التعاون الألماني
DEUTSCHE ZUSAMMENARBEIT

Amman: From Grey to Green

Environmental Benefits of Green Infrastructure

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DEFINITIONS

Infrastructure

Defined as a "substructure or underlying foundation on which the continuance and growth of a community or state depends" (Benedict & McMahon, 2006, p.1).

Green Infrastructure (GI) and Urban Green Infrastructure (UGI)

First Definition

GI is, "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (European Commission, 2013, p.3).

Second Definition

In urban settings, "UGI planning, based on certain principles, has emerged as a way to conceptualize connected greenspace in urbanized environments. This is achieved through the application of processes and approaches linked to policy themes. Taken together the processes, approaches and policy themes constitute the principles of UGI, which when adopted can promote, maintain and enhance quality of life in resource-efficient, compact and climate-resilient cities" (Davies et al., 2017, p.93).

Ecosystem Services

Defined as the various benefits that people obtain from ecosystems. These services are categorized into four main groups:

1. Provisioning services (e.g., food production)
2. Regulating services (e.g. water and air filtration)
3. Supporting services (e.g. soil formation)
4. Cultural services (e.g. community recreation) (MEA, 2005).

Urban Sprawl Also called sprawl or suburban sprawl, the rapid expansion of the geographic extent of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation. Urban sprawl is caused in part by the need to accommodate a rising urban population; however, in many metropolitan areas, it results from a desire for increased living space and other residential amenities. Urban sprawl has been correlated with increased energy use, pollution, and traffic congestion and a decline in community distinctiveness and cohesiveness. In addition, by increasing the physical and environmental "footprints" of metropolitan areas, the phenomenon leads to the destruction of wildlife habitat and to the fragmentation of remaining natural areas (Rafferty, 2020).

Cimate Change is defined as, "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2014, p. 127).

DEFINITIONS

Resilience is defined as, "The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2014, p. 127).

Climate Adaptation is concerned with, "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities" (IPCC, 2014, p. 118).

Mitigation (of climate change) relates to any "human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)" (IPCC, 2014, p. 125).

ABOUT THIS PUBLICATION

This publication aims at raising awareness among urban planners, architects, and engineers in the city of Amman, about the importance of implementing Green Infrastructure (GI) networks in urban areas to address their existing environmental as well as socio-economic challenges. The main goal behind this publication is to identify future interventions, both major and minor, that occur within the city's public open spaces (POS), as a key component that supports in building the city's resilience. The publication is part of the project 'Improving Living Conditions in disadvantaged areas in Amman' (ILCA) executed by GIZ in partnership with the Jordanian Ministry of Environment (MoEnv) and the Greater Amman Muncipality (GAM) and commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ).

This publication consists of three main chapters that address the following topics:

CHAPTER I Elaborates on the environmental benefits of GI and the way in which it reinforces the functioning of the city's grey infrastructure.

CHAPTER II Examines the overall global challenges encountering urban areas. These challenges include climate change, urban poverty, and insufficient infrastructure networks. It also takes a closer look at the particular challenges facing the city of Amman.

CHAPTER III Concludes with a set of recommendations on how to better guide the implementation of GI in the city at both the planning and design levels.

INTRODUCTION

At present, and similar to many cities in the world, the city of Amman is experiencing many complex environmental challenges associated with the process of urbanization and the concentration of population and economic activities. These challenges include, but are not limited to, pollution, land consumption, and the loss of biodiversity. Furthermore, with the anticipated impacts of climate change, cities worldwide are yet expected to witness extreme weather events. Consequently, the need to develop policies to mitigate and adapt to climate change is now regarded as imperative to ensure the progress and sustainability of cities with time.

With the various urban challenges that cities are now witnessing, developing the green infrastructure (GI) of cities, such as parks and gardens, green roofs, rain gardens, and permeable pavements, has been increasingly argued to be a strategic planning concept and a key application approach that supports in developing climate-resilient cities. Traditional grey infrastructure networks, such as the water supply and stormwater drainage networks, have been increasingly revealing their deficiency to absorb urban growth and climatic changes, because of the continuous need to maintain as well as enhance the capacity and performance of such systems.

The challenging situation of modern cities, therefore, has necessitated a paradigm shift towards realizing the significance of preserving as well as enhancing the city's green network. With the wide range of social, economic and environmental benefits that are obtained through the development of the city's GI, the need to depart from the sole reliance on the traditional grey infrastructure networks is now becoming more recognized. Through providing various ecosystem services and benefits to societies, GI networks are advantaged in that they can enhance the overall quality of life in cities, as well as protect cities and their inhabitants from the anticipated impacts of climate change.

Based on the general understanding of the specific urban challenges witnessed by cities worldwide, as well as the potential solution that is offered by the concept of GI, this publication forms the forefront of the discussion around the significance of GI in addressing some of the most pressing concerns in the city of Amman. The publication will start the discussion by providing a brief overview of the concept of GI and its environmental benefits, and then follow by an outline of some of the key global and local urban challenges that are particular to Amman, and finally, conclude with a set of recommendations on how to develop the concept of GI in the city of Amman.

CHAPTER I

GREEN INFRASTRUCTURE, ITS MULTIFUNCTIONALITY & ENVIRONMENTAL BENEFITS

CHAPTER I

GREEN INFRASTRUCTURE, ITS MULTIFUNCTIONALITY & ENVIRONMENTAL BENEFITS

This chapter discusses three main topics around the concept of green infrastructure (GI). The first section elaborates on the deficiencies of the traditional grey infrastructure and compares these networks with the concept of GI and the various benefits that are gained through its development. The second section concentrates on the environmental benefits obtained from GI. The last section, finally, discusses the way in which green infrastructure networks can be developed in cities.

1.1 FROM GREY TO GREEN INFRASTRUCTURE NETWORKS

The concept of transitioning from traditional grey infrastructure to green infrastructure is advocated due to the various shortcomings of grey infrastructure (EPA, 2020a). This concept is particularly discussed in relation to stormwater infrastructure networks. With time, these conventional piped networks revealed their deficiency in absorbing the increasing amount of stormwater runoff that is generated from the continuous growth of cities. Additionally, through having the sole purpose of rapidly disposing stormwater runoff outside of urban boundaries, these networks have detrimental impacts on the quality of stormwater, such as increasing stormwater pollution and preventing its infiltration into the ground. The concept of green infrastructure, on the other hand, presents an opportunity to address the various shortcomings of traditional stormwater networks (ibid.).

It encompasses the implementation of small green interventions in strategic nodes, while ensuring their connection, to create a parallel infrastructure network that can support both existing buried and surface grey networks.

With the use of GI measures, for instance, rainwater is retained and allowed to infiltrate back into the soil. This process, hence, simulates the natural process that is adopted by the natural ecosystem to manage stormwater. Hence, creating healthier urban environments that aim to restore natural hydrological balances (ibid.). Consequently, through developing GI measures in parallel to the pre-existing stormwater network, the overloaded stormwater system then becomes supported by the stormwater regulating services that are delivered by the GI network.

1.2 AN OVERVIEW OF THE MULTIFUNC-TIONALITY OF GREEN INFRASTRUCTURE

GI, or UGI (to concentrate on its application in an urban setting), has been defined in the existing literature in numerous ways, in relation to different scales, and to serve varying objectives (Rouse & Bunster-Ossa, 2013). The concept, however, is commonly recognized as being a 'nature-based solution' (European Commission, 2013). A commonly cited definition in the existing literature is the one defined by the European Commission, which defines GI as, "A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (European Commission, 2013, p.3).

Common examples of GI measures include street trees; green roofs and walls; harvesting cisterns; swales; rain gardens; and stormwater basins. The significance of GI lies in its ability, to provide the urban environments with multiple benefits, whenever it is properly planned and managed. At its core, the concept supports the protection of biodiversity both within rural and urban settings (ibid.). While considering the insistent increase in concrete and paved surfaces and materials that are introduced with urban development, protecting and enhancing the biodiversity of the natural ecosystem becomes more necessary to preserve its ability to provide ecosystem services, and thus, maintain the health of urban environments. Developing a diverse and continuous green network throughout the urban environment would enable this network to efficiently deliver ecosystem services that result from ecosystem functions, and which have beneficial outcomes for both humans and the natural environment.

These services are generally categorized into:

Regulating Services: The benefits obtained from regulating ecosystem processes, such as water and air filtration, and climate regulation.

Supporting Services: The necessary services to produce all other ecosystem services, such as soil formation, and nutrient cycling.

Cultural Services: The nonmaterial benefits which are obtained by humans from the ecosystem, such as recreational, spiritual, and educational values (MEA, 2005).

Provisioning Services: The products that are obtained from the ecosystem, such as food, fresh water, and wood and fiber.

These services can also be classified based on the definition of sustainability, and hence, become linked to the social, economic, and environmental pillars of the concept (Lovell & Taylor, 2013). Accordingly, GI is widely defined as being a 'multifunctional' network since it has the capacity of providing multiple benefits simultaneously (Rouse & Bunster-Ossa, 2013).

While recognizing the wide scope of benefits that are delivered through the development of a city's GI, the following section particularly elaborates on the environmental benefits that are obtained by humans through sustaining the integrity of the natural ecosystems. Hence, it will briefly address some of the regulating services of GI, which are generally considered as covering the environmental realm of sustainability (Lovell & Taylor, 2013). The discussion will exclude the remaining services, due to the realization that: (1) cultural services are only concerned with those benefits that directly affect societies, and hence, they address the social realm of sustainability; (2) production services have market values through their products (e.g. food), and thus, are mostly related to the economic realm of sustainability; and finally, (3) supporting services are regarded as those that are essential to maintain all other ecosystem services, and therefore, they differ from the other services in that their impacts on humans are often indirect or occur over a long period, whereas the other categories of ecosystem services (i.e. regulating, provisioning and cultural) have a somewhat direct and short-impact on humans (ibid.). Based on this recognition of the scope and impact of ecosystem services, the following section will summarize some of the main regulating services provided by GI.

1.3 THE ENVIRONMENTAL BENEFITS OF GREEN INFRASTRUCTURE NETWORKS

Some of the main environmental benefits provided by GI networks are related to air quality regulation; climate regulation; regulation of water quality and quantity; and erosion regulation (CNT, 2010; EEA, 2011; EPA, 2017; EPA, 2020b; MEA, 2005).

Air quality regulation

The natural ecosystem influences the quality of air through both its contribution and extraction of chemicals from the atmosphere (MEA, 2005). For instance, vegetative cover, such as trees, bushes, and other greenery, can capture and reduce air pollutants, such as fine dust, metals and chemicals that are suspended in the air, through absorbing and filtering these particulate matters on their leaves (EPA, 2017; EPA, 2020b). The vegetative cover also reduces smog (intense air pollution that reduces visibility) near the ground level, by their removal of air pollutants, as well as their reduction of surface and air temperatures through plant shading and evapotranspiration processes (ibid.). By removing air pollutants, as well as reducing smog conditions, vegetation protect humans from various respiratory system diseases that can occur if these matters are inhaled, including chest pain, exacerbation of asthma, and premature death (ibid.). Hence, green cover is closely associated with air quality improvements, which are essential to preserve for human health.

Climate regulation and reducing urban heat island

Natural ecosystems have an influence on the climate at both the local and global scale (MEA, 2005). In relation to the global climate, ecosystems play a significant role by emitting or sequestering carbon and other greenhouse gases (GHG). Carbon dioxide is captured and removed from the atmosphere by

vegetation through the process of photosynthesis, amongst other natural processes. Changes in the natural land cover at the local level, on the other hand, can influence both local temperatures and rainfall patterns (ibid.).

To further elaborate on the impact of green surfaces on the local temperature, it is essential to discuss its influence on reducing the urban heat island effect. The urban heat island (UHI) effect is defined as, "a phenomenon where temperature in urban areas is higher than that in rural areas" (Balany et al., 2020, p. 1).

This phenomenon emerges as a result of modifying energy balances in urban areas, which, in turn, is caused by numerous factors, including the conversion of natural green cover to impervious surfaces along with the continuous urban development, in addition to the impact of global climate change (ibid.).

UHI negatively impacts the urban environment and its population, since it:

- Increases energy consumption through increasing cooling requirements; and
- Reduces the quality of air.
- Increases water demand.
- And increases heat-related illnesses and mortalities (ibid.)

