Green Infrastructure for Socio-Ecologically Resilient Cities: The Case of Amman City Center, Jordan

Islam Abdel-Latif M. Alshafei

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Prof. Dr. Ali Hakan Ulusoy
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Architecture.

Prof. Dr. Resmiye Alpar Atun
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Architecture.

Asst. Prof. Dr. Pınar Uluçay Righelato
Supervisor

Examining Committee

1. Prof. Dr. Ali A. Alrauf
2. Prof. Dr. Şebnem Hoşkara
3. Prof. Dr. Koray Velibeyoğlu
4. Asst. Prof. Dr. Hassina Nafa
5. Asst. Prof. Dr. Pınar Uluçay Righelato

ABSTRACT

Densely populated areas pose challenges for the local governments to tackle with the social and environmental problems of urbanization such as degraded natural environment, social and environmental injustice, reduced feeling of well-being, increased air temperatures, and high flooding risks, leaving urban communities vulnerable to stressors. These global challenges place a pressing encounter for urban environments demanding more resilient systems that can deal with the stresses of urbanization.

Moving on from this perspective, the research focuses on the socio-ecological theory of resilience, in an attempt to understand how this discipline evolved over the years to host the human ecosystem approach to study the interactions between social and ecological systems, and highlight approaches to reinstate nature into urban areas through the integration of urban Green Infrastructure (GI). The literature review indicates that there is limited research on the application of this approach in the field of urban planning and highlights the fact that GI embraces a potential for strengthening resilience and assisting disaster risk reduction (DRR). As such, the research focuses on understanding how GI can be implemented into the human ecosystem spatial networks of challenging inner-city urban contexts to reach socio-ecological resiliency, versus developing tactical solutions during emergency situations. Accordingly, a theoretical framework is proposed that approaches the reciprocal relationships between spatial patterns and sociocultural processes through the use of an integrated systems approach where the natural and cultural landscape can be spatially and functionally integrated to enable the creation of more socio-ecologically resilient cities through a GI oriented approach.

The research utilizes a mixed methodology where both quantitative and qualitative data are collected and analyzed. Questionnaire surveys are employed to measure the pro-environmental behavior of local communities in the city center of Amman. The methodology uses quantitative tools based on graph/space syntax theories. It is argued that these two methods withhold powerful diagnostic tools for the improvement of socio-ecological resilience in dense urban areas as in the case of Amman through visualizing and assessing human ecosystem spatial patterns to develop tactical solutions in emergency situations.

The findings of the study address the possibilities for the enhancement of the patchiness of the ecological system by re-establishing a socially driven landscape connectivity where GI can be developed and sustained. To this end, the study offers benefits for the development of socio-ecological resiliency and DRR within the context of the case and similar cases by suggesting specific context-sensitive aspects within its framework that can be generalized for planning, implementing, and managing urban GI, building resiliency capacities, and reducing vulnerabilities in urban communities.

Keywords: Socio-ecological Resiliency, Green Infrastructure “GI”, Disaster Risk Reduction “DRR”, Pro-environmental behavior, Space Syntax Theory, Graph Theory.

ÖZ

Yüksek nüfusa sahip yerleşimler, hızlı kentleşmenin yol açtığı bozulmuş doğal alanlar, sosyal ve çevresel adeletsizlik, insan sağlığının olumsuz etkilenmesi, hava sıcaklığının artması, sel ve taşkın riskinin yükselmesi gibi sosyal ve çevresel sorunlara neden olarak, kent topluluklarını streslere karşı daha duyarlı hale getirmekte ve yerel yönetimlerin acil durumlar karşısında mücadele edebilme kabiliyetlerini olumsuz etkilemektedir. Halbuki dünyamızda daha kaliteli kentsel çevrelerin yaratılması, kentleşmenin etkileri ve stresleriyle başa çıkabilen daha esnek sistemlerin oluşturulması ile mümkündür.

Bu çerçeveden hareketle, kentlerde sosyal ve ekolojik sistemler arasındaki etkileşimleri insan ekosistemi yaklaşımı üzerinden inceleyen bu çalışma, bu kavramın zaman içinde farklı disiplinlerde nasıl dönüştüğüne bakarak, sosyo-ekolojik esneklik kuramına odaklanmakta ve doğanın kendini yenileyebilmesi için Yeşil Altyapı'nın (YA), kent alan larına nasıl dahil edilebileceğini araştırmaktadır.

Literatür taraması, bu konunun kentsel planlama alanında sınırlı bir araştırmaya konu olduğunu kanıtlamakta, ve YA'nın kentsel toplulukların direncinin güçlendirilmesinde ve afet risklerinin azaltılmasında önemli bir role sahip olduğu göstermektedir.

Bu çerçevede araştırma, Ürdün'deki Amman şehir merkezi örneğinde, YA'nın, kentlerde sosyo-ekolojik esnekliği sağlamak ve afet durumlarında acil tedbirler üretebilmek için karmaşık kent sistemlerinde nasıl uygulandığı konusuna odaklanmaktadır. Bu hedefle, YA planlamasında mekansal ve işlevsel olarak kente bakmak yanında insan hareketinin de dikkate alınarak entegre bir sistem yaklaşımının geliştirilmesinin önemini vurgulayan çalışma, mekansal örüntüler ve sosyokültürel süreçler arasındaki ilişkileri incelemektedir.

Araştırma, hem nicel hem de nitel verilerin toplandığı ve analiz edildiği karma bir metodolojik yaklaşımı benimsemektedir. Çevreye Duyarlı Davranışları (ÇDD) ölçen bir anket yöntemine başvuran araştırma, aynı zamanda grafik/mekan sentaks teorilerine dayalı nicel araçlardan da faydalanmaktadır. Bu iki yöntem entegre olarak kullanıldığında, Amman ve benzeri alan çalışmalarında, bağlama duyarlı bir yaklaşımla kent sistemlerinde sosyo-ekolojik esnekliğin geliştirilmesi ve afet durumlarında acil tedbirler üretilmesi amacı ile kullanılabilecektir.

Çalışmanın bulguları, YA'nın peyzaj sistemleri arasındaki ekolojik bağların sosyal ilişkiler ağı ile birlikte değerlendirildiği zaman sürdürülebilir bir yapıya sahip olabileceğini ortaya koymuştur. Kentlerin sosyal ve ekolojik sistemlerindeki kırılganlıkları tolere edebilmesi için kentlerin daha esnek bir yapıya sahip olmalarının önemine vurgu yapan çalışma, YA'nın kentteki sosyal ilişkilerin de incelenerek planlanlanabilmesi, uygulanabilmesi ve yönetilmesi için metodolojik bir çerçeve sunmakta ve benzeri dinamiklere sahip bağlamlarda sosyo-ekolojik esnekliği sağlamak ve doğal afet risklerini azaltmak için öneriler sunmaktadır.

Anahtar Kelimeler: Sosyo-ekolojik Esneklik, Yeşil Altyapı "YA", Afet Risklerini Azaltma, Çevre dostu davranış, Mekan Sentaksı Teorisi, Grafik Teorisi.

DEDICATION

This work is dedicated to my late father, who had dreamed and wished for me to become a Dr. since early childhood. Even though I did not become a Doctor in medicine, I sure became a Doctor in Philosophy ☺….

