004–2014, household energy consumption grew at a rate of 8.5% at the national level (GAM, 2019). Some mitigation measures have been introduced, including issuing building licenses and providing occupancy certificates. There is a low application rate of such measures due to incentives misalignments.

Shortage of green space

It is well known that urban green spaces address heat and air pollution. Some areas of GAM, particularly the East of GAM, have little access to green public spaces due to rapid and poorly planned urbanization. In GAM, the green spaces do not exceed 2.5% of the total area (Whitman, 2013). Residents of GAM enjoy 2.5 m^2 of park area per capita, while the WHO standard is 9 m2 per capita. Accessing green spaces reduces well-being as global research suggests that physical 2020activity in a natural environment can reduce mental disorders (GAM, 2019).

Expanding the green space has always been on GAM's agenda. For instance, in partnership with EBRD, GAM is developing a Green City Action Plan. In June 2019, GAM identified an innovative vision and prioritized the challenges that Amman is currently facing. The project team has developed a list of over 300 action plans that might be enforced to respond to those prioritized challenges. With its Green City Action Plan, GAM is collaborating with Jordan's National Action

Plan for Green Growth 2019–2030 to (i) rethink solutions to economic, environmental, and social challenges and (ii) rethink the environment's role in increasing economic opportunities for sustainable development (Mehrotra et al.,). City parks reduce overall temperatures. GAM has 11.72 km2 of green area, including parks, recreation, and pavement landscapes (Bazian, 2019). This area includes 143 parks distributed all over the 22 districts. GAM planted around 25,000 trees in 2019, compared with 23,000 in 2018. All the trees that have been planted are authentic species as per the agreements signed with the International Union for Conservation of Nature, the Valley Association, and the GIZ organization and are appropriate for the climatic conditions in these areas, such as acacia trees, ornamental peppers, agendas, conifers, and carobs, GAM planted 25,000 trees in 2019 (GAM, 2020). In 2006, GAM established a specialized Urban Agriculture Unit. Around 110 homes, mainly in the eastern regions. GAM has also been educating urban farmers on using water efficiently.

Table 8:
Abstraction from groundwater basins in Jordan and their safe yields in 2015 (Molle et al., 2017)

Basin		Safe yield (MCM)	Total users (MCM)	Balance	No. of wells	Percent of safe yield
1	Yarmouk	40	54.16	-14.16	203	135
2	Amman Zarqa	87.5	166.1	-78.61	955	190
3	Jordan River Side Wadis	15	46.73	-31.73	139	312
4	Jordan Valley	21	17.02	3.98	334	81
5	Dead Sea	57	89.98	-32.98	469	158
6	Azraq Basin	24	52.54	-28.54	580	219
7	Hammad Basin	8	1.87	6.13	15	23
8	Wadi Araba North	3.5	6.33	-2.83	37	181
9	Wadi Araba south	5.5	8.48	-2.98	62	154
10	Sirhan	5	1.71	3.29	23	34
11	Jofer, non-renewable	9	32.85	-21.85	205	365
12	Disi, non-renewable	125	146.96		115	118
Total		418.5	624.72		3138	149

Source: MWI (2016) open files Tielbörger et al. (2016)

Poor urban planning

Jordan formerly mixed the British city planning method of 1950 with the American downzoning strategy of the early 1970s to preserve open spaces, resulting in gaps in the entire planning system owing to the local Jordanian circumstances of a weak economy, centralization, and restricted involvement. Because of new environmental problems, Amman's city planning will have to change dramatically from previous development methods.At the GAM scale, urban environmental planning is insufficient, and it lacks the essential tools to assist decision-making. Diverse issues impede the transition to a "resilient" strategy, both at the national and local level Vertical relationships and dynamics between GAM and the central government, centralized governance, top-down policymaking, limited vertical and horizontal coordination, insufficient urban planning, limited public participation in planning and decision-making processes, and