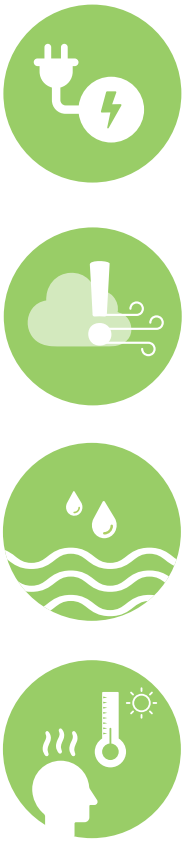


Fig 1: Negative impact of UHI on the urban environment & its population

One of the key strategies that are proposed to mitigate the adverse impacts of UHI is the development of GI in cities. Adopting a GI strategy would considerably contribute to mitigating the UHI since it supports the increase in the city's green spaces. These spaces, in turn, create microclimates with less extreme ambient temperatures for buildings and outdoor areas in urban settings. Vegetation has the capacity of regulating the microclimate through evapotranspiration from plant foliage, as well as through shading surfaces. Reducing temperature is particularly provided by tree canopies, grass, shrubs, and green walls. Consequently, having these green measures in cities improves human thermal comfort (ibid.).

Regulation of water quality and quantity

Changes in land cover, and particularly the alterations that modify the water storage capacity of the system, such as the removal of forest cover or the replacement of croplands with urban areas, can have a direct impact on the timing and magnitude of aquifer recharge, runoff, and flooding (MEA, 2005).

The challenge with stormwater runoff that is generated in urban areas, is that it carries pollutants, such as heavy metal and sediment, into the receiving water bodies (e.g., rivers, lakes, and beaches) (EPA, 2020b). Additionally, in the cases of cities that have a combined sewer system (which combine the drainage of sewage and stormwater), the high flow of stormwater can lead to the discharge of sewage into water bodies and hence, their pollution. Nonetheless, preserving and developing the city's GI supports in reducing the amount of stormwater runoff that is generated and drained from

cities, due to the capacity of green and permeable surfaces to retain, evaporate, and infiltrate rainwater through their unique interception, evapotranspiration, and porous features. Rainwater is also purified when it infiltrates into the ground through soil and subsoil processes. Hence, GI preserves the quality of water quality and reduces its pollution by urban contaminants (ibid.). Reducing stormwater-related impacts (i.e., flooding, combined sewer overflow, pollutant loading and erosion) also reduce the exposure of the population to related health risks, such as waterborne illnesses (EPA, 2017).

Other than enhancing the quality of water resources, GI also regulates the quantity of water and provides flood mitigation and water supply services (EPA, 2020b). By reducing and slowing the flow of stormwater, GI mitigates flooding risks that are attributed to the increase in the stormwater peak flow (ibid.). Additionally, GI features that support rainwater harvesting and infiltration practices increase the sources of water supply. Harvested rainwater, for instance, can be used as a source for irrigation. Water that infiltrates into the ground, on the other hand, contribute to the water supply system through recharging groundwater resources (ibid.).

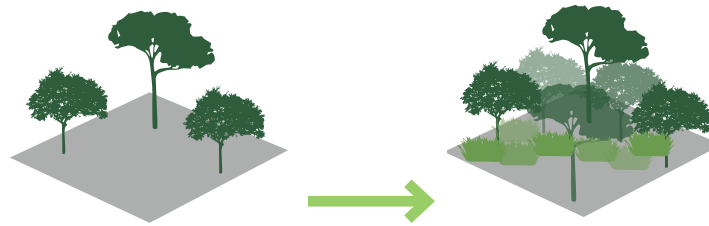
Erosion regulation

Maintaining the green cover greatly supports the retention of soil and the prevention of landslides (MEA, 2005). Soil erosion is regarded as a serious environmental problem that occurs throughout the world's terrestrial ecosystems (Zuazo & Pleguezuelo, 2009). The negative impacts of erosion lie in the loss of soil nutrients and organic matter; the reduction of the water storage capacity of soil due to rapid water runoff; as well as the significant decline in the diversity of plants and

animal species, amongst others. Hence, the establishment of green covers is regarded as an effective measure to control soil erosion and restore the formerly degraded soil surfaces. Both the aboveground biomass of plants (i.e., leaves and stems) that shelter the soil from raindrops, as well as the underground biomass (i.e. roots) that fix the soil surface, contribute to the reduction of erosion rates, because of their capacity to intercept rainfall and reduce water runoff by increasing the infiltration of water into the soil (ibid.)

1.4 THE DEVELOPMENT OF GREEN INFRASTRUCTURE NETWORKS

Figure 2 below is a further illustration of the various ways in which the concept GI can be developed in urban environments.



Vegetated areas when rainfall is NOT absorbed or retained

Vegetated areas when rainfall IS absorbed or retained

Fig 2: Example showing increased vegetation when rainfall is retained

Protecting and increasing vegetated areas

The more vegetated areas and permeable surfaces that can absorb and retain rainfall, the less surface water that is collected into the traditional stormwater networks. Protecting existing green areas and developing new ones is a key factor in the performance of GI. Vegetated areas include parks, urban forests, buffer zones, roadside plants, public and private gardens, and vegetated rooftops. These green areas, along with permeable pavements, help retain rainwater in the soil and replenish groundwater supplies.

Directing runoff to vegetated areas (passive rainwater harvesting)

Various green measures support the passive harvesting of rainwater, meaning its infiltration into soil surfaces. The significance of these measures lies in their capacity to retain stormwater runoff away from the drainage system, and rather allow it to feed groundwater resources, as further discussed. Below is a summary of some of the key green measures that can be adopted in urban environments.

Bioswales

Swales or bioswales are open water conveyance systems that are easily implementable by simple land contouring (grading), as illustrated in figure 3 below. They help move surface water to larger permeable areas (such as detention ponds), and also absorb and filter rainwater in the process. Bioswales can also be used to slow the release of stormwater into the traditional stormwater network.

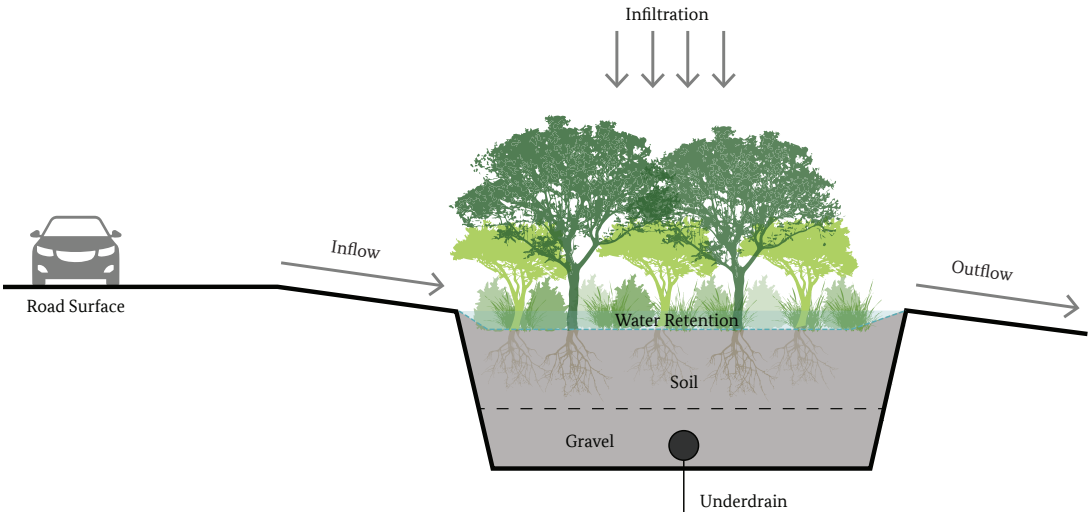


Fig 3: Bioswales

Rain gardens

Rain gardens typically contain native vegetation planted in shallow basins and can be used in a variety of settings including street medians and small private gardens. They are designed to capture street runoff (in sidewalk zones or street medians) or to capture runoff from roofs or paved areas (in home gardens) and allow it to slowly infiltrate into the ground. Hence, they slow down stormwater runoff, filter it, and support groundwater recharge. They also provide suitable habitat for urban wildlife.

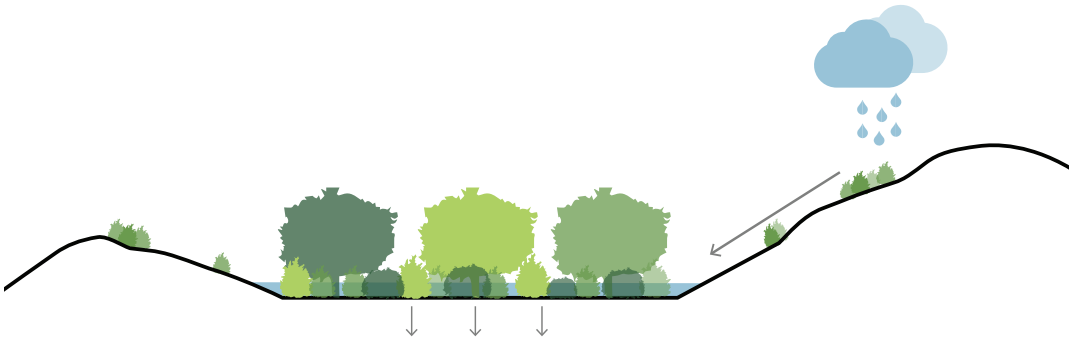


Fig 4: Water collection using rain gardens

Stormwater basins

Stormwater basins/detention ponds are permeable basins designed to collect stormwater and either hold it until it evaporates or release it at a rate at which the stormwater network can accommodate. They are usually located in low-laying areas. Detention ponds reduce erosion and relieve pressure on the stormwater network by reducing the peak runoff volumes. Used in combination with bioswales, and rain gardens, they make an efficient and cost-effective primary or secondary stormwater system.

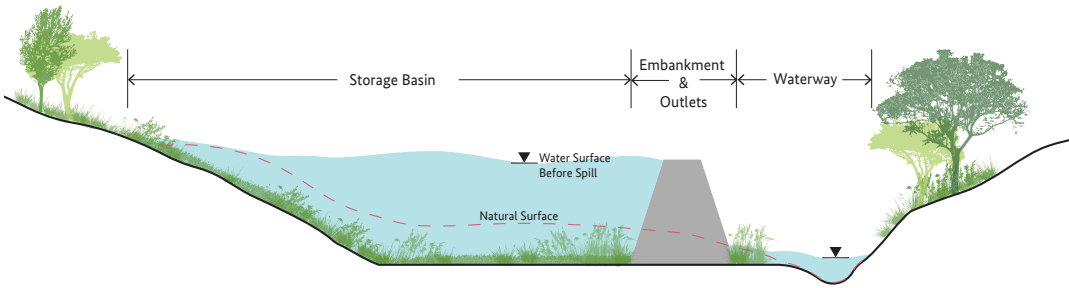


Fig 5: Stormwater basin

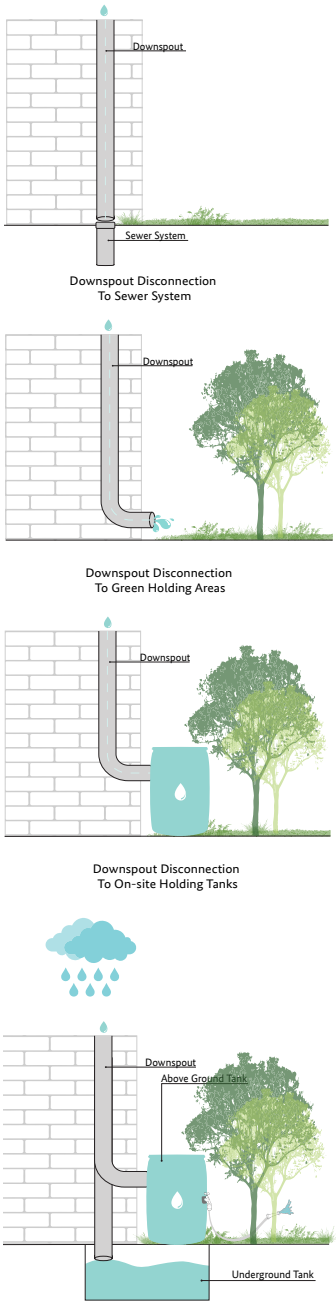


Fig 6: Redirecting water to be collected and reused later

Roof downspout disconnection

Roof downspout disconnection is a practice of redirecting water collected on roofs (or hard surfaces) from the stormwater network to on-site holding tanks or green holding areas such as lawns or planted areas, as shown in figure 6.

Collecting rainwater (active rainwater harvesting)

Rainwater harvesting refers to collecting rainfall in underground or above ground tanks which reduces pressure on the stormwater network during the winter season and could be used in the dry season. The practice is recommended for both the city's private and public domains. Harvested rainwater can be used for irrigation or other domestic uses. Large public parks can also greatly benefit from collecting rainwater for irrigation purposes.

How GI supports infrastructure networks, preserves natural resources, and reduces pollution

In urban contexts, green sidewalks and green pockets can help reduce heat island through permeable floors. As opposed to traditional pavement, permeable surfaces charge groundwater levels, and reduce water runoff which builds flood resilience and decreases pressure on existing storm water infrastructure.