May your soul Rest in Peace….

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Chapter 1

INTRODUCTION

At the dawn of the 21st century, with half of the world's population living in cities, and urban areas, with their high concentration of population, industries, and infrastructure, cities face the most severe impacts of climate change, natural and human-made disasters, overcrowded built environment, diminishing green spaces, production of waste and its management, and energy crises, therefore, becoming more vulnerable to shocks and stresses. This challenge necessitates cities to enhance the resilience of engineered structures, organizations, and communities to achieve more sustainable environments. However, urban resilience requires new approaches to tackle the multidimensional challenges that cities- with complex dynamics- will likely face or are already facing.

Green Infrastructure (GI) is becoming a critical part of cities' approaches toward tackling resilience as it has the potential to moderate climate change while also providing recreational and health amenities to the citizens. Although GI can help support approaches towards better infrastructure performance and welfare and health, current research on the topic argue that the studies on the GI's contribution to urban resiliency and social interaction are still relatively limited and offers opportunities for further investigation. Within this perspective, the research will look into the ways GI can be integrated into cities with dense urban fabric so that tactical solutions can be created to respond to uncertainties during crisis/disaster situations. To achieve this target, the research reviews the relationship between socio-ecological resiliency and

GI to construct the theoretical framework of the research, and generate appropriate tools for measuring it in dense urban environments with challenging socio-demographic characteristics.

Within this perspective, the study will overview the most significant interventions in building eco-sociological resilience based on frameworks designed by various foundations and organizations. Some of these are; UNISDR (UN Office for Disaster Risk Reduction), Rockefeller, Resilience Alliance, and others that provide tools for tackling challenges faced by the built environment towards enhancing resiliency in cities. Many resilience frameworks/indicators now help understand critical drivers to resilience in the context of complex cities' dynamics. However, there is still only limited availability of tools for specific assessment of the instrumental role of GI in contributing to social-ecological resilience in urban environments. The study defines resilience as the ability of urban communities to cope with external stresses both socially and ecologically. This definition highlights social resilience in relation to the concept of ecological resilience which is a characteristic of ecosystems to maintain themselves in the face of disturbance. There is a clear link between social and ecological resilience, particularly for communities that are dependent on ecological and environmental resources for their livelihoods. However, it is not clear whether resilient ecosystems enable resilient communities in such situations.

In this perspective, the study defines social-ecological resiliency as a theory that first emerged from the discipline of ecology and later became the subject of urbanism to tackle DRR and climate mitigation with several sets of characteristics that imply urban communities withhold sufficient adaptive capacities to positively contribute to the development and transformation of urban systems.

The literature review conducted also provides scientific evidence that GI is a multifunctional naturally inspired type of urban infrastructure that comprises various contributions towards promoting human/ecosystem health and well-being by building up adaptive capacities of their systems, which further help transform existing urban systems into resilient structures through addressing urban communities. This way, the human system interacts and benefits from ecosystem services delivered by GI, making the urban structure transform positively towards a social-ecological resilient structure.

However, in the literature, there is little evidence of tools that can help measure how GI can be implemented in urban systems with dense urban fabric, and challenging socio-demographic characteristics for developing tactical solutions to help DRR in times of uncertainty. To achieve this, the study develops a methodological approach for a context-sensitive framework that translates relevant theories into real practice for the integration of GI into the spatial networks of human ecosystems with complex city dynamics. This framework is original with the methods and tools it provides as it responds to a gap existing between theory and practice. Within the research, this framework will be applied and tested through a case study, the inner city of Amman with a challenging city context that has been facing many natural disasters and climate change-related shocks and stresses for some time now. Amman, as the capital and largest city of Jordan, creates an appropriate base for this study being one of the most populated and fastest-growing cities in the Middle East with complex dynamics. In the last century, the city of Amman experienced phenomenal growth as its inhabitants increased from 3000 (approximately) to almost 4 million in the last century. As a result of this population explosion, the city center of Amman is currently facing disturbing social and environmental challenges that are reflected negatively on its urban environment. This situation creates hindrances for the city to deal with any kinds of shocks and stresses which have brought a lot of losses in human life and assets over the years.

The research will utilize a mixed methodology, firstly, a qualitative case study methodology to identify intangible factors, and will make use of the most common qualitative method, which is; questionnaire surveys (effective in producing data on communities in mixed populations such as Amman). The collected data will help understand the community's awareness, abilities, and willingness to participate in a better GI, highlighting the importance of community members' role in measuring and achieving resilience and identifying community priorities. From this perspective, the study investigates within its literature review relevant theories that can provide necessary tools and approaches to build a methodological framework and further test it on the case study Amman. The research will approach pro-environmental behaviour models (dealing with human-environment psychology) to configure the community-based view of positive environmental behaviour, its motivations, and drivers, as well as its barrier to taking action.

Moreover, the study within its quantitative research methodology introduces spatial modelling tools that are based on other relevant theories to visually map and analyse social and ecological spatial patterns within the case study. The space syntax theory methods and tools will be used to evaluate space structure/human relationships. As for the ecological system, the study will use graph theory methods and tools to assess landscape connectivity, fragmentation, and patchiness of the existing natural system within the study area. As part of its theoretical framework, the research proposes that merging these methods will create a diagnostic tool for suggesting tactical solutions for improving socio-ecological resilience in complex urban contexts during emergency situations. The method will facilitate the provision of specific locations for GI integration where high environmental and GI awareness exist which will encourage urban communities to interact and therefore enhance their adaptive capacities.

The expected findings of the study will also facilitate the enhancement of the patchiness of the ecological system by re-establishing a socially driven landscape connectivity where GI can be created and sustained in the city center of Amman – Jordan towards achieving a socio-ecologically resilient urban environment to deal with uncertainties in disaster risk situations. This human/ecosystem integration approach will not only help develop tactical solutions towards disaster risk reduction in emergency situations but help towards the health and well-being of communities and climate change mitigation in challenging urban environments.

1.1 Research Problem and Justification of the Study

There seems to be a gap regarding how GI can be engaged within complex urban environments where dense urban fabric and challenging socio-demographic characteristics exist, for transforming them into socially and ecologically resilient systems. This gap is especially acknowledged within current urban practices as there is not enough research regarding how a conduit can be constructed between the theory and practice in regards to building resiliency capacities of communities to achieve social-ecological resilience whilst maximizing the multi-functional benefits of GI.

Studies on the topic mainly discuss the significance of GI in creating environmentally resilient landscapes but do not focus on how GI can deliver numerous ecosystem goods and services, leading to enhanced human/ecosystem well-being and health. Accordingly, recent studies argue that the research on the socio-ecological impact of GI is still relatively weak.

The literature review on GI shows that it is primarily integrated in a single functional way and therefore, it can advance resiliency and hence enable DRR when adequately integrated. However, integrating urban GI into urban environments for its multi-functional benefits is still limited as it is challenging and faces many barriers from different perspectives.

Literature from the discipline of human sciences addresses the concept of GI in terms of its positive effect on human health and well-being. On the other hand, ecological and environmental sciences literature focus on resiliency building by utilizing the adaptive capacities of the natural environment, taking humans as part of natural ecosystems. The relationship between the concepts requires critical analysis to understand the concepts' theoretical value (GI, and social Ecological resiliency) and find tools for translating this theory into actual practice.