regional political instability are just a few of these factors. Al-Zu'bi (2017) notes that many beneficial improvements in management have happened, including 100RC, C40, and Green cities. When government funds have fallen short, donor money has been a vital component of the budget for environmental and sustainability initiatives.
As a result, Amman's growth has been chaotic. Amman's urban planning failed to achieve a healthy urban environment with planned and authorized development. No clear planning strategies were developed to address critical issues such as population influxes that increased from 1.7 million in 2004 to more than four million in 2020 in just one and a half decades (Department of Statistics, 2020). Due to these factors, the urban structure of Amman has been altered, resulting in informal settlements and overcrowding, agricultural land degradation; poor urban services; pollution; congestion; a lack of green spaces, and increasing flood risks. Many of Amman's industries are located in or near metropolitan areas, as are many of its surrounding cities. Due to the co-location, it is more challenging to separate residential and industrial waste.GAM started creating a new planning framework in 2006 to address some of the past shortcomings, mainly because of the need to manage population increase. So in 2008, the Amman Master Plan 2025 was authorized as a roadmap for the city's growth. For its part, GAM does not have any particular law and instead uses national policy legislation (Cavoli, 2017).
A study by Meaton and Alnsour (2012) looked at environmental planning based on GAM 2025. (2019). This new planning framework includes two levels of operation: a short-term level that handles immediate problems and challenges and a long-term level that addresses long-term sustainability issues. Environmental issues such as severe water shortages, limited power supply, and waste management are addressed under the Jordanian National Green Growth Plan and UN-New Habitat's National Urban Strategy for Jordan. Provides all parties engaged in urban affairs with an institutional structure that promotes collaboration and policy consistency. GAM, part of the EBRD, has created a Green City Change Plan that integrates current resilience and climate action efforts backed by the Austrian government.In conclusion, GAM's integrated urban planning needs some improvements. The interrelations with the large metropolitan cities should be strengthened. GAM has been unable to develop institutional relations with the large neighboring cities of Russeifa and Zarqa. Besides, there is a lack of capacity building by the urban planners in GAM and the secondary cities. Also, the integrated urban planning approach is scattered across different projects, with inadequate coordination among project partners.

Additionally, encouraging the citizens to change their behaviors and reduce their adverse impact on the environment is one of the substantial challenges faced by GAM. Some of the measures that can be adopted include improving the connection to public transport, increasing public spaces accessibility, recycling, using hybrid cars, using solar panels for electricity, and supporting Jordan in achieving its commitments at the global and national levels. Last, to manage urban growth effectively, policy tools need revaluation and should consider regional levels. Alnsour (2016) argued that although Jordan is divided into three regions, the regional levels are not considered in planning.

Poor infrastructure

The recent influx of migrants has put pressure on the city's infrastructure and its capacity to deliver essential services; for instance, water networks and sewage systems need to be upgraded; in fact, water losses in bad networks account for water 50% of the water distribution. Several other factors, including the current planning legislation, influence the city's infrastructure and result in air pollution, uncontrolled land use, water shortages, increased energy consumption, and ineffective waste management. Further, GAM has a semi-arid climate and suffers from aridity and lack of renewable water sources, due to which Jordan imports 96 % of its energy. Since the 1960s, the World Bank has supported GAM financially and technically to solve its main urban and environmental problems by completing the highway network upgrading of informal settlements and sites and services policies. GAM's urban issues have not been fixed even with the help of international support. As a result of population growth, the city is no longer functional regarding access to public spaces, transportation, and housing (Department of Statistics, 2020).