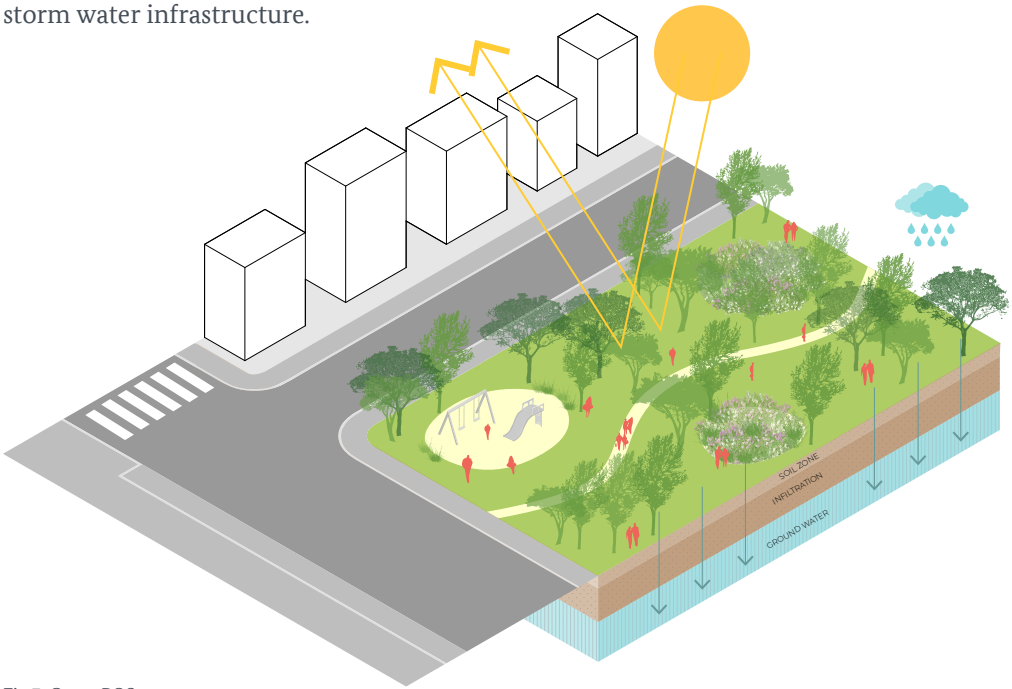
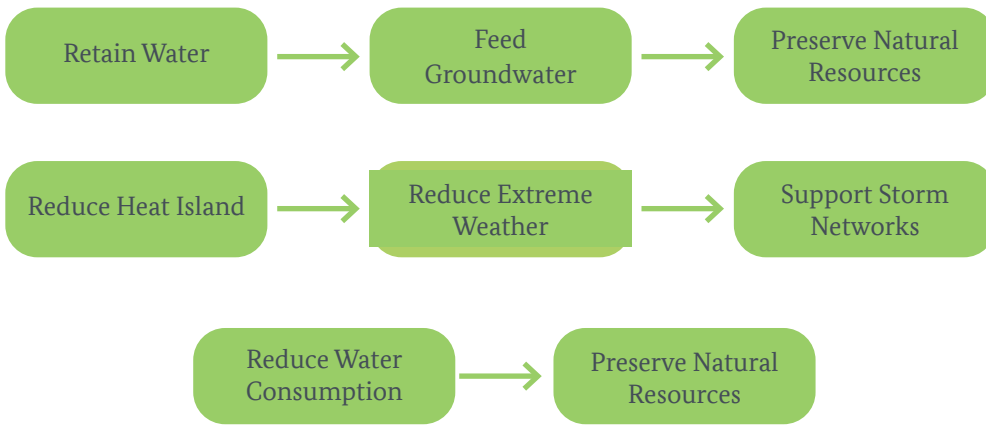


Fig 7: Green POS



Trees and vegetation on sidewalks purify the air while providing shade and cooling. This, alongside other considerations such as proper sizing, safe connections, quality surfaces, and efficient drainage enhances pedestrian mobility which can affect dependence on cars.

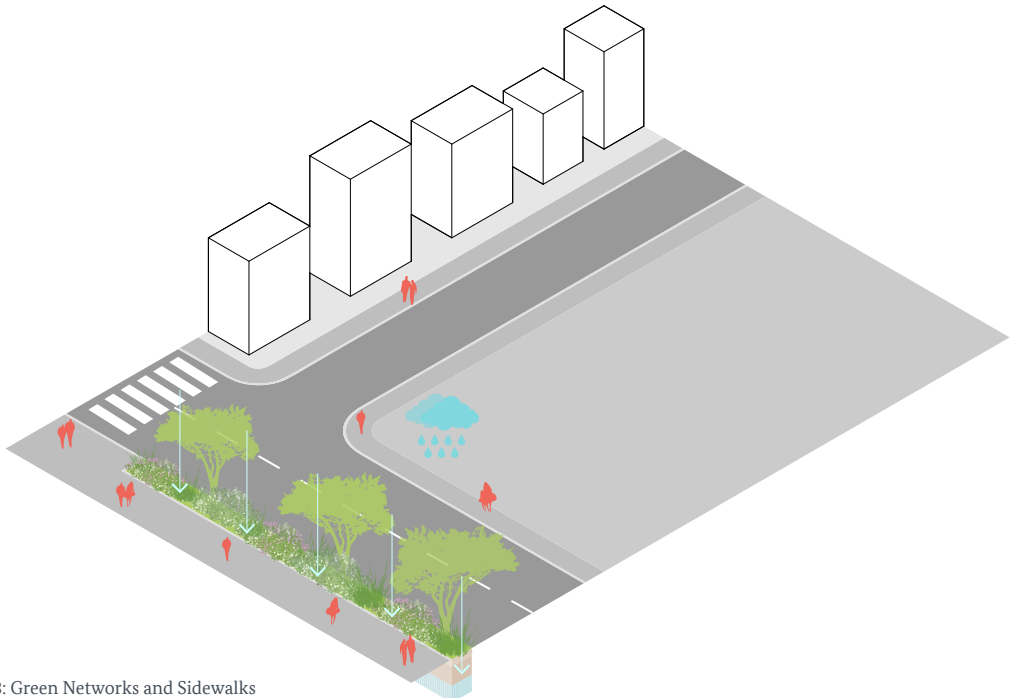
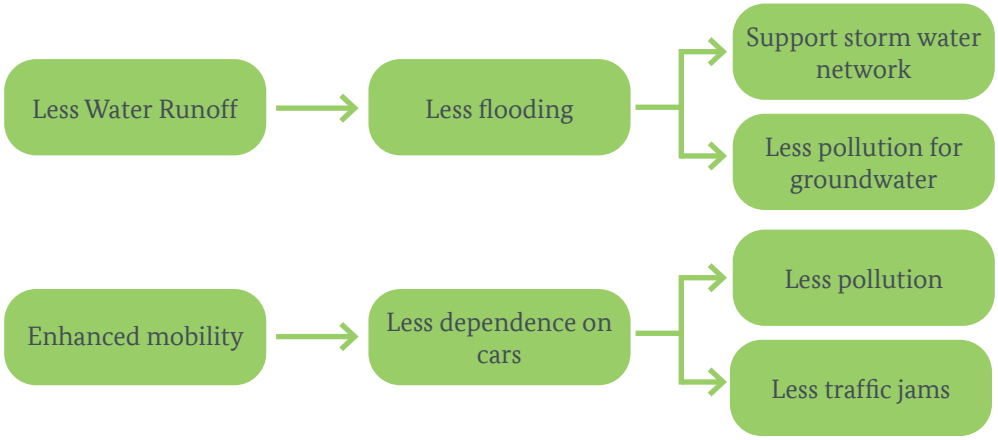


Fig 8: Green Networks and Sidewalks



CHAPTER II

GLOBAL AND LOCAL URBAN CHALLENGES

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2.1 GLOBAL URBAN CHALLENGES

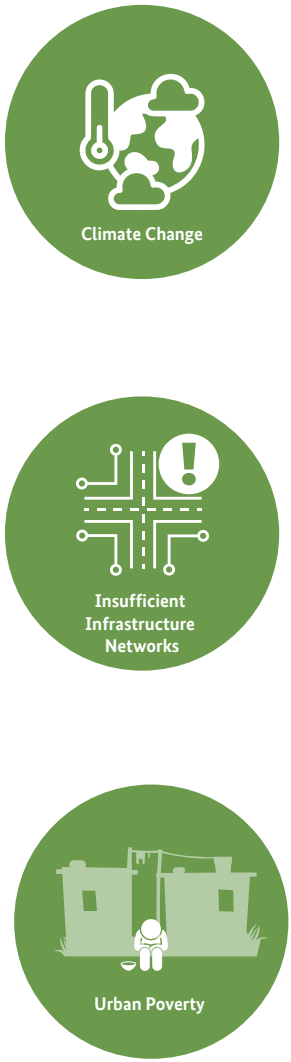

Fig 9: Global Urban Challenges

For centuries, cities have been the core centers of culture, commerce, and innovation (Palanivel, 2017). It is not surprising, therefore, that the most urbanized cities of the world tend to be the richest and have the greatest forms of human development. Planned urbanization has the potential of improving the well-being of societies by ensuring the suitable provision of essential services for all urban dwellers (ibid.). Now, and more than ever, cities are vulnerable. This is evident in that 70% of cities are witnessing climate change effects such as rising sea levels, extreme weather conditions, and flooding (C40 Cities, 2012). Mitigating climate change, on the one hand, and adapting to its effects, on the other, are some of the major challenges of urban centers during this age. Climate change, however, disproportionately affects impoverished people, especially those living in areas prone to the effects of climate change such as coastal areas.

The second global challenge is related to the rise of poverty. While the world continues to urbanize, most of the growth will take place in low and middle-income countries (Walnycki, n.d.). The greatest inequalities, at present, appear in the cities of these nations. These urban areas house more than 2.8 billion people living in underprivileged conditions characterized by overcrowded housing and insufficient public services, amongst others (ibid.).

The effects of these two major urban challenges, climate change and urban poverty, become more devastating and more challenging to cities when the existing infrastructure networks fail to mitigate the effects of the first and serve the latter, making the sufficient provision of infrastructure networks the third urban challenge (National Geographic, 2019). The causes and effects of these three challenges: urban poverty; climate change; and insufficient infrastructure networks at the global level will be further discussed in this section.

Climate change

Why the climate is changing

Human beings have become an increasingly powerful force over the last 10,000 years, and have, predominantly, acted against the pre-existing natural environment (Torrey, 2004). With the adoption of agricultural activity around 8,000 years ago, humans began to change the land (ibid.). Followed by the advent of the industrial revolution and rapid urbanization, humans began to affect the natural environment (ibid.). Consequently, humans have increasingly influenced the climate and the temperature of the earth through the various activities that they have adopted, including the burning of fossil fuels (e.g., coal, gas and oil), deforestation, and unsustainable farming practices (European Commission, 2021b). Such activities have continuously increased the concentration of GHG in the earth's atmosphere, which, in turn, has increased the GHG effect and global warming. As a result, the global average temperature, at present, is 0.85ºC higher when compared to its state in the 19th century. Scientists believe that an increase of 2°C, in comparison to the temperature in the pre-industrial period, will present a key threshold.

Beyond this threshold, it is anticipated that the global environment will be at a greater risk to experience catastrophic changes. Thus, the goal now recognized by the international community is to preserve the warming of the planet below the threshold of 2°C (ibid.).

Humans inhabit the land in varying development concentrations, which led to the emergence of both rural and urban areas. Nonetheless, urban populations are known to have different consumption patterns from rural communities, as they consume more food, energy, water, durable goods, and land (ibid.), and thus, can be understood as having a larger carbon footprint. Today, cities are responsible for 70% of the global carbon dioxide (CO2) emissions and other greenhouse gas (GHG) emissions that are contributing to climate change (C40 Cities, 2012).

How climate change affects the urban environment

The effects of climate change include variations in ambient temperature leading to heat stress, change in rainfall patterns, sea-level rise, saltwater intrusion, loss of biodiversity, drought, habitat loss, and freshwater depletion and pollution (Philander, 2012).

Below is a description of how climate change directly affects humans and the overall natural environment (European Commission, 2021a; IPCC, 2014; Philander, 2012):

- **Melting ice and sea-level rise**: Water has the characteristic of expanding when it is warmed up. Global warming, at the same time, is causing the melting of polar ice sheets and glaciers. This directly increases sea levels and puts coastal urban agglomerations at the risk of floods and erosion.