Virtually no studies draw a strong relationship between resiliency building from a GI perspective. It is mentioned briefly within some literature, but no real effort has been put towards developing a framework to assess the capability of urban settlements to achieve resiliency through their urban communities. The studies are case-oriented, focus on one side of GI, or are cultivated and general. Some systematic reviews draw attention to how this topic needs more research. Moreover, there are still no appropriate tools for assessing both systems in actual practice where landscape connectivity (spatial patterns between ecosystem patches in an urban context) and social-spatial patterns (individuals flow, movement, centralization, etc.) are interconnected, studied, and developed from a social-ecological urban system perspective. Existing frameworks that help understand critical drivers to resilience in the context of complex cities' dynamics offer limited tools for specific assessment of the contributory role of GI to urban resilience, especially the appreciation and incorporation of the society within the indicators of these frameworks.

Previous experiences engaging GI toward a more resilient urban environment have shown some barriers that city administrations should tackle before choosing the most appropriate strategies. However, to achieve the implementation of these long-term strategies, tactics prove useful in meeting short-term goals in emergency situations. Addressing GI barriers is crucial for several reasons, one of which is that not all strategies can be applied to all urban settlements with existing built and natural environments. An identical approach can be used in another urban context, but may not necessarily be successful due to social and cultural differences. Within this framework, the importance of community awareness and participation is highlighted in this research, underlining the significance of human psychology sciences known as pro-environmental behavior, and the necessity to include this method in the research.

More barriers facing the aftermath of the implication of GI towards resiliency must be considered as part of the research problem to avoid any downfalls and ensure the success of a resilient transition. These include technological barriers (non-efficient maintenance), perceptual barriers (lack of social acceptance, public education, and acceptance), and institutional barriers (lack of political support and coordination). Moreover, GI must be implemented appropriately, as such, must be context-sensitive to communities' preferences, land use, and scale of implementation.

Therefore, building a framework based on theory and translating it into practice is essential to consider context-sensitive factors is the key driver of this research.

1.2 Research Hypothesis

GI advances the resiliency of urban communities; If GI is to be properly integrated within human ecosystem spatial networks of complex urban systems, then urban communities' capacities could be positively promoted, and their vulnerabilities would be decreased. Hence, social-ecological resiliency could be achieved.

1.3 Research Question

The study underlines a central research question; *How can GI be implemented into the human ecosystem spatial networks of challenging inner city urban contexts to reach socio-ecological resiliency, versus developing tactical solutions during emergency situations?*

To answer this question in a comprehensive theoretical evidence-based manner, the researcher raises the following set of sub-questions to find the most relevant links towards building an understanding of all possible aspects of the main question;

- How can the GI-oriented human ecosystem approach be implemented in challenging socio-demographic contexts to achieve social-ecological resilience?
- What are the relevant theories and methods to approach human ecosystem spatial networks toward socially enhanced landscape connectivity?
- How can GI with its vast strategies and ecosystem services be integrated in a multi-functional manner within an inner city urban context to reduce urban communities' vulnerabilities as well as increase their capacities?
- How would the theoretical framework constructed be implemented in the practice to achieve tactical solutions regarding DRR? What are the requirements of this framework to be context-sensitive?

1.4 Aim and Objectives

The study aims at**;** *Developing a theoretically based framework that approaches a GI-oriented resilient inner city structure through the spatial networks of its urban communities so that it can be further applied to the real practice of urban planning and DRR.* Accordingly, the following objectives are highlighted as follows;

- Understanding the relationship between GI, Resiliency, DRR, and social-ecological components of the urban system in terms of vulnerabilities and resiliency capaities.
- Explore GI multi-functional contributions in advancing social-ecological resiliency.
- Clarify the suitability of approaching resiliency for DRR of urban structures through their social and ecological systems.
- Identify relevant theories and methods to approach urban communities through their spatial networks.
- Investigate approaches to properly implement GI through a social-ecological based resiliency framework that can translate theory into practice, and also be flexible, adjustable as well as context-sensitive.
- Explore existing GI frameworks and tools that can assess the resiliency of cities in terms of DRR with the acceptance of the urban structure as a socio-ecological complex system.
- Identify theories, methods, and tools for assessing and measuring spatial flows of urban communities; in the social system "space syntax theory" and ecological system "graph theory" within an urban structure.

1.5 Limitations

- This study aims at developing a framework to approach a GI-oriented resiliency that can be applicable in real practice to help develop tactical solutions for DRR. As such, specific locations or types of disasters in the study area are generally mentioned to highlight the significance of the issue as the method is not necessarily tailored to locate where natural disasters are likely to occur, and this can be the subject of further research. The method is capable of locating areas for proper GI integration within human ecosystem spatial networks, the areas that withhold high human impact; and public accessibility.

- The study overlooks all GI strategies, elements, and types in relevant theoretical studies. However, the study within its focus limits them to those most suitable for an inner city urban context which will make choosing and implementing GI more practical.
- While this study overlooks the most notable practical studies, frameworks, and indexes that highlight within their context all components of the urban system, the study is focused on those with a specific ecological/social focus.
- Limiting the focus of the study towards a GI-oriented resiliency comes from the notion that even though the city chosen for analysis, Amman Jordan, is part of the 100 RC initiative, there is no mention of GI implementation based on a human ecosystem approach.
- The study area was limited to the inner city context due to a lack of available data and also difficulties in reaching the existing data. For example, some data available within governmental and non-governmental institutions are unobtainable because the institutions are unwilling to share them. Moreover, the data collection of existing maps from the municipality is incomprehensive, up-to-date, or accurate, limiting the researcher’s sources. More limitations to data collection for primary data about the case studies, such as original greening typologies, statistical data, and other issues, exist due to the poor documentation of relevant authorities; they are somewhat limited or non-existing or not available to the public.
- Lack of collaboration by relevant authorities such as the municipality and resiliency officers of Amman’s resilient strategy, amongst others with researchers, is a fact that makes acquiring some critical data or doing focus interviews hard.

1.6 Methodology Structure

The thesis conducts a mixed-method approach in response to the research question addressed. The developed framework is original with its tools and methods. It will be tested in a case study to elaborate it as a practical approach and to provide proof to the research's main hypothesis. The steps of building the theoretical framework are adapted to a set of data and are as follows;

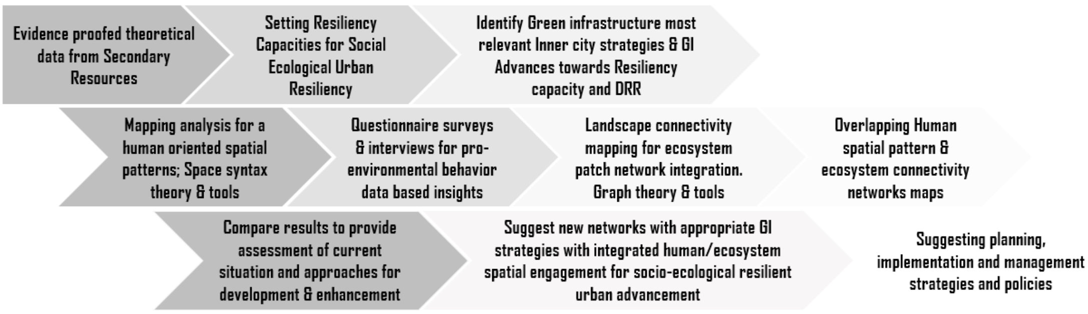


Figure 1: Preliminary theoretical framework of the study.