Responding to challenges

Mitigation measures that GAM has adopted to reform action that might reduce urbanization's environmental impacts:

- Efficient water resources management
- Ain-Ghazal/As-Samra wastewater treatment system expansion and improvement
- Air quality monitoring
- The government has set satisfactory pollutant gas emissions levels from industries and vehicles (2006)
- Significantly limiting lead pollution by introducing two types of unleaded petrol (90 and 95 octanes) and determining the maximum emission levels (2006)
- Policy white paper
- Wastewater reuse
- Waste management system improvement
- Operating of emergency preparedness and response
- Legislation for environmental protection (2006) reinforcement
- Amman Metropolitan Growth Plan (2008)
- The Environmental Police Unit, established in 2009
- Transportation and Mobility Master Plan (TMMP) based on information and surveys conducted more than ten years ago in 2010
- Amman Disaster Risk Management Master Plan
- Amman joins the 100 Resilient Cities initiative (2014)
- Amman Resilient strategy (2017)
- Amman Green Policies and Projects (2017) and Green Amman (2020)
- Amman Climate Plan vision for 2050 implementation
- Promoting walkability
- Connecting the city digitally and institutionalizing the planning by implementing a bus rapid transit system
- Improving energy efficiency
- Applying green building guidelines
- Feasibility study for Amman Metro
- Healthy Cities Initiative (2018)

Table 9:
Approximated Road transport air emission external cost in Jordan (Mio EUR/year)

Emission	Jordan	Amman	Irbid	Zarqa
HC	3.0	1.5	0.4	0.3
NOx	13.8	6.3	1.5	1.3
PM Urban	83.7	39.7	9.5	7.9
PM Rural	15.6	7.4	1.8	1.5
SO2	7.8	3.6	0.9	0.7
Pb low value	0.3	0.2	0.0	0.0
Pb high value	8.4	4.2	1.0	0.8
Total costs, low Pb value	134.0	63.3	15.2	12.7
Total costs, low Pb value	142.1	67.3	16.2	13.5

Note: Pb low value only includes direct effects; Pb high value includes total effects
Source: Cervigni and Naber (2010)

Environmental expenditure

Environmental degradation is costly to society. The cost of environmental degradation (COED) in Jordan accounts for both immediate and long-term consequences. Employing well-established and globally accepted techniques, the COED is approximated to be between JOD143–332 million and a JOD237 million average or 2.35% of Gross Domestic Product in 2006.

The relatively high cost of outdoor air pollution is indicated degradation in identified road traffic and industrial hotspots. The pollutants' sources include companies located in the Amman and Zarqa industrial districts, as shown in

***Table* 9**.

A review of the public ecological expenditure (PEE) performed for the first time in Jordan indicates that between 2002 and 2006, the PEE averaged at 0.8% of Jordan's GDP at actual prices and 2.3% of government expenditure.

Table ***10*** illustrates the percentage of public environmental spending to total government expenditures (TGE) at current prices from 2002–2006. The PEE's proportion to TGE over the five years varied from 1.4% to 2.6% in 2003(Ghaemi & Smith, 2020).

Table 10:
Public environmental expenditure (2002–2006; Million JOR)

Public bodies	2002	2003	2004	2005	2006
Control Govermen spending	16,643,790	19,697,810	19,527,840	29,921,881	40,330,438
Public autonomous agencies	14,108,743	58,490,879	34,342,933	22,059,170	13,027,794
Municipalities	2,952,468	3,507,401	2,362,524	4.415,806	4,453,667
Greater Amman Municipality*	7,588,650	8,320,550	14,486,300	18,932,020	16,437,000
Total PEE	41,293,651	90,016,640	70,719,597	75,932,020	74,248,899
Total Goverment expenditure TGE	2,977,826,500	3,457,445,000	3.852,437,700	4,270,459,800	4,712,500,000
Percentage of PEE to TGE	1.4 %	2.6 %	1.8 %	1.8 %	1.6 %

Source: Ministry of Finance, except for the data from GAM

GAM is an independent public institution with a budget. It is not included in the bulletins issued by GBD. The GAM reports indicate that the total expenditure on ecological preservation for the surveyed duration from 2002 to 2006 was JOD65.8 million. The average yearly GAM spending comprised 20% of Jordan's average PEE; over 90% included solid-waste management. The environment ministry and ASEZA accounted for 2% each for the PEE (GAM, 2020).