- **Extreme weather and shifting rainfall patterns**: Heavy rain and long periods of drought are becoming more common. This can lead to a decrease in the quality and availability of water resources, exemplified, for instance, in the reduction in the recharge of freshwater resources due to the decrease in rainfall, as well as in the possible increase in water pollution with the increase in intense precipitation days that can transfer human pollutants to water bodies. In the Mediterranean area, the climate is expected to become drier, making it even more vulnerable to drought and wildfires.
- **Risk for biodiversity**: Many plants and animal species are struggling to cope with climate change. Some plant and animal species will be at increased risk of extinction if global average temperatures continue to rise. This age is regarded as a serious environmental threat to humanity and planetary balance due to the accelerating losses in biodiversity, leading many species to the brink of extinction. Scientists, therefore, refer to this age as "the sixth mass extinction" that is caused by humans (Ceballos, Ehrlich & Raven, 2020). In the urban environment and its vicinity, these species are at risk because of habitat loss and fragmentation caused by changes initiated by expanding human settlements.
- **Risk for human health:** Heat waves could increase the number of heat-related deaths. The changes in temperatures and rainfall patterns have also altered the distribution of water-borne illnesses and disease vectors.
- **Costs for society and economy**: Between the years 1980 and 2011, floods have affected more than 5.5 million people, and

also caused direct economic losses, estimated to be more than €90 billion in total (European Commission, 2021a). Work sectors that rely greatly on the state of the climate, and on certain temperatures and precipitation levels, such as the sectors of agriculture, energy and tourism, are particularly affected by the change in the climate.

Cities are particularly recognized for being vulnerable to climate change impacts. As stated by the Intergovernmental Panel on Climate Change (IPCC) (2014, p. 69), "in urban areas, climate change is projected to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surges."

Certain urban areas are anticipated to be exposed to higher risk levels, due to their particular location in exposed areas, as well as their lack of essential infrastructure and services. Additionally, climate change is projected to place additional burdens on poor and marginalized communities in specific, whether those residing in rural or urban settings (ibid.). These groups are recognized as being some of the most vulnerable populations to climate change, since they mostly occupy areas that are highly exposed to climate-related impacts, while, at the same time, being characterized as having low adaptive capacities due to their disadvantaged socio-economic state.

Hence, climate change, which has been identified as being 'a threat multiplier', is anticipated to introduce new threats to these populations, including exposing them to various extreme weather conditions (e.g. heat waves, droughts, floods) (ibid.).

Way forward... Mitigating and adapting to the effects of climate change

The impact of climate change on human settlements and the environment is a pressing challenge that must be addressed by policy makers and planners to build the resilience of cities and their urban communities, as well as ensure the survival of different plant and animal species. As it is expected that the majority of humans will reside in cities in the near future, a better global prospect depends on urban innovation and action (C40 Cities, 2012). Adapting to or mitigating the effects of climate change by taking appropriate action to prevent or minimize the damage, should be a strategy that guides governments and the actions of policy makers.

Sustainable approaches need to be adopted to combat the impacts of climate change. Actions should be concentrated on two levels: mitigating climate change; and adopting the necessary adaptation measures to ensure that cities and their communities can endure the effects of climate change. It is very important to take concrete steps towards reducing carbon dioxide emissions to mitigate climate change. This could be done by enhancing mobility alternatives and encouraging public transportation. To better adapt to climate change, there is a need to increase green areas and use tree species and forestry practices that are less vulnerable to storms and fires and that have the capacity to reduce urban heat islands. In a water-scarce country, and while considering the necessity of having more green spaces, available water resources must be used more efficiently. The biodiversity of urban systems must also be enriched to restore natural flood defenses.

Urban poverty & increasing inequalities

Why urban poverty is on the rise

People move to the city to seek the various opportunities that are present there. Cities offer more jobs and higher incomes, greater collaboration and innovation opportunities, and access to essential services such as education and healthcare (Lucci et al., 2018). But the high cost of living in cities forces a big portion of these migrants to live in poorly serviced areas and informal settlements creating what is known as urban poverty or the urban poor.

Underprivileged neighborhoods usually do not enjoy the same level of services as other neighborhoods in the city, adding additional layers of segregation. The inability of governments to uplift the state of the urban poor, creates a cycle where they become trapped in these underprivileged settlements, and are, thus, unable to obtain the various benefits that the city offers to its other residents (ibid.).

Urban poverty can be characterized by the lack of sufficient public services such as public transportation, functional infrastructure networks, public open spaces, and access to safe residences. This puts these disadvantaged areas at higher risk from the extreme weather events caused by climate change.

How urban poverty affects the urban environment

The conditions that cause urban poverty prevent the city from being the multiplying wealth generator that it is expected to be for residents in these areas. Depleted public spaces and the absence of services can quickly become barriers that prevent the integration of an important segment of society in productive economic cycles and social landscapes. This contributes to the rising rates of crime and delinquency that can interrupt the lives and stigmatize entire neighborhoods.

The absence of infrastructure networks and services, such as waste management, also participates in accelerating global environmental degradation.

Way forward... Sustainability, participation, and inclusivity

The sustainable development goals (SDG), which promise to 'leave no one behind' (UNSDG, 2021), becomes unattainable if governments and international organizations cannot improve the way they identify, deal with, and support the urban poor. Interventions must be inclusive. The voice of local communities must be heard whenever future urban interventions or projects are planned since any alteration in their encountered physical environment has an inevitable impact on their lives and wellbeing.

- **Inclusive...** recognizing different priorities
  Recognizing different priorities within any vulnerable population; gender, age and ethnicity is crucial to achieving a sustainable design. This recognition helps to explain the different constraints people face, the opportunities they see, and therefore the differences in their priorities. Focusing on solving root problems, quickly and efficiently, can have a ripple effect resulting in tangible economic benefits for the community and hence to the city as a whole.
- **Participatory...** increasing people's participation
  So often, one of the consequences of being poor is that someone else at a higher level and a distant institution is making choices on their behalf (Anzorena et al., 1998). Participatory approaches, nonetheless, should be adopted to ensure the inclusion of local communities in the decision-making process.

Insufficient infrastructure networks

Why do infrastructure networks fail?

Traditional infrastructure networks are disadvantaged in that they cannot easily accommodate urban growth, for with continuous growth comes the necessity of continuously enhancing the capacity and coverage of these networks (Rouse & Bunster-Ossa, 2013). The challenges posed to the city's infrastructure with urban growth, are exemplified in the case of stormwater and road networks.

Stormwater networks are designed to serve a certain catchment area. The network, nonetheless, eventually becomes stressed with time, due to urban growth and the parallel increase in impervious surfaces, which increase the amount of stormwater that must be drained by the system.

Upgrading the network, however, is usually difficult to achieve due to high energy and construction costs, leading to its failure to sufficiently drain the large amount of stormwater generated within the city (Rouse & Bunster-Ossa, 2013).

For the road networks, the challenge arises when the adopted urban growth model does not support public transportation and other sustainable transport modes, which would guide the excessive use of cars, leading, eventually, to traffic congestion in the city's streets. Numerous studies have documented the phenomenon known as induced demand in transportation. "More streets, more cars", or in other words, if you build more highway lanes, more drivers will come (Schmitt, 2017).

Therefore, the expansion of road infrastructure at the expense of other mobility alternatives can be considered a short-term solution because people are encouraged to own cars and the roads will ultimately reach their maximum capacity, creating traffic congestion problems.

How insufficient infrastructure networks affect the urban environment

Failing stormwater networks have devastating financial and environmental effects on cities and the environment; they cause damage and contaminate water. The loss of lives and properties can entail a series of social problems that degrade the quality of life in a certain area. These are some of the reasons many cities have actively started taking steps to adapt to this problem by introducing various measures that reduce the stress caused by excessive rainfall or sea water surge.

The expansion of road infrastructure unfortunately does not necessarily mean more sidewalks. When roads are expanded at the expense of sidewalks, and without the presence of other mobility alternatives such as public transport, cars end up dominating the streets. This results in a myriad of issues such as increased carbon dioxide emissions, and a decline in average health. Citizens in walkable cities enjoy better health than those that depend on cars (WHO/Europe, 2017).

Way forward... Supporting existing infrastructure networks

Replacing stormwater infrastructure networks to accommodate growth and face climate change challenges is unconceivable. It is a very costly process that requires resources that most of today's municipalities do not have. Supporting existing grey storm networks is still possible by means of small interventions.

These interventions can be implemented in public open spaces, streets, and sidewalks. Many green interventions are small in scale, and thus, require neither major construction works nor land expropriation. Enhancing mobility by providing safe crossing and pleasant sidewalks can encourage people to walk more. This will surely reduce dependence on cars and participate in reducing carbon dioxide emissions when combined with other alternatives such as public transport or cycling where possible.

2.2 LOCAL URBAN CHALLENGES

Like many cities in the world, Amman faces many challenges associated with climate change, increasing inequalities and urban poverty, as well as insufficient infrastructure networks. Some of the effects of these challenges get amplified by the city's spatial morphology, which is the result of multiple planning decisions and socio-economic factors.

Amman is a city that grew at a fast pace during the last decades while adopting a horizontal growth model (GAM, 2008). Horizontal growth implies low density, high dependence on cars, and the increased burden of meeting the needs of expanding, upgrading, and maintaining infrastructure networks (ibid.). Such patterns, therefore, resulted in directing governmental revenues towards constructing the city's infrastructure. Due to limited financial resources, signs of degradation have emerged in numerous parts of the city. To name a few: various areas get flooded almost yearly, inequalities between the different neighborhoods of the city are staggering, and the transport system is plagued by a lack of viable public transport, an increasing number of cars, traffic congestion, and ever-increasing spaces designated for streets.

Addressing these challenges requires:

- Engaging local communities in the decision-making process and in setting priorities. Not everything can be done at once, however, implemented urban projects and interventions must endure with time. The only way to achieve sustainability is to create a sense of ownership in local communities.
- Adapt existing engineering practices to new realities. With climate change and the uncertainties that it entails, as well as the ever-increasing urban population, building infrastructure networks that lack the necessary resilience and durability to absorb change, is no longer feasible.
- Adopting new legislation that governs public open spaces at the national and local level to ensure that sufficient and suitable spaces are provided to address the city's local challenges.

Below are some of the challenges that are specific to Amman, and mainly those concerned with:

- Planning practice and urban growth choices.
- Lack of resources.

Planning practices and urban growth choices

The low-density growth pattern that the city adopted in the last century resulted in depleting the city's natural reserves, which is apparent, for instance, in the removal of most of the oak forest and tree cover located in the west of the municipality (GAM, 2008). Horizontal cities require extensive budgets for operation and maintenance. As stated in Amman's Metropolitan Growth Plan (MGP), the country of Jordan has witnessed an influx of foreign investment during the last decade, with the majority of this investment being directed towards the tourism and property sectors.

This flow of capital has, ultimately, directed excess spending on the city's growth, triggered a construction boom that does not address domestic needs and demands, and eventually led to a distorted land development pattern (ibid.). Today, on the other hand, densification, increasing open spaces, and building public transportation systems are becoming central to policy makers at GAM.

In 2010, the Greater Amman Municipality adopted Amman's Metropolitan Growth Plan (MGP) (GAM, 2008). This plan was developed to regulate the city's growth until the year 2025. Below are the three strategies defining the metropolitan growth plan:

- Densification and intensification within the metropolitan area;
- Promotion of high-density mixed-use areas (HDMU); and,
- Preservation of the city's Natural Heritage Systems (NHS).
- This plan wan was quickly followed with the Transportation and Mobility Master Plan (TMMP) in 2010 (GAM, 2010). This plan governs:
- Transportation;
- Designated growth and no-growth areas; and
- Public open spaces.
- The Bus Rapid Transit (BRT) is one of the TMMP's outputs.

The Amman Climate Plan has also been published in 2019 to define the city's vision by the year 2050 as, "in 2050 Amman is utilizing its unique diversity and natural resources to optimize economic growth and urban livability, equity and health for all its residents. The city has maintained its strong traditions while improving municipal services and building a more prosperous, safe, inclusive and green urban experience. Transportation is sustainable, buildings are efficient, public spaces are open and green, water is clean and plentiful, and waste is minimized" (GAM & MoEnv, 2019, p. 7).

The plan suggests the adoption of cross-sector planning and land use actions to mitigate GHG emissions and advance the city of Amman to become an 'environmentally proactive city' (ibid.).

In this section, some of the specific characteristics of Amman, which were a direct consequence of municipal planning practices and growth pattern choices, will be further discussed. These characteristics directly affect both the urban environment, as well as the quality of urban life and service provision, identified as:

Fig 10: Amman Characteristics

Low population density

Why Amman is considered a low-density city

Amman is a sprawling city. Its rapid and dispersed growth has led to its development into an urban growth model, which necessitates the population's dependency on privately-owned cars as the primary means of transportation. This choice, in turn, became immediately reflected in its urban structure, which witnessed a continuous increase in the carrying capacity and width of roads, as well as their common upgrade into tunnel and bridge systems, to accommodate increasing traffic and to serve the city's scattered urban development (GAM, 2008).