Firstly, a qualitative research methodology is utilized to test a case study adopted. Secondly, the study will conduct a quantitative research method introducing a spatial modelling tool by utilizing GIS and space syntax tools – Depth map, Spatial CAD analysis tools, and Arc-GIS and Graph Map visualizing tools within; linkage mapper. The detailed methodology is presented in chapter 3; however, the primary structure of the proposed method is as follows:

a. Literature review: A literature review will be done in a descriptive approach to explore gaps and limitations and present the initial steps towards critically describing, analyzing, synthesizing, and evaluating the data towards tailoring the theoretical framework of the study.

b. Developing a framework for assessment that link theory into practice, with several methdological approaches that incorporates relevant theories with their methods and tools. As such, the study will be exploring the theories, methods, and tools for assessing, measuring, visualizing, and analyzing social and ecological spatial patterns within an urban context for applying socio-ecological resiliency through GI - human–ecosystem integration, such as space syntax theory for the social system and landscape connectivity/ graph theory for the ecological system

c. Data Collection: Collecting the data from the study area will depend on exploring the communities based on pro-environmental behavior models. The study will conduct action and survey research strategies to collect, and analyze data regarding the community through questionnaire surveys.

d. Mapping the area of study: In this part of the methodology, the researcher will analyze the case to explore, and map out the urban development through history. Also, tools of space syntax will further help develop a clear image of potential human networks and places with activity. Landscape connectivity and graph theory methods and tools are used to accurately visualize and map out the reality of the spatial flow between the ecosystem patches using tools such as CAD visual analysis, ARC-GIS, and linkage mapper.

e. Conclusions and final remarks: The outcome highlights using the case study as a testbed for the theoretical framework this study proposes for tackling GI-oriented social-ecological resilience within complex urban systems as a new approach for bridging the relevant theory into practice. The expected findings of the study will be incorporated into enhancing the patchiness of the ecological system and developing strategies for strengthening citizen engagement, broadening participation, and improving the social dimensions of resilience by re-establishing a socially driven landscape connectivity where GI can be created and sustained in the city center of Amman – Jordan towards achieving a socio-ecologically resilient urban environment; Human/ecosystem integration through space/structure relationships for advanced human ecosystem relationships.

This will benefit projects for the development of socio-ecological resiliency and natural disaster risk reduction within the context of the case and similar cases with complex dynamics by suggesting approaches for planning for, implementing, and managing Urban GI, building resiliency capacities, and reducing vulnerabilities in both the social and ecological system of the urban structure.

Chapter 2

LITERATURE REVIEW

The second chapter focuses on the data collection, description, and analysis of the relevant literature to benefit the methodology of the research. By this integrative approach, literature is critiqued, synthesized, and narrowed down from broad different focuses into a classified analysis towards building a theoretical framework for this study; Figure 2. In this review, the main ideas based on given keywords, will be presented then, they will be interlinked to further over look relevant theories with sufficient methods to support the methodology of the research. The main focus of the literature is on Resiliency theory, Disaster risk reduction, and Green infrastructure. As well as relevant theories supporting the methods which are space syntax theory, graph theory and pro-environmental behavior, See figure 2.

Figure 2: Literature review process structure.

2.1 Data Collection, Description and Analysis

The literature overviewed a total of 455 references of secondary data resources that varied in type, including; archives, organizational reports and guidelines, governmental documents, institutional reports, articles from scientific journals, conference papers, and published books; Table 1. As the data collection period overlapped with the COVID-19 lockdown -January - June 2020- access to scholarly resources was primarily limited to online data reached during this period. The scholarly sources accessed were categorized according to the type of secondary data and topic/focus relevant to identified keywords, Table 1.

Table 1: Summary of the secondary data resources retrieved for the literature review – developed by the researcher.

Secondary Data Resources	Category	Reference		Focus	Period
	Books	Tönnies, 1887		Socio-Economy	1887
		Herman, 1992		Social – Human Sciences	1992
		Hillier & Hanson, 1984	Hillier & Hanson, 1989	Space syntax theory	1984 - 1989
		Smith K., 2001		Natural DRR- NDRR	2001
		Ritchie &Thomas, 2009		Sustainable urbanism	2009
		Dicken, 2011		Disaster and Recovery	2011
		Haggett & Chorley, 1969 Levin, S.A., 1999	Van Der Ryn & Cowen, 2007 Gunderson et al., 2012	Ecological sciences - geography	1969 -2012
	Scientific Journals	A.D. Basiago, 1996 Lam et al., 2017 Holling 1973,1986,1996 Angeler et al., 2014 Elmqvist et al., 2003 Ludwig et al., 1997 Gunderson., 2000 Scheffer & Carpenter, 2003 Dublin et al., 1990 Cardinale & Palmer, 2002 Adger, 2006 Timpane-Padgham et al., 2017 Beatley, 2012 Schulze &Mooney, 1993 Nystr &Folke, 2001 Jackson et al., 2001 Scheffer et al., 2001 McCay, B.J., 1981 Folke et al., 2004 Beechie et al., 2010 Wong & Jim., 2017 With et al., 1997 Taylor et al., 1993 Lefkovitch & Fahrig., 1985 Fahrig, L., 1988 Henein & Merriam, 1990 Wiens & Milne, 1989 Fuller et al., 2006 Urban & Keitt, 2001 Urban et al., 2009 Collinge & Forman, 1998	Smit & Wandel, 2006 Engle. 2011 Chapin et al., 2006 Scheffer & Carpenter, 2003 Brown &Westaway, 2011 Folke, 2003 Folke et al., 2004 Kates et al., 2006 Tilman et al., 2001 Scheffer et al., 2001 Steward et al., 2014 Wu, J & Wu, T., 2013 Nelson et al., 2007 Beechie et al., 2013 Hansen et al., 2003 Seavy et al., 2009 Tilman, D., 1997 Berkes & Folke, 2002 Vayda & McCay, 1975 Panzacchi et al., 2016 Banzhaf et al., 2014 Grimm et al., 2008 Merriam, G.,1984 Levin, S. A., 1974, 1976 Roff, D. A., 1974 Wiens, J. A., 1997 Drielsma et al., 2007 Fortuna et al 2008 Laliberté & St-Laurent, 2020 Bunn et al., 2000 Rodin, 201	Environmental – Ecological sciences – Biological sciences -Ecological Resilience - Landscape connectivity – graph theory- ecosystem health	1975 - 2020