Table 11 illustrates the central spending domains on ecological preservation GAM made. It demonstrates that GAM's expenditure on environmental management between 2002 and 2006 totaled JOD65.8 million; 93% of this was spent on waste management, as shown in table 11.

Table 11:
GAM Protection Expenditure by domain (2002–2006)

Functional classification	**2002**	**2003**	**2004**	**2005**	**2006**
Waste management	6.84	7.33	13.60	17.87	15.29
Wastewater management	-	-	-	-	-

Pollution abatement	0.43	0.53	0.60	0.65	0.70
Protection of biodiversity and landscape	0.33	0.47	0.29	0.41	0.45
R & D Environmental Preservation	-	-	-	-	-
Environmental protection	-	-	-	-	-
Total	**7.59**	**8.32**	**14.49**	**18.93**	**16.44**

Source: Calculation from the records of GAM 2002–2007

The environmental statistics report for the ecological expenditures (EE) in 2015 also indicated that the municipalities ranked first by spending JOD55.6 million on environment protection, where the central region had the highest budget of JOD53.76 million (DoS, 2018), as shown in

Table *13*.
Table 12:
Budget Allocations by Function (in Jordanian dinars, millions) in GAM

Actual budgetary allocations by sector		
	FY 2015	**FY 2016**
Mayor of Amman	1,600,000	2,105,000
City Manager	130,863,015	143,513,143
Environment & Regions	54,017	2,285,609
Public Works	117,559,335	188,267,705
Agriculture Affairs	764,369	684,947
Finance and Administration	35,202,303	70,973,932
Social Development	595,000	935,000
Economic Development and Planning	30,200,000	22,097,089
Total	**335,838,039**	**430,862,515**

Source: GAM Finance Department.
Note: GAM started to prepare sectoral budgets during FY 2015. Therefore, only the sectoral budgets for FYs 2015 and 2016 are included in this table.

Table 13:
Environmental expenditure in the municipal sector in the central region of Jordan, 2015

Environmental Expenditure	**Funding sources**			**Type of expenditure**		
Environmental domain	Other sources	Government Grants	Own source	Total	Capital Expense	Current expense.
Waste Management	**398.0**	**0.0**	**51868762**	**51869.160**	**819308.4**	**34548938**
Treatment of waste	0.0	0.0	30181675.0	30181675.0	0.0	30181675.0
Purchase of vehicles	0.0	0.0	4578050.0	4578050.0	206050.0	4372.0
Fuel	0.0	0.0	8472592.0	8472592.0	610122.0	7862470.0
Maintenance cost	0.0	0.0	5500421.0	5500421.0	0.0	5500421.0
Purchase of container	398.0	0.0	3136024.0	3136422.0	3136.4	0.0
Activities to protect public parks	**0.0**	**7400**	**1440766**	**1448166**	**0.0**	**1448166**
Trees plantation	0.0	7400	1440766	1448166	0.0	1448166
Environmental research and development	**0.0**	**0.0**	**2000**	**2000**	**0.0**	**2000**
Waste studies	0.0	0.0	2000	2000	0.0	2000

Environmental protection activities	**0.0**	**13054**	**429933**	**442987**	**0.0**	**442987**
Training courses	0.0	0.0	13755	13755	0.0	13755
Spraying pesticides	0.0	13054	416178	429232	0.0	429232
Total	398	20454	53741461	53762313	0.0	45442091

Conclusions and recommendations

This paper addresses the environmental problems that GAM faces, potential mitigating strategies, and the effects of population growth over the past decade and urbanization. Another significant problem in GAM is the prevalence of automobiles, which contributes to traffic congestion and air pollution. In addition, if GAM continues to allow the unregulated rate of urban development and deforestation, there will be other floods. Unless appropriate precautions are taken, urban flooding is predicted to rise. Storm sewer infrastructure, for example, is the foundation of urban drainage, and action is required to replace the old, inadequate systems.The initial research results showed the importance of implementing specific projects such as BRT for tackling the environmental challenges faced by GAM. BRT aims to link cities across GAM's boundaries and is being supported with policies along the two trunk routes, permitting the city to scale up earlier comprehensive housing initiatives into more walkable, mixed-use neighborhoods with carbon-free electricity and green buildings standards. The Al Ghabawi Landfill, a gas recovery system, is also considered one of the solutions to mitigate the negative impacts of climate change.