The horizontal sprawling of the city, hence, has had an impact on its population density characteristic since it allowed for the distribution of the city residents into dispersed urban areas. Thus, Amman is generally considered a low-density city, which becomes evident when its overall population is placed in relation to its total urban area. The resultant population density in Amman is significantly low when compared to other cities in the world (as presented below). Nonetheless, although the population density at the city scale suggests a low population density, it is important to recognize that there remain discrepancies in the population densities across the city, and more particularly between its eastern and western neighborhoods. In fact, eastern areas are identified as having higher population densities when compared to western ones, with the estimate that population density in eastern areas falls between 14,000-30,000 inhabitants/km^2, while western areas were estimated to have densities that vary between 2,500-6,000 inhabitants/km^2, hence, less than a quarter of the population density range in eastern neighborhoods (Potter et al., 2009).

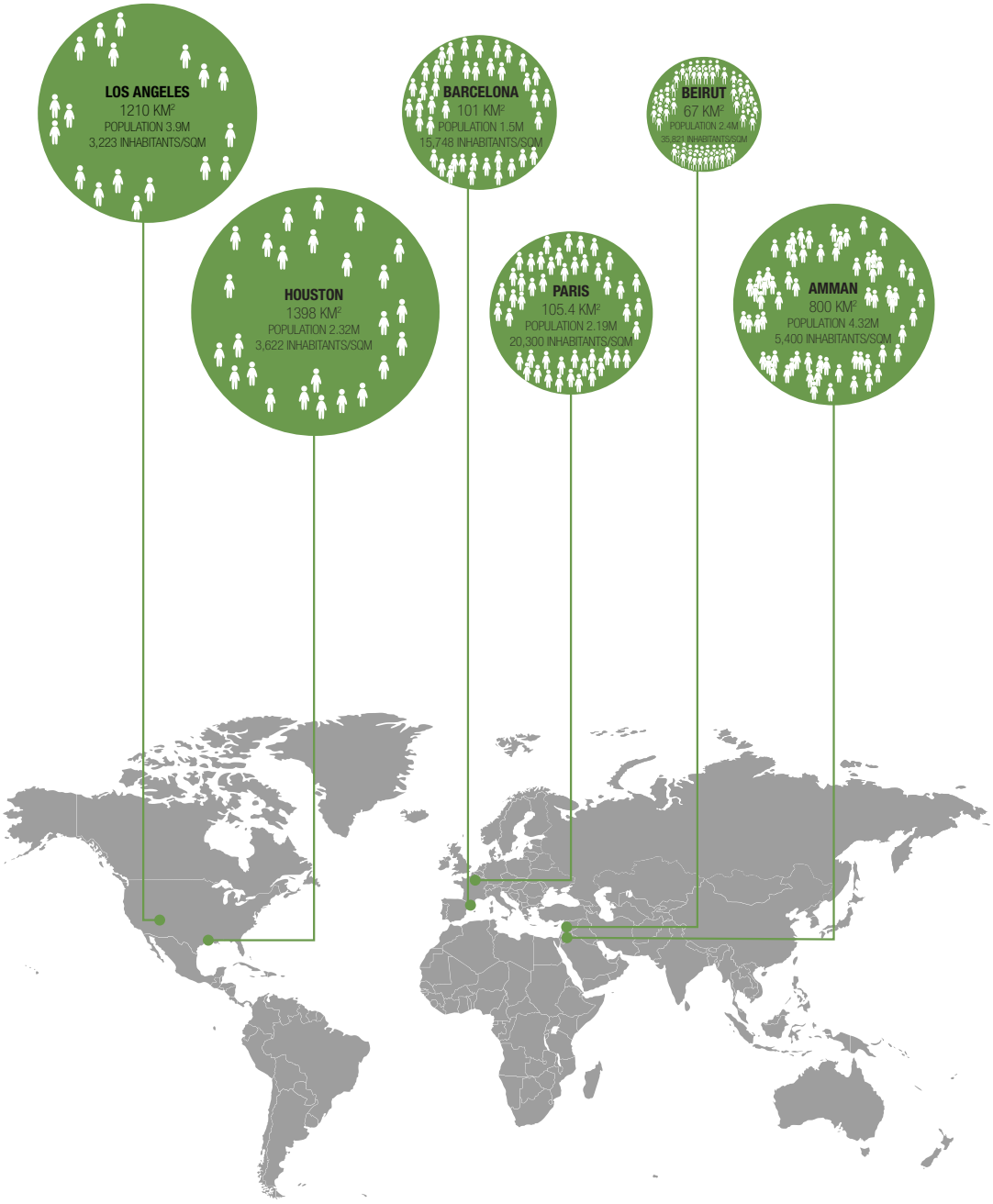

Fig 11: Map showing various cities size and population density

How density affects the urban environment

Urban density is concerned with the number of people residing in a particular urban area and is an essential feature that determines the way in which cities operate (Berggren, 2014). Higher urban densities have been advocated by many modern urban planners, due to the widespread theory that cities operate more efficiently whenever residents live in denser urban settings, such as in their ability to encourage walking and multiple other sustainable transport alternatives. Additionally, the quality of infrastructure services provided in cities tends to be higher when these networks are concentrated within small-sized and manageable urban areas, rather than being largely dispersed (ibid.).

Way forward... Adopting a compact urban growth model

The Amman Metropolitan Growth Plan has identified strategies to contain the city's physical growth while anticipating that the population of the city will increase to a total of 6,500,000 residents by the year 2025 (GAM, 2008). Consequently, the plan identifies preferred locations for future settlement expansion and directs future urban developments within existing settlement areas to hinder their outward horizontal sprawl over agricultural lands located within the Metropolitan Planning Area. The plan adopts an intensification and densification policy in built-up areas, supports the development of large vacant lands within the built-up area through 'High-Density Mixed-Use' (HDMU) developments, and encourages the development of more intensive mixed-use development areas within designated Metropolitan Corridors (e.g. Airport Road, Amman Development Corridor, and Sahab – Al Muwaqqar Corridor) and Metropolitan Growth Centers (e.g. at the Arafat Airport Road Intersection).

Through adopting these strategies, the plan carefully guides the city's development within a defined urban envelope to increase population density and generate a compact urban form. Managing the city's urban development through adopting a more compact and mixed-use growth model would not only limit the city's continuous sprawl and ensure the provision of urban services at suitable standards but also promote the use of sustainable modes of transportation, such as walking (ibid.).

The MGP, for instance, has supported the development of the Abdali Central Business District and envisioned it to become a "vibrant centre for commerce and modern living" (GAM, 2008, p.32). The Abdali project, therefore, was encouraged and facilitated by the MGP as a form of a consolidating development project in the existing built-up area of the city, and it can be considered as one of the outcomes of the growth plan.

Changing demographics

Why Amman is facing constant change in its demographics

Amman has faced a continuous change in its demographics across time, mainly attributed to the constant influx of refugees because of the geo-political circumstances of the region (such as the 1948 and 1967 influx of Palestinian refugees), in addition to the internal rural-urban migration and natural population growth (GAM, 2008). Such changes in the city's social structure have had an inevitable impact on the built environment, evident in the population transition from the city's old neighborhoods, as well as the wide variation between the city's eastern and western neighborhoods.

How changing demographics affect the urban environment

Many old neighborhoods of central and eastern Amman that are located on the hilltops feature some unique semi-public spaces, such as the hill descending stairways, for they are essentially pre-automobile communities that functioned through pedestrian circulation (Al-Faqih, 2009; GAM, 2008). These neighborhoods, such as Jabal Amman and Jabal Hussein, used to house extended affluent families or families with close relationships. With the growth of the city, however, many of these families moved out from these old neighborhoods to newly emerging western neighborhoods that are characterized by larger lots for housing, better public services, and a dominant automobile development pattern. Consequently, these old neighborhoods became occupied by low and middle-income population and witnessed a change in their social composition (ibid.).

Unfortunately, the quality of old neighborhoods has deteriorated with time, particularly when compared to the new emerging western neighborhoods of the city. While former inhabitants used to treat semi-public spaces as an extension of their own houses, today, however, with the departure of original inhabitants and the arrival of new less-fortunate ones, many of these spaces have lost their significance and association as urban social spaces (Al-Faqih, 2009). Additionally, while considering that the physical structure of old neighborhoods was based on the pedestrian orientation of the previous society, the proper maintenance of these neighborhoods has also become more challenging with time and with the advancement in the systems of service provision.

Garbage piles and rodents, for example, are becoming common features in these areas, under the pretext that municipal garbage collection cars are unable to access many areas in these neighborhoods (ibid.). Consequently, the state of these old neighborhoods is now posing serious social and environmental challenges for the city.

Other than the decay of older, formerly affluent neighborhoods, the city's east-west divide has also added another layer of complexity in the spatial characteristics of the city. The discrepancy between the city's neighborhoods is revealed in the great variation in their population densities, with low-density western neighborhoods and high-density eastern ones. The eastern neighborhoods were also the areas that absorbed the lower-income migrants, while western areas are generally occupied by affluent population groups due to high land and housing prices, resulting in socio-economic polarization between the eastern and western neighborhoods (GAM, 2008). Hence, the growth of eastern neighborhoods in Amman with the flow of immigrants has led to the emergence of poor urban environments, characterized by informality, building density and infrastructure failure (Ababsa, 2011).

Way forward... rehabilitating old and deteriorated neighborhoods in the city

The process of rehabilitating the built environment, and mainly the old and deteriorated neighborhoods, must become emphasized as an essential component in the planning practice (Mare'e, 2019). The consideration of rehabilitation must be reflected in the laws and regulations that guide the city's development, which currently have a clear emphasis on guiding new developments in the city and fail to sufficiently address the issue of rehabilitation, for they do not provide any details regarding rehabilitation such as responsibilities, timespans and specific principles that would guide the rehabilitation process (ibid.). Consequently, the practice of maintaining many old and deteriorated public open spaces in the city, such as public stairs, is carried out by the municipality through common practice, and the opportunity of rehabilitating these spaces to a better state is not being exploited due to the lack of rehabilitation guidelines (ibid.). Rehabilitating old areas in the city is a long and winding road that requires tremendous effort and dedication from GAM's employees and support from higher administration, in order to enhance the living conditions of poor urban communities and preserve the character of distinct old neighborhoods in the city.

Fig 12: Construction progress from the Seventh Stair on Al-Quds Street

Car-oriented mobility

Why Amman is a car-oriented city and does not promote all possible modes of transportation

Amman has largely progressed with time to become a car-oriented city. Its advancement to such a state not only stems from the ever-increasing support to expand the city's road network but also from the poor consideration of transportation alternatives during the planning process. The unsustainable impact of current transportations condition is evident in the sector's great contribution to the city's emissions, with 31% of greenhouse gas emissions in Amman being attributed to transportation (GAM & MoEnv, 2019).

The way in which Amman is planned and designed, and the way it operates as a city, promotes the use of automobiles. Road infrastructure development has largely been biased towards personal automobiles, which is evident in the continuous expansion of the city's road network, and the increasing construction of tunnels, circles, and bridges, to accommodate the increasing vehicular traffic. Consequently, automobiles became the dominant transportation mean in the city of Amman (GAM, 2010; GAM, 2008).

While the city has constantly developed its road network, it still, however, suffers from the poor state of its public transportation system. During the last decades, there has been little investment in the city's public transportation (GAM, 2010; GAM, 2008). Amman lacks an integrated public transit service that serves a broad section of its population. The public transit service, therefore, is only used by captive users, or those who have no practical transportation alternatives (ibid.).
The TMMP estimates that the public transport system, composed of public buses, minibuses and white taxis (servis), made up only 2.8% of the total vehicles in Amman's

transportation system, and represented around 14% of all trips made in the city of Amman (GAM, 2010). Consequently, the city still needs transportation infrastructure that would initiate a shift from the dominant use of private cars, towards the wider adoption of sustainable public transportation systems.

Apart from automobiles, the streets in Amman have neglected all other modes of transportation. Transportation alternatives suffer from weak infrastructure dedicated for their use, which hinders their widescale adoption by city residents. This includes, for instance, the city's poor sidewalks, which are unsafe and uncomfortable for use, and still require major development if Amman is to become a pedestrian-friendly city (GAM, 2008). The city's stairways have also not been properly maintained (ibid.). Other than the poor condition of sidewalks and stairways, pedestrian crossings are also a major challenge in Amman's streets. Pedestrian street crossings in the city are mainly designed with the principle of reducing the convergence between vehicle and pedestrian movements (GAM, 2010). Thus, places that are designated for pedestrian crossings at the street level remain minimal and lack necessary infrastructure (e.g. signalized crossings, designated locations at suitable distances).

Signalized crossings are currently being introduced along certain segments of the Bus Rapid Transit (BRT) project, but are still not widely adopted. Hence, pedestrian crossings in Amman mainly take the form of pedestrian bridges and tunnels (ibid.). Such forms of pedestrian crossing, however, do not prioritize the ease of pedestrian movement (ITDP, 2019). With these structures being elevated above highways, prioritizing vehicle

traffic becomes apparent in that the compromise comes from the pedestrian side, in their need to put more effort to cross streets through climbing and descending from elevated pedestrian bridges.