		Meerow et al., 2016 Gunderson & Light, 2006 Walters 1986, 1997 Johnson et al., 1999 de Vries et al., 2003 Kinzig & Grove., 2001 Rapport., 1998 Mageau et al., 1995 Moss, M.R., 2000 Brussard et al., 1998 Sandström, U.F., 2002 van der Ryn & Cowan, 1996 Tilman, D., 1997 Bratton, S.P., 1997 Opdam et al., 2006 Kuo et al., 1998 St Leger, L., 2003 Lennon & Scott 2014 Kabisch et al., 2016 Andersson et al., 2014 Voskamp & Van de Ven, 2015 Heynen, N. 2006., Wolch et al., 2014 Newell et al., 2013 Casal-Campos et al., 2015 Pauleit et al., 2011 Shwartz et al., 2014 Cameron et al., 2012 Voigt et al., 2014 Carter & Fowler., 2008 Ramos-Gonzalez, 2014 Madureira & Andresen, 2014 Norton et al., 2015 McDonald et al., 2005 Amati & Taylor, 2010 Wolch et al., 2014 Byrne, J., 2012 Burgess et al., 1998	Maclean et al 2014 Westoby et al 1989 Maler, K.-G. 2000 Gunderson 1999 TDouglaet al 2007 Lackey, R. T., 1998 Costanza et al 1998 Massa, I., 1991 Grimm et al 2000 Takano et al 2002 Costanza, R., 1992 Turner, T., 1996 Lu, F., Li, Z., 2003 Rapport, D.J. 1995 Jongman &Pungetti 2004 Kuo, F. E., 2001 Pickett et al 2001 Madureira & Andresen 2013 Ahern, J. 2007 Kardan et al 2015 Maas et al 2009 Dunn, A. D. 2010 Pugh et al 2012 Berkooz, C. B. 2011 Wang & Banzhaf 2018 Van der Windt &Swart 2008 Hunter & Brown 2012 Williams et al 2014 De la Barrera et al 2016 Ignatieva et al 2011 Demuzere et al 2014 Liquete et al 2015 Koc et al 2016 Beauchamp & Adamowski 2013 Staddon et al 2018 Baptiste et al 2015 Stern et al 2016 OWENS, S. 2000	Landscape – Environmental sciences – environmental planning – management - policies - conservation – urban GI – ecosystem/human health – urban/landscape ecology	1989 - 2018
		Chelleri, 2012 Klein et al., 1998	Walker et al., 2009 Cutter, 1996	Geographical Sciences Human geography	1996 - 2012
		Tönnies, 1931 Tonnies & Loomis, 2002 MacQueen et al., 2001 Story et al., 2018 Sonn & Fisher., 1998 Oxfam, 2005 Buikstra et al., 2010 Kulig et al., 2005 Coleman, 1990 Knight et al., 2002 Kim & Kaplan, 2004 Kuo & Sullivan, 2001 Gatersleben et al, 2014 Kollmuss & Agyeman 2002 Thøgersen 2004 Thøgersen & Oland 2003	Kasarda & Janowitz, 1974 Malik, 2015 Williams et al., 2018 Max-Neef, 1991 Kimhi & Shamai, 2004 Cuthill et al., 2008 Eade, 1997 Feld & Basso, 1996 Prichard et al., 2010 Levin et al., 1998 Payne et al., 1998 Abercrombie et al., 2008 Nordlund & Garvill, 2002 Balundė et al., 2019 Steg et al., 2014 Milfont et al., 2006 Rajecki, 1982 Allen & Ferrand,1999 Diekmann & Franzen, 1999 Lehmann, 1999	Social – Human Sciences – Public health – human health – socioeconomics – pro-environmental behavior – human-environmental psychology	1931 - 2018

		Folke, 2006 Beigi, 2016 Adger, 2000 Jones et al., 2018 Barthel et al., 2005 Gunderson, 2010 Sapountzaki, 2007 Holling & Gunderson, 2002 Walker et al., 2004 Lebel et al., 2006 Troell et al., 2005 Walker &Salt, 2006 Holling, 2001 Gunderson & Holling, 2002 Mooney & Ehrlich, 1997 Berkes &Folke, 1998 Carpenter et al., 1999 Haase et al., 2017 Davidson-Hunt & Berkes, 2003 Wilkinson, C., 2011	Walker & Meyers 2004 Folke et al., 2010 Berkes et al., 2003 Adger et al., 2005 Janssen et al., 2006 Clauss-Ehlers & Lopez-Levi, 2002 Holling et al., 2002 Westley 2002 Fazey et al., 2007 Scheffer et al., 2002 Wallace &Wallace, 2008 Carpenter et al., 2008 Ernstson et al., 2013 Berkes et al., 2008 Folke et al., 1998 (a) Folke et al., 1998 (b) Lamson, C., 1986 Walker, 2012	Social-Ecological sciences - SES Resiliency SoSocialcological planning	1986 - 2018
		Toseroni et al., 2016 Mayunga, 2007 Cutter et al., 2008 Mayunga, 2013 Cohen et al., 2013 Mayer, 2019 Oktari et al., 2018 Coetzee et al., 2018 Haney, 2018 Kwok et al., 2018 Kontokosta & Malik, 2017 Sapirstein, 2006 Kimhi & Shamai, 2004 Breton, 2001 Moore et al., 2004 Saja et al., 2018 Yoon et al., 2016 Sharifi., 2016 Burton, 2015	Ostadtaghizadeh et al., 2015 Pfefferbaum et al., 2013 Joerin et al., 2012 (b) Mayunga, 2007 Ainuddin &Routray, 2012 Pandey, 2019 Osofsky, 2018 Hikichi et al., 2018 MacGillivray, 2018 Chuang et al., 2018 Summers et al 2014 Lalonde, 2006 Maguire & Hagan 2007 Pooley et al 2006 Heavyrunner &Marshall 2003 Alshehri et al 2015 Cutter et al 2008 Abenayake et al 1990	Social / Community / Human / cultural Resiliency – DRR Climate-relatedd NDRR	1990 - 2019
		Maruyama 2016 Sharifi & Yamagata 2018 Gallopín 2006 Klein et al 2003 Godschalk 2003 Romero-Lankao et al 2013 Burch & Robinson 2007 Nelson et al 2007 Cimellaro &Arcidiacono 2013 Liu et al 2018 Meyer 2018 Serfilippi & Ramnath 2018 Zou et al 2018 Bertilsson et al 2018 BOGARDI 2006 Enemark 2006 Aldunce et al 2015 Godschalk 2003	Bisri MBF 2011 Shaw & Team 2009 Parvin & Shaw 2011 Joerin et al 2012 (a) Prashar et al 2012 Cutter et al 2010 Hiete et al 2012 Aitsi-Selmi et al 2015 Sellberg et al 2018 Demiroz &Haase 2018 Cai et al 2018 Horney et al 2018 Zobel et al 2018 Moghadas et al 2019 Pelling 2003 Buckle et al 2000 Manyena 2006 Meerow et al 2016	Urban Resiliency – DRR – NDRR – Climate resilience	2000 - 2019
		Sharifi et al., 2017 CANNON et al 2002 Childers et al 2014 Ahern, J. 2011, 2013 Newton et al 2013 Wong, T.H.F. 2006 Bhaskar et al 2016	Folke et al 2002 Holling 1986 Yli-Pelkonen &Kohl 2005 Lehmann, S. 2010 Frantzeskaki et al 2017 Pakzad et al 2017 Ranjha, S. 2016	Sustainable urbanism - DRR resilience Sustainable, resilient planning – GI sustainability/resiliency	1986 - 2017