This study listed the most critical environmental challenges and the corresponding mitigation measures that the city authorities (particularly the GAM with other national and international organizations) implemented. Though these efforts are considered to improve the overall condition of GAM, several challenging tasks are to be completed to address the complicated environmental problems and move towards a resilient, sustainable city. For instance, although Jordan has replaced lead fuels with unleaded fuels, the rapid urban expansion puts more significant pressure on the environment in cities.Several issues have considerably constrained the success of urban environment improvement programs in GAM in general; however, they have to do with continuous evaluation, gaps in environmental and urban policy development, and institutional or organizational weaknesses by enhancing capacity building for the sustainability of a resilient city approach. These results can help decision-makers and people engaged in sustainable environment issues, and environmental policies in GAM identify the most suitable methods for evaluation and continuous development for the city and the country.

Some other recommendations are as follows:

- Future studies should focus on fiscal expenditure effects on environmental pollution.
- Institutional cooperation and electronic reporting systems gathered from all institutions should solve data gaps and availability.
- A good urban design and planning system can mitigate the lack of water and high temperatures.
- The introduction of alternative scenarios for a viable development of Amman and Jordan is required
- Highlight onsite recycling with sorting, composting, and bio gasification at the Ghabawi landfill importance.
- Institutionalize urban planning in the city to promote sustainable growth.
- Highlight innovative digital technologies need and reshape city living ways for an integrated strategy to city planning.
- Implement demand management measures to make the road networks modern, efficient, and responsive to Amman's needs.
- Improve integrated planning
- Promote walking by constructing suitable sidewalks in Amman.
- Update Amman's Transportation and Mobility Master Plan.
- Implement emission reduction technologies.
- Adapt clean and efficient energy resources and green.

- Collaborate with government agencies and communities in environmental management programs.
- Update legislations and improve infrastructure
- Create awareness programs on waste disposal and recycling systems and establish incentives for electric cars.

References

Ahmadi, A., Esmaeilion, F., Esmaeilion, A., Ehyaei, M. A., & Silveira, J. (2020). Benefits and limitations of waste-to-energy conversion in Iran. *Renewable Energy Research and Application, 1*(1), 27-45. doi: https://dx.doi.org/10.22044/rera.2019.8666.1007

Al-Sayaydeh, R. (2020). Sustainable Urban Planning and Public Transportation Amman. from https://www.metropolis.org/sites/default/files/2019-01/06.%20Amman%2C%20Jordan_2018%20Urban%20Planning%20City%20Presentation.pdf

Al-Zu'bi, M. (2017). *Water–Energy–Food–Climate Change Nexus in The Arab Cities: The Case of Amman City, Jordan*. (doctoral Dissertations), University of Calgary, Calgary,CANADA. Retrieved from http://hdl.handle.net/11023/3569

Al-Zyoud, S., Rühaak, W., Forootan, E., & Sass, I. (2015). Over exploitation of groundwater in the Centre of Amman Zarqa Basin—Jordan: evaluation of well data and GRACE satellite observations. *Resources, 4*(4), 819-830. doi: https://doi.org/10.3390/resources4040819

Al Rawashdeh, S., & Saleh, B. (2006). Satellite Monitoring of Urban Spatial Growth in the Amman Area, Jordan. *Journal of Urban Planning and Development, 132*(4), 211-216. doi: 10.1061/(ASCE)0733-9488(2006)132:4(211)