Drivers, on the other hand, can continue their movement at high speeds, without stopping for pedestrians crossing (ibid.). Nonetheless, elevated pedestrian bridges are still being constructed, to date, in the city of Amman, such as the newly built bridges along the busy street of the University of Jordan (Queen Rania Str.). Consequently, the presence of these pedestrian bridges, along with the poor condition of the other pedestrian network components, send a clear message that pedestrians are not the priority on Amman's streets, and instead reinforce the development of a car-oriented city.

How mobility affects the urban environment

Besides reducing the number of car trips and carbon dioxide emissions, busy sidewalks promote safety. Safety, especially for women and children comes from eyes on the street, which are more likely to be present when sidewalks and public spaces are properly implemented (Jacobs, 1961).
Additionally, residents of walkable cities tend to be healthier than car-dependent cities. Cities with wide sidewalks and mixed-use developments encourage their residents to adopt walking as a mean of transportation.

Way forward... Encourage the various modes of mobility

During the 2020 nationwide lockdown, which was enforced by the government to slow the spread of COVID-19, residents of Amman were only permitted to walk during certain hours of the day, to obtain their essential services (Suboh et al., 2020). With this dramatic change in transport behavior, the city's residents were forced to use non-motorized transportation modes, including walking and cycling, and thus, came face to face with the fact that existing sidewalks needed major upgrading (GAM, 2020). The dissatisfaction of residents in the condition of pedestrian sidewalks was revealed in the survey that was carried out by GAM during the COVID-19 pandemic. The outcome of the survey reveals that 37% of participants believe that the neighborhood that they reside in does not support walking, 41% claim that their neighborhood needs maintenance to become suitable for walking, while only 23% of participants thought their neighborhoods support walking.

Additionally, the majority of participants believed that the design of the sidewalks was unqualified for walking because of the presence of barriers (e.g., trees and plants basins) (36%); their need for maintenance (35%); and their narrow width (21%) (ibid.). However, what was also interesting to discover during the pandemic, is that people are willing to walk and use bicycles if provided with the right mediums (Suboh et al., 2020). The lockdown allowed the residents of Amman to use the streets for their walking activity. In fact, to reach essential local services (e.g., bakery, supermarket, pharmacy) during the lockdown period, 55.6% of the participants in GAM's survey identified walking as their main transportation mean (GAM, 2020).

Accordingly, qualifying the city streets to become pedestrian-friendly was identified as a key recommendation following the study's outcomes.

Much attention should be given to the state of existing sidewalks and providing safe and pleasant pathways that would be suitable for children, women, and the elderly. Amman's 2010 Transportation and Mobility Master Plan promotes mobility (GAM, 2010). The Bus Rapid Transit (BRT) is one of this plan's outputs. It is a small, but important step towards building a more comprehensive transportation system. However, while developing the state of the various transportation modes in the city of Amman, it remains necessary to consider GI as a major component in the city's transportation network, and design and plan these networks with this mindset.

Fig 13: Empty streets due to the lockdown in Amman, however the importance of the sidwalk is overlooked in this area.

Fig 14: Person traveling by foot because of the full lockdown measures implemented during the COVID-19 pandemic.

Depleted natural resources

Why natural resources, in and around the city, have disappeared

Overlooking the environment and planning without the consideration of nature is not sustainable. Expanding at the expense of natural resources can take many forms. Relying completely on private cars to serve newly developed areas is one form of over-exploiting natural resources and increasing air pollution. Expanding on agricultural land, whenever there are other possible choices, is another form of over-exploitation.

Cities can afford, for a while, to pay the price for wrong choices when they are wealthy or small. But when they grow, unsustainable solutions become harder to maintain. In Amman, and within the last century, the building and planning practice has directed the urban expansion over agricultural lands, and placed major arteries in wadis (valleys), as further explained in the following points. Natural resources have thus, been over-exploited, because of improper growth and unsustainable planning practices.

Improper growth around the city

Amman originated on sites adjacent to ancient Roman ruins that were founded on the confluence of central wadis surrounded by several hills, in the now downtown area of the city (GAM, 2008). In the forties and the fifties of the last decade, the residents of Amman chose to climb the high hills surrounding the center, including the green hills to the west, rather than expanding their neighborhoods on the desert plains to the east and south. Consequently, the urban growth of the city had an impact on the land cover in the region, including the agriculture and forest land. Unfortunately, the poor planning decision that was adopted caused the depletion of the natural green cover that used to surround the city, reflected in the removal of most of the Deciduous and Evergreen Oak forest and tree cover

that was located west of the municipality, and which used to be part of an extensive belt that ran along the eastern bank of the Rift Valley (GAM, 2008). Additionally, the expansion has led to the loss of agricultural lands, which were converted into urban areas with the city's constant expansion (Khawaldah, 2016). Had urban growth been directed towards the bare desert lands to the east and south of Amman's core, this would have provided an opportunity to grow more sustainably while preserving some of the city's green cover.

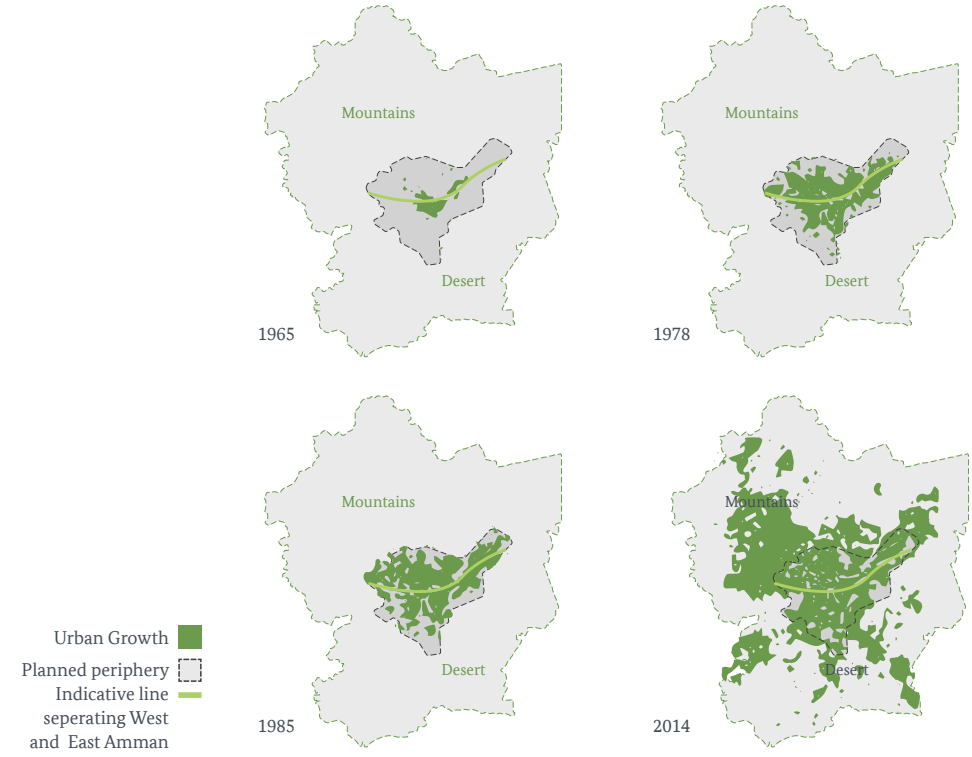

Fig 15: Illustrating Amman growing towards the Western agricultrural lands rather than the Eastern desert

Unsustainable planning practices

Amman's main wadis were mostly covered by asphalt. The city's main arterial roads run along the lowest points and at the bottom of natural wadis (GAM, 2008), which reduces the cut-and-fill construction costs of these roads. The natural wadis have been converted into drainage culverts and pipes placed beneath the road pathways, without proper consideration of the impact that this alteration would have on the quality and quantity of stormwater. These wadis have the natural characteristics of collecting and filtrating rainwater and could have become the nucleus of Amman's green lungs, giving birth to a unique cityscape that is responsive to the existing natural features.

Topography

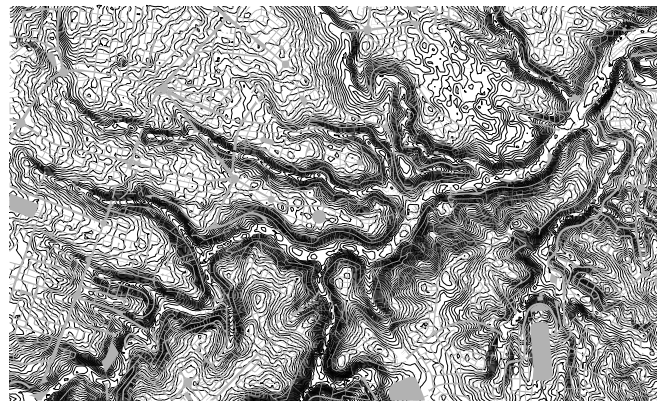

Fig 16: Topographic map revealing Amman's natural path of watercourses

Streets

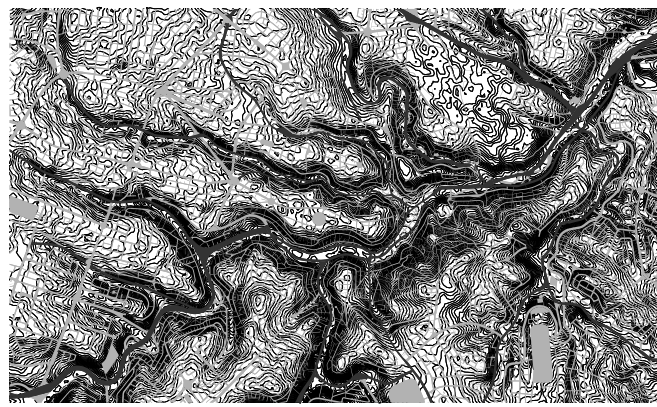

Fig 17: Overlaying main road network reveals how natural paths of watercourses were replaced by streets with no permeable surfaces.

How depleted natural resources affect the urban environment

The results of overlooking the environment and working against nature are manifest, at present, in the city's urban reality.

- Expanding the city over agricultural and forest lands, rather than the open flat desert, has deprived the country of a major source of revenue and stripped the city from its natural green zone that could have participated in alleviating summer temperatures, dropping pollution levels, and reducing the risks of weather extremities.

- Interfering with the natural path of watercourses is recognized as being an unsustainable management practice (SEPA, 2000). Intervening with these natural systems is known to cause various problems, including increasing stormwater runoff, flooding, and erosion (ibid.). Consequently, constructing Amman's main road arteries in major wadis had negative implications that can be witnessed at present. The negative effect is evident in the way in which rainwater is now drained from a large urban area and then accumulates in the lower parts of the city, causing rainwater pollution as well as numerous economic losses due to the flooding of these low-lying areas.

Way forward... considering nature and sustainability at the early stages of planning and design

"Preserving the Natural Heritage Systems of Amman is one of the three main pillars of the 2010 Amman Metropolitan Growth Plan. Different departments in GAM should be aware of this plan, its recommendations, and ways in which current practices should change to restore green reserves and face future challenges" (Odeh, 2021).

GAM became aware of the effects of unsustainable planning practices especially those regarding main arteries design and its devastating effects on both the economy and the environment. The increase in municipal awareness is reflected in the new Overlay Zoning tool that was added in the recent version of the Building and Zoning Regulation in the city of Amman (2018). This tool regulates the future development of areas of special character, including lands located on watercourses, by allowing planning committees to introduce site-specific regulatory provisions for these areas. Hence, it supports the objective of conserving water resources and reducing surface water runoff in the streets running along natural wadis. Through this regulatory tool, GAM can now require the provision of wider front setbacks on lands adjacent to watercourses to retain rainwater within the property limit (Odeh, 2021).

It is important to conclude that all future expansions, beyond the actual administrative boundaries of GAM, should avoid the green and agricultural areas that remain to date. As for compensating for the loss of green areas inside the city, it is important to seize each opportunity to plant and increase green surfaces. When looking closely, it becomes apparent that the city still contains many left-over lands that offer opportunities to bring back greenery into the city.

Lack of public green space

Why Amman does not have enough public green spaces

"GAM area covers nearly 800 square kilometers... there are 11.72 square kilometers of green area in the GAM. Those include parks, designated recreation areas, reserves, pavement landscapes (trees on the sidewalks) and other "green areas" [...] Divided by 4.32 million people, residents of Amman enjoy 2.5 square meters of park area per capita," as clarified by Dr. Mervat Mheirat, the Deputy City Manager for the Health and Agriculture Affairs Sector at GAM (Bazian, 2019).

When compared to the World Health Organization's standard, which is equal to 9 square meters of green area per capita, the shortage in the total amount of green areas in the city of Amman becomes clear. The ratio of green areas per capita in the city of Amman is also 37.5 square meters less than the set US standard (ibid.).