		A van Nes & Yamu 2017 Dawes & Ostwald 2013 Netto, V. M. 2016 Hillier & Leaman 1974 Hillier, 2007, 2016, 2005 Hillier et al 2012 Van Nes & López 2010 Ascensão et al 2003 Benedikt, M.L. 1979 Penn, A. 2020 Van der Hoeven & van Nes 2014	Ratti, C. 2004 Ascensão et al 2019 LEACH, E. 1978 Hillier et al 1976 Osman& Suliman 1994 Yamu et al 2021 Seamon, D 2003 Bafna, S. 2003 Batty, M. 2001 Turner et al 2001	Space syntax – urban sciences – architecture research – social/environmental sciences – urban morphology	1976 - 2019
	Conference papers - proceedings	Melkunaite & Guay, 2016		Urban Resiliency	2016
		Saja et al., 2018		Social Resiliency	2018
		Schroder et al., 2007 Dalton, N., 2001 Hillier & Lida, 2005 Hillier et al., 2007 Penn & Turner, 2001	Turner, 2001 Hillier 2001, 2005 Wang et al., 2007 Turner & Penn, 1999	Space syntax – urbanism – architecture	1999 - 2007
	Organizational reports, reviews	Un-Habitat 2018, 2020 Urban Resilience Hub Org.,2018	United Nations 2016 UNISDR 2003, 2008, 2020	Disaster risk reduction DRR	2003 - 2020
		UN-Habitat SRG, 2018	HUTTON – ICLR org 2001	Social Resilience	2001 – 2020
		UN. Singh, S 2018 OECD, 2018 VASTA, K. S.- UNISDR 2005	Urban Resilience Hub 2020 UN-Habitat, 2017	Urban Resilience	2005 - 2020
		United Nations, 2015 SDG's 2000, 2016	BCWWA 2010	Sustainable development	2000- 2016
		UN-General assembly 2000, 1989 NaHRSI – Summers et al., 2018 DAYTON-JOHNSON "OECD" 2004	ACCCRN 2020 C40 Cities, 2020	NDRR – Climate resilience	1989 - 2020
		WHO, 1948		Human health	1948
		The Conservation Fund, 2004 Cohen-Shacham et al., 2016	Natural England. 2009 Pakzad, P. 2019	GI – Urban resiliency	2004-2019
	Governmental documents	ICLEI, 2020	New Urban Agenda – HabitatIII 2020	Urban resiliency	2020
		Yokohama strategy, 1994 Paris Agreement, 2016 Pitt, M., 2008	Intergovernmental Panel on Climate Change 2014	NDRR – Climate resilience	1994 – 2016
		Hyogo declaration, 2005		DRR	2005
		Agenda for Humanity, WHS 2016		Humanity	2016
		EC, 2003		Human/Env Health	2003
		Hyogo Framework, 2010		Community Resiliency	2010
	Institutional reports,	Smit et al., 2001 Klineberg, 2002	Bazerman & Watkins, 2004	Climate Resilience	2001-2004
		Ospina & Heeks, 2016 Aguirre, 2006 Vale &Campanella, 2005	Marron Institute of Urban Management, 2018 Ostrom, E., 2005	Urban Resiliency	2005 -2018

		Scheiner & Willig, 2011 Perrings & Walker, 1995 Moran, E.F., 1990 Barlow, S., 2011	Berkes & Folke, 1998 Gunderson et al., 1995 Loreau et al., 2002	Ecological science – urban ecology	1990 - 2011
		Birch & Wachter, 2008	Sarté, S.B., 2010	Sustainable urbanism	2008- 2010
		Cole et al., 2017		GI	2017
		Asami et al., 2003 Lawrence, R., 1990 Batty, M. 2004 Cutini, 2010 Grajewski, T., 1992 Turner, A., 2008	Space syntax online training platform 2020 Alan Penn 2021 Klarqvist, B. 2015 Hillier et al. 1997 Penn et al., 1997	Space syntax – theory - urbanism	1990 - 2021
	Practitioner workbooks, guidelines, technical reports	Resilience Alliance, 2010		SSocialecological resilience	2010
		TEEB, 2010		Ecology - Socioeconomic	2010
		100 Resilient Cities 2013		Urban Resiliency	2013
		Courtney et al., 2008 Brenson-Lazan, 2003	Renschler et al "Peoples", 2010 Twigg, 2009	Social / Community resiliency	2003 – 2010
		Wyeth & Hunter, 2009		Sustainable planning	2009
		Elmqvist et al., 2016 Benedict & Bjornland, 2002a (EEA), 2011, 2017	Jaffe et al., 2009 Benedict & Bjornland 2002b Gallet, D. 2011	Urban green infrastructure – environmental protection	2002 – 2017
		Worpole & Knox, 2008		Social science - urbanism	2008
		Space Syntax Limited, 2004		Space syntax - urbanism	2004

The description and analysis of the literature helped develop an overall understanding of how the notion of resiliency developed in various disciplines over the years. As also stated by Alexander (2013) in Figure 3, the term resilience is used in different fields such as psychology, structural engineering, and management strategy, but in the social sciences, it is primarily discussed in the context of society and ecology. The concept of resilience first appeared in ecology-focused studies in the 1970s. However, in the field of planning, resilience came into discussion in the late 1980s as a response to the increasing effects of climate change in urban areas. Since then, the concept of resilience has been considered regarding existing and future risks that are threats to many cities. The literature reviewed hints that the primary aim of the resilience theory is to contribute to complex socioecological systems and their sustainable management, especially to climate change and natural disaster risk reduction (Meerow et al., 2016). Socio-ecological systems have also been examined as part of such studies, revealing how the complexity caused by the mutual relationship between humans and nature is linked to the negativities experienced. The socio-ecological approach reveals the necessity of resilience in order to cope with possible uncertainties in the future, as all systems are in a continuous change cycle with nonlinear ways (Rodin, 2014). In this context, both ecological systems and social systems were found to have important roles in determining the overall resilience of an urban location.

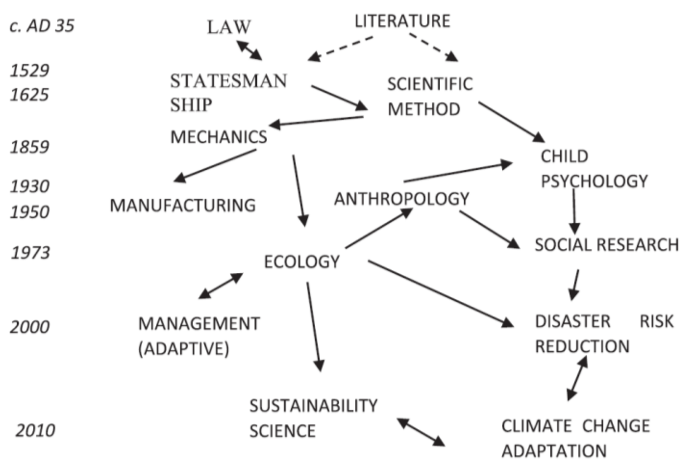


Figure 3: Schematic diagram of the evolution “resilience” (Alexander, 2013).