Alnawaiseh, N. A., Hashim, J. H., & Isa, Z. M. (2012). Relationship Between Vehicle Count and Particulate Air Pollution in Amman, Jordan. *Asia Pacific Journal of Public Health, 27*(2), NP1742-NP1751. doi: 10.1177/1010539512455046

Alnsour, J. A. (2016). Managing urban growth in the city of Amman, Jordan. *Cities, 50*, 93-99. doi: https://doi.org/10.1016/j.cities.2015.08.011

Bazian, A. R. (2019). AM cites challenges to expanding parks as whose standards reveal a 'great shortage' of green areas., *Jordan Times*. Retrieved from http://www.jordantimes.com/news/local/gam-cites-challenges-expanding-parks-who-standards-reveal-%E2%80%98great-shortage%E2%80%99-green-areas

C40. (2019). Bus Rapid Transit to Tackle Air Pollution, CO2 Emissions, and Improve Mass Public Transportation. from https://www.c40.org/case_studies/bus-rapid-transit-to-tackle-air-pollution-co2-emissions-and-improve-mass-public-transportation

C40.(2021): Clean Cities Through Better Waste Management Systems (2021.) Retrieved from https://www.c40.org/case_studies/clean-cities-through-better-waste-management-systems

Cavoli, C. (2017). Past, Present and Future mobility challenges and opportunities in Skopje *Association of Transport Engineers (EB ATI)*. doi: https://lib.traffic-ing.ru/handle/123456789/140

Cervigni, R., & Naber, H. (2010). *Achieving Sustainable Development in Jordan*: Amman: World Bank.

Cox, W. (2021). Demographia world urban areas: 16th annual edition. from Demographia http://www.demographia.com/db-worldua.pdf

Croitoru, L., & Sarraf, M. (2010). *The cost of environmental degradation: case studies from the Middle East and North Africa*: World Bank Publications.

Dar-Mousa, R. N., & Makhamreh, Z. (2019). Analysis of the pattern of energy consumptions and its impact on urban environmental sustainability in Jordan: Amman City as a case study. *Energy, Sustainability and Society, 9*(1), 1-12. doi: https://doi.org/10.1186/s13705-019-0197-0

Department of Statistics. (2020). Jordan census. from http://ghdx.healthdata.org/organizations/department-statistics-jordan

Dosweb. (2018). Figures in Jordan from http://dosweb.dos.gov.jo/DataBank/JordanInFigures/2018.pdf

GAM. (2019). GAM cites challenges to expanding parks as whose standards reveal a 'great shortage' of green areas., *Jordan Times*. Retrieved from http://www.jordantimes.com/news/local/gam-cites-challenges-expanding-parks-who-standards-reveal-%E2%80%98great-shortage%E2%80%99-green-areas

GAM. (2020). GAM planted 25,000 trees in 2019—Official, *Jordan Times*. Retrieved from http://www.jordantimes.com/news/local/gam-planted-25000-trees-2019-%E2%80%94-official

Ghaemi, Z., & Smith, A. D. (2020). A review on the quantification of life cycle greenhouse gas emissions at urban scale. *Journal of Cleaner Production, 252*, 1-34. doi: https://doi.org/10.1016/j.jclepro.2019.119634

Hadjidimoulas, C. (2018). Methane Gas Emissions: Methods of Improving the Efficiency of the Biggest Landfill Gas Waste to Energy Project in the Middle East Installed in Amman, Jordan. *Open Access Library Journal, 5*(8), 1-35. doi: https://doi.org/10.4236/oalib.1104476

Helmer, R., & Hespanhol, I. (1997). *Water pollution control: a guide to the use of water quality management principles*: CRC Press.

Khawaldah, H. A. (2016). A prediction of future land use/land cover in Amman area using GIS-based Markov Model and remote sensing. *Journal of Geographic Information System, 8*(3), 412-427. doi: http://dx.doi.org/10.4236/jgis.2016.83035

Li, X., Hussein, T., Viana, M., Petäjä, T., & Kerminen, V. M. (2020). *Aerosol Physics-PM2.5 and PM10 characterizations focus on sand and dust storms episodes in the urban atmosphere in Amman.* (Master thesis), The University of Helsinki, Jordan.