GAM's planning guidelines comprise two levels for land division: level 1, the Zone "Mantiqah" and level 2, the Sector "Hawd" (Odeh, 2021). These two levels work at the city scale. Each one of these levels gets the required lands for services during the design stages. At the city level, lands for services such as parks, schools, and medical center are reserved, in advance, by governmental authorities. King Abdullah and King Hussein Parks are the results of this division hierarchy, as they serve the residents at the city level (ibid.).

What is neglected, because of this division, is the neighborhood level, which works at a smaller scale. The absence of the neighborhood division level strips the city from a huge number of small parks that should be available at this level, to provide the residents with green spaces at walking distance. The absence of a sufficient number of parks at the neighborhood level contributes to the low percentage of POS in Amman.

How public green spaces affect the urban environment

Preserving the presence of nature in the urban environment is essential, whether in the form of street trees, planted gardens, or even flowers on balconies. It is well known that green areas provide humans and their cities with multiple social, economic, and environmental benefits (Mair, 2020). While the environmental benefits of green areas are elaborately discussed in the following (Chapter 2), and more particularly their environmental benefits, below are some examples of the wide range of benefits obtained from natural green areas (EEA, 2011; MEA, 2005):

- Improve environmental conditions in cities, by reducing ambient temperatures, retaining rainwater, and absorbing GHG that are emitted by human activities, including the use of cars, amongst many other environmental benefits.
- Build social relations and offer community recreational areas.
- Provide the city with multiple products that are essential for human survival, for example, the direct production of food and fiber on agricultural land and gardens.
- Positively impact the value of land and property.
- Make cities more attractive: Many aspects of the natural environments are perceived by people as having a unique aesthetic value.

Way forward... Restore and introduce new green spaces

Humans are responsible for taking care of nature in cities and must play an active role in maintaining the necessary balance on the planet. In return, numerous benefits would be obtained in relation to human health and wellbeing. Amman's low-density areas should be exploited to introduce new public green spaces, whenever it is possible.

GAM is paying attention to this challenge in newly planned areas. Lands for future neighborhood parks are being reserved at the early planning stage. Unfortunately, developing new neighborhood parks in existing urban areas is more challenging at present, as it requires allocating huge unavailable financial budgets for expropriation (Odeh, 2021).

Fig 18: Completion of the pocket park on Palestine Street which was previously a leftover plot

Lack of resources

Why Amman lacks resources

For long decades, depleting the few available natural resources, including the removal of the pre-existing forest cover, was generally overlooked to allow for the city's growth. While huge budgets, on the other hand, were allocated to serve the city's unsustainable growth pattern, once they were provided by foreign investors (GAM, 2008) (As discussed in the previous sections). Nonetheless, with the prevailing instability in the geopolitical scene in the region, and the resulting influx of refugees over the years, the county of Jordan, including its capital Amman, has suffered from an increasing pressure to serve population needs, while having an already fragile financial, and natural capital.

How the lack of resources affects the urban environment

Lack of financial resources

In the last decade, Amman has been forced to deal with limited financial resources and operate within limited budgets. This exposed decades of neglecting maintenance and investing in unsustainable expensive projects, such as the increasing construction of tunnels and bridges and the expansion of the city's road network (GAM, 2010; GAM, 2008), as mentioned in the previous discussion. Cities need budgets to operate. Relatively speaking, larger cities require bigger budgets. Today, the city is facing real financial problems resulting in many socio-economic and environmental challenges. Budget limitations are preventing the city from:

- Upgrading the failing stormwater network in old parts of the city. This negatively affects the local communities and the environment.
- Providing public parks with sufficient quality and quantity. The city only has a limited number of parks with basic services and amenities, which eventually develop into derelict sites with time

- Upgrading sidewalks, which are currently hindering pedestrian mobility.
- Building a proper public transportation system. This is resulting in major traffic jams and air pollution.

Lack of natural resources

The lack of green natural reserves affects the quality of urban life (as discussed in the previous Section 2.1.2 Depleted natural resources). The lack of water resources triggers a long chain of environmental challenges that comprises a lack of greenery, elevated temperatures, and extreme weather conditions. The lack of conventional energy resources puts a lot of pressure on Jordan's budget. This directly affects all the services provided by the government and municipalities.

Way forward... Sustainable use of available resources

The elevated energy costs in Jordan, caused by the need to import energy resources, should encourage us to build compact cities, rather than adopting horizontal growth models that increase energy use and consumption. In a country with limited natural and financial resources, sustainable growth models should be prioritized, whenever possible. Water scarcity in Jordan should generally direct us towards adopting a more sensitive mindset towards available natural resources. Maintaining and upgrading the existing infrastructure networks is a way to save non-renewable and limited water resources, though, for instance, reducing water leakages that are caused by old and degraded pipelines.

CHAPTER III

GREEN INFRASTRUCTURE RECOMMENDATIONS FOR AMMAN

CHAPTER III GREEN INFRASTRUCTURE RECOMMENDATIONS FOR AMMAN

The set of recommendations provided in this section is an outcome of the previous literature review on urban challenges and the potential solution that is presented through the concept of GI. The suggested recommendations are categorized at the levels of planning and design, to ensure that GI is considered at the early phases of urban development.

3.1 AT THE PLANNING LEVEL

Fig 19: GI Implementation

GI can easily be implemented in the city of Amman for the following reasons:

- **The availability of empty leftover lands:** These lands, if properly exploited, can constitute the small-scale nodes of the city's GI network.
- **The availability of wide right of ways:** The city's wide right of ways contain medians and sidewalks within their domain. These urban components can act as the linear connections between the GI nodes.
- **The presence of slopes in the hills of the city:** The advantage of having slopes in the city of Amman is that these areas are ideal for directing and collecting rainwater, which can be later used for irrigation.
- **Amman's moderate weather:** Having moderate weather can encourage active mobility, including walking and cycling.
- **The presence of well-established engineering departments at GAM, and in other concerned ministries:** Having these departments, which employ a skilled workforce, would support the proper planning and design of the city's GI.

But

Planners, architects and engineers must accept the fact that the planning, design, building, and use of the city must be changed. The consequences of the choices that are made, whether big or small in scale, must become recognized.

There must be an increase in awareness that the degradation of the natural environment will have an inevitable impact on all living beings, including humans.

Plan for sustainable public open spaces

Site selection and activating public open spaces through programming

In the late 20th century, a major shift in the way cities conceive their public open spaces took place (Comberg, 2018). Besides fulfilling their traditional roles, planners, architects, and landscape architects became aware of the full potential of these spaces and the ways in which they can contribute to enhancing the socio-spatial qualities in urban settings. This requires a shift in the way these spaces are conceived. Besides their traditional role, these valuable sites can become the central nodes of the city's green infrastructure network.

Parks are platforms that reflect development. Festivals, book fairs, concerts, and lectures, all take place in parks. Public open spaces, in fact, form some of the world's most famous cities.

Fig 20: Activating public space, Souk el Tayeb Beirut

Fig 21: Nour Al-Baraka Saturday market, Amman

Legislations

In Jordan, many typologies of public open spaces, such as public parks, central islands, and squares, are lacking designated regulations and instructions that guide their proper development according to clear standards (Mare'e, 2019). The consequence of this is visible in all Jordanian cities, including the capital city of Amman, in terms of the quality and quantity of these spaces. Many GI interventions that have been developed were spearheaded by international organizations and non-governmental organizations that support GAM in meeting sustainable development goals (SDGs) and supporting local climate ambitions, which is exemplified, for instance, in the work done by the Center for the Study of the Built Environment (CSBE) in the National Gallery of Fine Arts Park (Al-Asad & Zureikat, 2005), as well as the GIZ ILCA project that introduces new possibilities for the development of the city's POS. The various typologies of POS can be properly exploited for their potential as key components in the city's GI network once these spaces have designated regulations and instructions that support their proper development as green components (Mare'e, 2019). These regulations and instructions can contain certain set standards related to the planning of these spaces (e.g. proper site selection); their design and construction, including green ratio, suitable plants, and specifications for construction and materials (e.g. permeable pavements); as well as their maintenance (e.g. maintenance schedules and responsibilities). Establishing these legal documents is the first essential step to undertake in order to ensure the development of the city's POS in a manner that supports the advancement of the city's green infrastructure network.

Plan with nature not against it

Planning with nature entails being sensitive to the natural environment during the planning of the city. This would be reflected, for instance, through consciously minimizing the environmental impact of urban development and exploiting all possible opportunities to integrate natural features within the built environment.

Reducing human interference with natural watercourses

Manipulating watercourses goes against their sustainable management and would result in many negative implications if the natural balance of these watercourses is not sufficiently maintained (SEPA, 2000). In the case of Amman, interfering with natural watercourses (wadis) has negatively affected the urban environment on two levels:

- These arterial roads drain stormwater from remote areas, and direct this water towards the downtown area, which has led to its frequent flooding for many years; and
- Amman's wadis could have been preserved and developed as a natural green lung for the city, which sinks the various forms of city pollution and provides the city residents with a fresh natural escape.

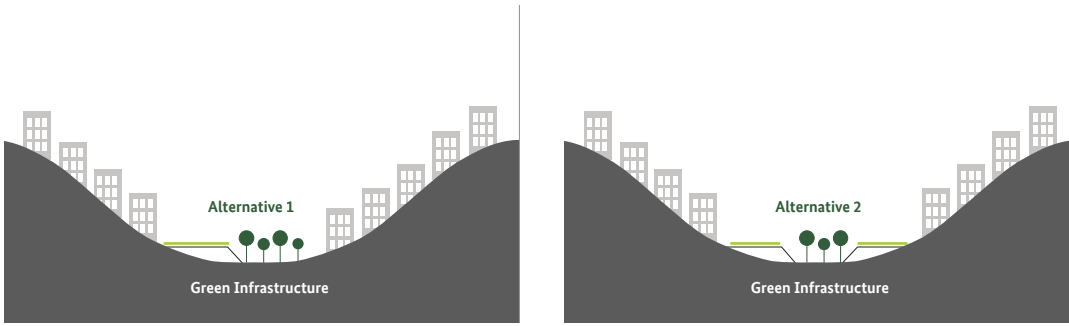

Fig 22: Valley section alternatives

Street medians and sidewalks present opportunities for future interventions

Fig 23: Illustration of bioswale implemented on sidewalks to retain stormwater

Wide streets are common in Amman. How can this reality help in implementing GI?

- Small GI interventions that increase porosity should be implemented in the long sidewalks and medians (central islands) that lead to the downtown area and other flood-prone neighborhoods to retain some of the stormwater and reduce environmental damage and financial losses that are attributed to floods; and
- Sidewalks should be designed to facilitate smart mobility and follow the concept of complete streets that supports the development of safe and vibrant streets that accommodate all street users (e.g. pedestrians, cyclists, public transit, private vehicles) (Toronto City Council, 2017). Strict standards should be applied to ensure the quality, continuity and sustainability of sidewalks in residential and commercial streets, including the provision of tree canopies that provide a walking-friendly environment.

Plan for smart mobility

Complete streets

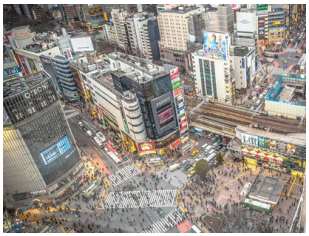

Fig 24: Example of pedestian network.

GI within the city's street network is closely tied to the concept of complete streets (Toronto City Council, 2017). Urban planners and designers, engineers, and transport planners should work collaboratively to ensure Amman's streets serve all types of users—pedestrians, public transport users, private car users, goods vehicles, and even cyclists, when an appropriate context is available. More often than not, streets in Amman are designed for the private car as the primary user and beneficiary. This is evident in the space provided to car users (relative to other users) and to interventions favoring the car, such as building pedestrian bridges and multi-level interchanges. Complete streets require a paradigm shift, where the objective

becomes facilitating the movement of people and goods, rather than merely the movement of cars (Toronto City Council, 2017). At the street level, this involves, at the minimum standard, providing safe and continuous pedestrian networks—not only in terms of sidewalks but also at-grade and preferably signal-controlled crossings. Space should also be allocated for public transport vehicles to stop, allowing passengers to safely board and alight the vehicle.

Fig 25: The community surrounding Mahmoud Al-Qudah Park in Al-Nasr district taking part in participatory co-design workshops.

The need for more space for pedestrians and cyclists was brought to the forefront in the recent COVID-19 lockdown (GAM, 2020; Suboh et al., 2020). City dwellers were restricted from using their cars and ended up walking or using bicycles, many of which were purchased during the lockdown (ibid.). Anecdotal evidence showed that people were willing to continue using those modes for certain trips even after the lockdown, provided the necessary infrastructure and policies were in place. GAM should take advantage of this unique momentum caused by the lockdown to introduce measures that support walking and non-motorized transport.