Regarding GI, many scholarly resources discuss the benefit and function of urban green spaces to the ecosystem and/or urban residents including environmental benefits; economic and aesthetic benefits; social and psychological benefits. However, regarding the assessment of GI in urban areas, there seems to be very little alternative to standard approaches. As more megacities emerge in the world with denser urban fabrics, elevated human impact, and more exclusive sociodemographic and ecosystem characteristics, there rises the need to adopt a needs-based approach for forecasting and supplying urban green spaces that can respond better to the requirements of urban populations, and urban practices in forecasting uncertainties in emergency situations. The research attempts to structure a methodology based on a need-based approach toward the assessment of GI in dense urban areas with unique sociodemographic characteristics to attain social-ecological resilience in times of uncertainty to benefit urban practices.

The following section provides the evidence obtained from the literature review to support the argument provided above which forms the basis of this research. But firstly, the study analysis the previous set of data resources, the study mainly focuses on its theoretical framework by firstly discussing the development of concepts and theories of Resiliency and Green infrastructure to highlight how the two concepts overlap. In this perspective, the sources within the previous table is further minimized into those theoretical and practical studies towards resiliency and GI. The researcher traces the emergence of several concepts and draws a timeline for each, highlighting urban resilience for urban communities, as well as highlighting how resilience emerged into the field of developing urban GI; As in the timeline conducted indicates that GI/Resilience concepts overlap within studies around early 2010's. The summery timeline is shown as following, figure 4;

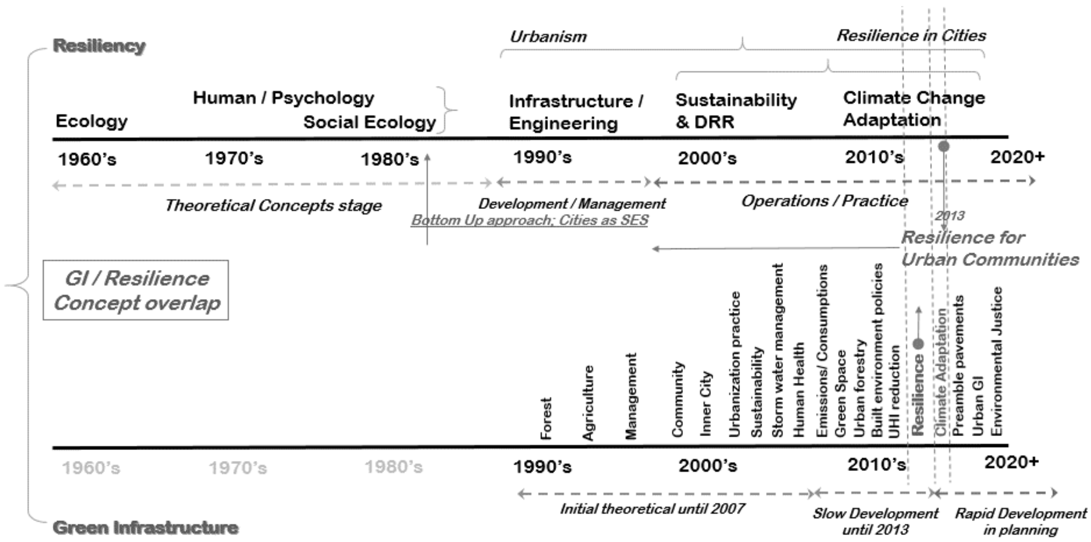


Figure 4: Summary timeline of emerging concepts of Resilience and GI as retrieved from literature and adapted by author.

2.2 Data Synthesis and Evaluation

Based on the evidence that resiliency has started being discussed in urban systems in the last three decades, the synthesis and evaluation process looks into the available data on this area, compares, overlaps/interlinks the findings, and then presents the results in section 2.5 of the thesis.

The first resiliency thinking derived from ecology as a reaction to the stability theory, where it is stated that ecological systems are not stable but undergo periodic phases of change. (Clements. 1916, Holling. 1970, Hiroshi. 2016).

Yet, other disciplines such as psychology, sociology, anthropology, mechanics, and management also stressed the significance of resiliency from the perspective of their discourse (Alexander, 2013, Folke, 2006, MackAskill & Guthrie, 2014) – see table 2. The concern for urban systems in the field of planning appears in scholarly sources starting from the 1990s (table 1). In the following part of the thesis, resiliency in urban systems will be the focus of the study.

Table 2: Timeline summary of the evolution of the resiliency theory. (Beigi, 2016) (Alexander, 2013) (Folke, 2006) – developed by the researcher.

1960 - 1970	**1971-1980**	**1987-1990**	**1991-2000**	**2001-2010**	**2011-Present**
Phase 1	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 6**
Generation	**Emergence**	**Expansion**	**Integration with infrastructure**	**Synthesis**	**Operationalization**
Exploring the stability theory and alternative stable states from the early 1900s.	**Resilience in Ecology "social-ecological systems" Emerges and develops**				**-**
	Resilience in Psychology "individuals" emerges and develops				**-**
	Resilience in Mechanics "materials" emerges and develops				**-**
	-			**Resilience in urban systems emerges**	

2.2.1 Resilience in Urban Systems

Human actions and urbanization-related distresses have led researchers to focus on natural disasters and the risks and aftershocks they create for societies. Resiliency thinking has developed as an approach toward the reduction and mitigation of natural disasters which are now almost unavoidable due to climate change. Natural disasters are happening more frequently, and if cities are not prepared to face them, the penalties will be causing impermanence and affect the quality of life of the citizens. As a result, the systems will not be able to operate where the non-resilient components of the system will suffer significant damage, whether these will be the vulnerable individuals in the social system, the degraded habitats in the ecological systems, or the poor infrastructures in the urban system, among others. (Wolfensohn 1996, Beigi, 2016, United Nations, 2016, Toseroni, et. Al 2016, World Bank 2016, UNISDR 2017, UNISDR 2016).

Most understandings of resiliency regarding the urban system contain attributes of "adaptability – coping with stress", "adaptive capacity - being prepared to stress/remain function through it", and "transformability - reorganizing/restructuring to a new function to remain functional after stress". (Walker. Et al. 2014, Smit et al. 2001, Holling,1973, Angeler et al 2014, Folke. Et al. 2010, Walker. Et al. 2009). Moreover, the literature emphasizes the significance of "learning" attribute to resiliency, which refers to gaining experience from stress and preparing for the next. (Godschalk, 2003, UN-Habitat, UNISDR 2009, ACCCRN – Asian Cities Climate Change Resilience Network).

Conceptually, urban resiliency depends on decreasing vulnerabilities and increasing the capacities of systems. Vulnerabilities refer to falling out of equilibrium or failing – being negatively affected by stress, whereas capacities refer to the assets/resources of systems – that can help them positively respond and remain functional through stress, both of which allow assessment and measurement of the system's resiliency. (Field, C et al. 2014, Folke, C. 2002, Gallopin, G. 2006, Romero et al. 2013, Burch, et al. 2007).

However, some studies consider the notion of robustness as the main resiliency attribute. Although robustness refers to the system's capacity to remain functional under stress (Fulker, 2006), in its general understanding, it resembles the concept of adaptive capacity used more commonly and frequently in the literature.

Regardless of how it is defined, resiliency for urban disaster risk reduction is considered to be a measurable ability of the urban system with all its components to continue living & tolerate disasters while adapting & transforming positively (UN-Habitat, Meerow, et al., 2016, Lam, et al. 2017, Dicken, 2011).