Meaton, J., & Alnsour, J. (2012). Spatial and Environmental Planning Challenges in Amman, Jordan. *Planning Practice & Research, 27*(3), 367-386. doi: 10.1080/02697459.2012.673321

Mehrotra, S., Lewis, L., Orloff, M., & Olberding, B. (2020). Greater Than Parts: A Metropolitan Opportunity. Washington, DC: World Bank.

Molle, F., Al Karablieh, E., Al Naber, M., Closas, A., & Salman, A. (2017). Groundwater governance in Jordan: the case of Azraq Basin. A Policy White Paper (pp. 30). Colombo, Sri Lanka: International Water Management Institute.

Mujahed, L. (2020). Community Resilience in Response to the Population Growth in Al-Thahabiah Neighborhood. *International Journal of Urban and Civil Engineering, 14*(8), 278-287.

MWI. (2016). Jordan Ministry of Water and Irrigation. from https://portal.jordan.gov.jo/wps/portal/Home/GovernmentEntities/Ministries/Ministry/

MWI. (2021). Jordan Ministry of Water and Irrigation. from https://portal.jordan.gov.jo/wps/portal/Home/GovernmentEntities/Ministries/Ministry/

OECD. (2018). Rethinking Urban Sprawl Moving Towards Sustainable Cities. *OECD Publishing*, 168. doi: https://doi.org/10.1787/9789264189881-en

Riad, P., Graefe, S., Hussein, H., & Buerkert, A. (2020). Landscape transformation processes in two large and two small cities in Egypt and Jordan over the last five decades using remote sensing data. *Landscape and Urban Planning, 197*, 103766. doi: https://doi.org/10.1016/j.landurbplan.2020.103766

Saleh, B., & Al Rawashdeh, S. (2007). Study of urban expansion in jordanian cities using GIS and remoth Sensing. *International Journal of Applied Science and Engineering, 5*(1), 41-52. doi: https://gigvvy.com/journals/ijase/articles/ijase-200707-5-1-041.pdf

Sandri, S., Hussein, H., & Alshyab, N. (2020). Sustainability of the Energy Sector in Jordan: Challenges and Opportunities. *Sustainability, 12*(24), 1-25. doi: 10.3390/su122410465

Slideshare.net. (2017). Amman Resilience Strategy. from https://www.slideshare.net/coolgirl0000/amman-resilience-strategy?from_action=save

Tarawneh, Z., Hadadin, N., & Tarawneh, E. (2020). Extreme floods in central Jordan: Frequency analysis. *Italian Journal of Engineering Geology and Environment, 20*(1), 17-23. doi: 10.4408/IJEGE.2020-01.O-02

Tielbörger, K., Claus, C., Schloz, D., Twite, R., Al-Karablieh, E., Salman, A., . . . Alpert, P. (2016). Sustainable Water and Land Management Under Global Change—The GLOWA Jordan River Project. In D. Borchardt, J. J. Bogardi & R. B. Ibisch (Eds.), *Integrated Water Resources Management: Concept, Research and Implementation* (pp. 721-747). Cham: Springer International Publishing.

Tsiouri, V., Kakosimos, K. E., & Kumar, P. (2015). Concentrations, sources and exposure risks associated with particulate matter in the Middle East Area—a review. *Air Quality, Atmosphere & Health, 8*(1), 67-80. doi: 10.1007/s11869-014-0277-4

Worldometers. (2021). Worldometer - real-time world statistics: Jordan population. from https://www.worldometers.info/world-population/jordan-population/

Zgheib, N. (2018). EBRD helps expand Amman's first landfill gas recovery system., from https://www.ebrd.com/news/2018/ebrd-helps-expand-ammans-first-landfill-gas-recovery-system.html

View publication stats