Even for motorized travel, certain measures can be taken to encourage a greener impact. These could involve electric vehicle charging stations or smart city and data-related interventions that limit car use. For example, providing information on available parking spaces (a measure that GAM is considering in the Al-Khalidi Hospital neighborhood) can limit the number of cars searching for parking (known as “cruising”), thus limiting greenhouse gas emissions.

Pedestrian bridges

A key challenge of pedestrian bridges is that they are not designed with a mindset that prioritizes the ease of pedestrian crossing, but rather, the movement of cars (ITDP, 2019). Not only does their elevation above highways make them challenging to use by all people, including children, the elderly, and people with special needs, but their greater length means that pedestrians need to place more effort and travel through a longer distance to cross the streets. For instance, the crossing of a street with an 11 meters width would necessitate a 103 meters bridge space due to the additional stairways or ramps that are required to elevate the bridges. Hence, having these structures discourages people from using them to cross streets. Additionally, the, sometimes, unsafe conditions of these bridges, such as when they are poorly lit, would discourage their use by pedestrians, and particularly women (ibid.)

It is also evident that these structures are not as effective as decision-makers would like them to be, because many people choose not to use them and cross at the street level, even though it is more dangerous. The presence of these structures reinforces the notion that Amman's streets prioritize cars. Streets should focus on moving people, not cars, and pedestrian bridges are some of the elements that do not support this idea because of the inconvenience and discomfort they cause.

Humanizing Streets

Cities are becoming more conscious about the impact of their street designs, and the way in which they might favor certain transportation means over others. The importance of considering the various types of street users is elevated with the alarming statistics issued by the WHO (2018), which identify pedestrians, cyclists and motorcyclists as vulnerable road users that represent more than half of all road traffic deaths in the world, with pedestrians and cyclists representing 26% of all deaths, while motorcyclists comprise another 28%. As a result, many cities in the world started to take various actions to humanize their streets and enhance their safety by perceiving them as social public places rather than just traffic throughways (Peinhardt & Gulati, 2019). For some architects, it was thought that addressing this challenge will require the removal of excess formality and street signage that are present in modern streets.

They suggest that the traffic flow could be, in many cases, regulated by social interactions between different street uses. Through following this principle of mindful interactions, many streets have been transformed in cities, like Geneva and Switzerland, and were designed in a manner that increases the driver's expectation of the presence of pedestrians, as they navigate the streets. Their design has also supported the removal of some traffic lights and their replacement with alternative street signages, including yield and stop signs.

Another approach for cities that are not yet prepared for the removal of their traffic lights and street signage would simply be to better design their streets to contain the necessary infrastructure for all street users. The street guidelines can direct streets to become more accommodating to certain street users by increasing the street space allocated for their use (e.g. wider sidewalks, bike lanes) (ibid.). The ultimate goal, in the end, is to direct a behavior change to allow for streets to progress with time as platforms that safely accommodate all their users.

3.2 AT THE DESIGN LEVEL

Green infrastructure projects are increasingly recognized, both in theory and in practice, for their need to be developed following a participatory approach across their project lifecycle (Willems et al., 2020; Wilker, Rusche & Rymsa-Fitschen, 2016). Project stages can be generally distinguished in terms of project design, project delivery, and project maintenance. All of these different project stages should have participation ambitions, in which local governments move towards adopting a facilitating role that opens the possibility for collaborating with a wide range of stakeholders, including local communities, private businesses, and NGOs, by utilizing suitable instruments at each project stage (e.g. statutory consultation and information provision through public hearings or community events; co-design of the project through partnership or open calls; partnership with local communities for maintenance; etc.).

Adopting ongoing participation along the project lifecycle would allow each stakeholder to contribute to the project through bringing in their ideas, experiences, resources, and local knowledge of the context; support in building shared commitment of multiple stakeholders; and promote the long-term sustainability of GI projects (e.g. lowering management costs, citizen volunteering to monitor GI projects). Consequently, realizing green infrastructure projects through adopting participatory approaches allows for new and innovative solutions to emerge as the outcome of involving multiple stakeholders. It also ensures that the end projects are more responsive to the site context and its specific challenges and that they are tailored to meet the needs and requirements of local communities (ibid.).

Fig 26: Participatory co-design workshops

Consequently, the design stage of the project can be regarded as a primary stage in which proper collaboration between the local government, experts (i.e. architects, urban designers, engineers), and local communities must be ensured. From the early design stages all the way to completion and operation, a dedicated team must be assigned to the project to discuss materials, systems, and constructability, make sure that the community's needs and requirements are considered, that modifications or alterations are communicated, and that approved budgets are met. Finally, to ensure the advancement in the state of design and practice, subsequent analysis and evaluation of implemented projects should be conducted to identify past mistakes and generate lessons that can be learnt and adopted to direct similar projects in the future. Therefore, the project design stage, should also consider the development of sustainable GI designs and also their maintenance in the long term.

Plan for sustainable designs

On construction materials

Each time a new urban design is embarked, several aspects must be considered, including the environment, existing environmental conditions and challenges, accessibility, and maintenance. These aspects should always be taken into consideration from the initial design stages of any project. Each time there is a possibility of replacing a hard surface with a porous one or reducing the use of asphalt, such a possibility should be pursued. Similarly, whenever an existing structure is maintained or reused, the prospect of integrating GI should be explored.

A GI strategy, in the end, is a high-level mindset that considers the integration of green measures in all development activities that occur in cities. This strategy accepts the notion that the road towards sustainability does not necessarily require large-scale structural changes in the city's fabric. It rather supports the adoption of small interventions that are spread throughout the city's landscape, with the belief that such low-cost interventions can complement one another and form a continuous functioning network at a larger scale.

The fact that most GI interventions take place on the surface level makes execution cost lower than that of traditional underground networks. Identifying problems, setting priorities, and coming up with specific design solutions is key to implement efficient GI interventions

Fig 27: Small GI intervention - trenches implemented next to planters on Seventh Stair on Al-Quds Street, as a green stormwater solution

On building with limited budgets

Establishing and sustaining vegetation in Amman is a challenging undertaking. It is especially difficult in parts of the city where rainfall averages are significantly lower than 100mm. Various considerations, discussed in the section below, need to be addressed in the establishment of an effective green infrastructure in the water-scarce Jordanian context (CSBE, 2011; CSBE, 2004).

Fig 28: Green retaining wall from the pocket park on palestine street

On water conservation

Plant selection

Plant selection should be based on the ability of plants to withstand drought and urban conditions. Native and adapted plants are highly recommended (Al Jaajaa & El Oqlah, 2021).

Emphasis should be placed on selecting plants that establish quickly and can be sustained with minimal irrigation after establishment. The establishment period of plants in Jordan is three to four years. During this period, trees and large deep rooting shrubs need to be irrigated during the dry summer months.

The amount of water supplied to the plants needs to be decreased every year until the plant establishes. After the third or fourth year, the trees and many of the shrubs that will be selected will not require supplemental irrigation.
Emphasis should also be placed on deep-rooting shrubs, and groundcovers should be minimized. Many deep rooting shrubs need little irrigation after establishment, while groundcovers need to be irrigated perpetually. Lawn areas should be kept to a minimum and used in areas with functional use, such as picnicking or play.

Fig 29: Green pods were used in Mahmoud Al-Qudah Park as a feasible strategy to introduce densely vegetated areas hosting a variety of functions.

Other factors to keep in mind are using native plants where possible, considering that the supply of native plants is limited in the market, as these plants provide good habitat value. Furthermore, canopy trees provide shade and thermal comfort for street users. They also protect understory plants and reduce their need for water.

Soil preparation

Soil should be prepared to retain moisture and provide the medium for optimal plant growth. Many parks and urban landscapes in Jordan suffer due to improper soil preparation in terms of tilling, the level of compaction, the presence of large stones and other debris, and inadequate amounts of organic matter. Soil preparation should be given priority.

Mulching

Moisture retention and the prevention of the growth of weeds (which compete for moisture and nutrients) are also key factors when sustaining green infrastructure in arid climates. Adding mineral mulch over the surface of the planted areas will conserve moisture in the soil and reduce the growth of weeds. The mulch layer also protects the surface irrigation pipes from exposure to the sun and prolongs their lifespan.

Irrigation

Jordan now ranks as the world's second water-poorest country, according to the Government of Jordan. Landscape drip irrigation systems can save up to 60-70% of freshwater compared to conventional surface irrigation and water spreading techniques that are applied in Amman.

One of the biggest challenges is the sustainable operations of landscape areas in Amman due to the high operational expenditures (OPEX). Drip irrigation systems have lower operational cost than the current water spreading and watering practices (tankers) in Amman. Cost-saving in OPEX can promote efficient operations and covering the percentage of green areas.

Frequent and continuous watering improves plant health, growth, and spread resulting in sustainable landscapes. Drip irrigation systems promote the application of continuous, slow, and precise irrigation of the plants to ensure healthy, uniform, and fast-growing plants.

Adequate, regular, and even irrigation is another key factor to consider when establishing green infrastructure. Each green area should be equipped with a minimum water storage facility (underground tank or overground tank) and an efficient irrigation system. Drip irrigation is to be used for all plants except lawn areas.
Hydro-zoning, the method of organizing the planting and irrigation according to water needs, is highly recommended. In this way, water consumption can be controlled to reach plants at the recommended consumption rates and irrigation can be discontinued at the end of the establishment period in certain zones without re-structuring the network.

Maintenance practices

It is recommended that maintenance budgets are allocated for each site (park or open space) for at least four years. This ensures the establishment of the vegetation. Watering schedules should be adhered to in addition to other practices such as tree staking, weeding, and proper pruning.

Plan for maintenance

Maintenance and operation constitute an important part of a project's life cycle that should not be overlooked. With traditional infrastructure systems maintenance often occurs when there is a complete failure of the system (Christian & Tech, 2010). Complete failures occur because these underground systems are out of sight, and hence, out of mind. Most green infrastructure measures, on the other hand, are visible and considered as an aesthetic amenity, which makes ignoring their maintenance needs much more difficult. Below are some suggested entry points to consider maintenance at the design, implementation and operation stages (Christian & Tech, 2010).

Maintenance at design stage... design for reduced maintenance

It is always important to design GI measures while keeping easy maintenance after operation in mind. This will support in reducing operating budgets. Many issues can be considered during the design stage to reduce future maintenance requirements.

Examples include the suitable selection of plants that are adapted to local climates; providing accessibility to GI measures; communicating the presence of GI by means of manuals and on-site signage explaining the function, use and specialized maintenance needs; involving maintenance staff in the selection of the GI measure at the design stage; and providing water pretreatments, including sediment traps and vegetative buffers (ibid.).

Maintenance at implementation... prepare manuals

Preparing manuals for the maintenance of GI measures is crucial to preserve their functionality in the long term. This should include developing standard operating procedures for maintenance (i.e. who, what, when, triggers); providing the necessary training for municipal employees and private entities; as well as implementing tracking systems.

The significance of implementing tracking systems lies in their capacity to:

- Provide an inventory of existing GI measures;
- Track maintenance and inspection of GI measures;
- Simplify the inspection and maintenance process;
- Provide documentation of GI measures for legal action;
- Relate the design of GI measure to actual performance;
- Be used as a tool to develop program cost estimates; and
- Support in identifying future GI retrofit opportunities (ibid.).

Maintenance at operation... inspections

Several actions can be taken during site inspections to maintain GI measures in the long run. These include, but are not limited to, inspecting the state of vegetation and examining the presence of any invasive species; inspecting the state of the water storage systems; inspecting sediment accumulation; inspecting all components of each system (i.e. tributary area, inlet, primary storage, outlet or overflow, downstream of the outlet); focusing on preventive measures to avoid costly corrective repairs; and managing waste and debris (ibid.).

C O N C L U S I O N

Greater Amman Municipality has been working with the GIZ to implement GI projects with local communities since 2017. Part of the community service staff and engineers are familiar with GI concepts; engineers and community service employees followed several training workshops covering all aspects and stages of implementing GI as part of the GIZ's ILCA project. They are also aware of the social and design skills, steps, and long negotiation periods that are sometimes required to accomplish even small green interventions.

Amman's topography, climate, and as strange as it might seem, its wide street network, puts it in a good position to implement GI interventions, to address some of its local challenges.

GI can provide an efficient parallel network to support the existing stormwater network. It can support the various modes of mobility and compensate for the lack of an efficient public transportation system. It can also help in increasing the below-standard area of green public spaces in the city.

GAM should capitalize on its qualified workforce to compensate for tight municipal budgets financial resources. GI is a manageable strategy since it works at the micro-level while maintaining consideration of the connection between green measures at the macro level. It is also the perfect medium where urban planners, architects, landscape architects, engineers, and community service employees can work together to introduce innovative green solutions that respond to the city's ongoing challenges.

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