These capacities are similar to those within the definitions of resilience from a complex system's perspective; social-ecological resiliency (Folke, 2006, Berkes et al., 2003, Nelson. Et al., 2007). Here, urban systems from a resiliency perspective resemble social-ecological systems where the system's components are embedded within the urban system, showing integration as they depend on each other's resources to face stress and the changes that come along, table 3.

Table 3: Comparison between different concepts of resiliency, highlighting SES resiliency – developed on Fulker, 2006 by the researcher.

Type	Focus	Character	Context
Engineering resiliency	Recovery Consistency	Return time Efficiency	Single Equilibrium
Ecological or ecosystem resiliency	Robustness Persistence	Capability to withstand stressors and remain functioning	Multiple equilibria Stable landscape
Social-ecological resiliency (ex; **urban communities**)	Adaptive capacity Transformability Learning, Development	Capability to reorganize, sustain and develop	Integrated systems feedback

Similarly, the relationship between urban systems' components is essential to achieving resiliency; ecological systems' "adaptive components" exist within communities. Strong resilient communities / social system drives ecological and urban resilience capable of DRR. (Adger,2000, Klein, 2003, Smith K,2001, Alexander, 2013, Melkunaite, et al. 2016).

As resiliency is still rather a vague concept in urban planning studies, and the connectivity between theory and practice is yet to be braced, and there is also an emerging need to develop tools for urban practices to deal with emergency situations in various socio-demographic settings makes this topic worthy of further research (Chelleri, 2012, Melkunaite, et al. 2016, Sharifi, A., & Yamagata, Y., 2018, UN 3rd Conference, 2015). However, literature on the topic shows multiple frameworks and agendas that help measure resiliency in urban systems. However, these seem more standard approaches and do not necessarily take the need of urban residents into consideration. Yet, they offer different focuses as well as address resiliency from a single system's perspective;

- Frameworks & agenda's with a focus on the Urban system as a whole; UN-Habitat 2018, Organization for Economic Co-operation &Development, 2012, 100RC, Council for local governments for sustainability, 2015, Aitsi-Selmi, et al. 2015, SDG, 2016, Sharifi, A., & Yamagata, Y 2018,
- Frameworks & agendas focus on ecological systems &climate change mitigation; UNFCCC. 2016, C40 Cities, 2017, Ospina, A. V., & Heeks, R. 2016
- Frameworks & agendas focus on Social systems; Urban Resilience Hub, 2000, United Nations Int strategy for disaster reduction 2009, WHS, 2016, UN-ISDR, 2005 "Hyogo action framework", Mayunga JS, 2007 "RABIT- 2016."
- Frameworks & agendas with a focus on cities as social-ecological systems; Resilience Alliance, 2010, 2016

On the other hand, the "needs-based" approach can help forecast and supply urban green spaces which consider the socio-demographic and ecological characteristics of areas for which parks are needed, or where parks facilities will be upgraded to help in an emergency situation regarding DRR. A needs-based assessment is better able to respond to the requirements of urban populations, and consider not only the entire number of people within a given urban area, but importantly also accounts for their socio-demographic composition, their leisure, and recreation preferences, and those of various sub-groups within this population, and the type and number of facilities required to serve those needs Byrne & Sipe (2010). Due to the significance given to the GI and the necessities of the community in a needs-based approach, the following section will provide insights on social, and ecological resilience.

2.2.2 Resilience in Social, Ecological, and Social-ecological Systems

For social systems, there is a specific resiliency thinking similar to the broader resiliency concept yet, this approach focuses more on social components; communities and individuals. Firstly, two types of social formulation call for different approaches: Community is " part of the bigger mass society, sharing intangible characteristics and ties", and society is "a fabric of connected communities within a geographic location". (Tonnies, 1887, Tonnies et al. 2002, Kasarda et al. 1974, Cambridge English Dictionary, 2020, McQueen et al. 2001). Nevertheless, community resiliency is necessary to achieve the more extensive scope of social resiliency as it enhances human health and well-being. (Aldunce, et al. 2016, Pfefferbaum, et al. 2013, Yoon, et al.2016, Alshehri, et al. 2015, Mayer, 2019, Cuthill, 2008).

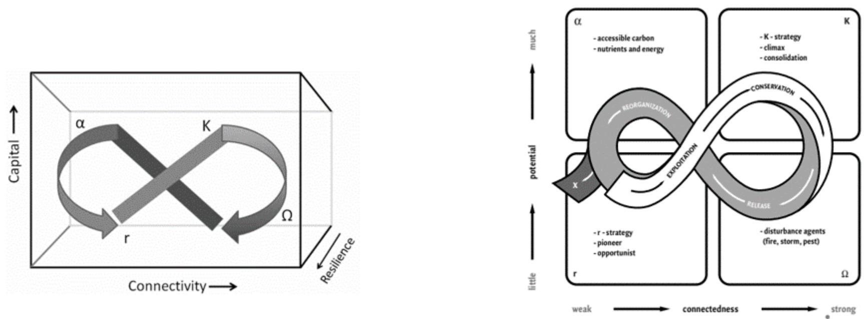
However, even though literature defines community and social resiliency separately, both apply to individuals, societies and communities within. For example, UNSDIR- DRR guide defines R mentions both community/society as an equally essential set of tariable. (UUNDER). Hence, Social, Community, and individual resiliency are crucial for DRR in terms of increasing adaptive capacities, decreasing vulnerabilities, learning, reorganizing, and fast positive recovery at all scales, where all systems components support each other creatively through stress. (Lazan, 2003, Hutton, 2001, Herman, 1991, Bazreman, et al. 2004, Sapirstein, 2006, Klineber. 2002, Vasta. 2005, Maguire & Hagan, 2007, Shamai, 2004, Adger, 2000, March et al., 2000, Berton, 2001, Aguirre, 2006, Kimhi et al., 2004, Pooley et al., 2006, Sapirstein, 2006, Cannon et al. 2002).

At the same time, it is acknowledged that with all the optimism about what community resiliency can offer as a guideline to DRR and recovery, efforts are still needed to clarify concepts of how to bridge theory to practice. Community resiliency is considered a forgotten dimension of DRR, lost, misguided, or minimized at best (Mayer, 2019, Sapirstein, 2006). Similarly, social resiliency as a concept lacks clear indicators within studies, as available indicators are minimal, different, and not strongly stated. (Maguire &Hagan 2007).

Within the scope of this study, it is essential to note that social resiliency cannot be achieved if communities within are not strongly bonded, which is referred to within literature as scattered societies due to cultural community diversity. This implies that if the communities are not strongly connected, their vulnerability to stressors will increase, decreasing their resiliency (Malik, 2015, Cutter et al., 2008).

For ecological systems, resiliency thinking focuses on adjusting positively to change and reorganizing into a new state due to adaptive cycles, figure 5 a; resiliency here implies constant change and positive transformation. (Pickett et al., 2014, Gunderson, 2010, Wallace et al., 2008) Similarly, complex social-ecological systems are characterized by their complexity and tendency to change in function and structure rather than return to prior ones. (Walker et al. 2006).

On the contrary, engineering resilience mainly focuses on returning to the pre-disaster state to leap backward (Skeat,1882). Resiliency thinking from ecological resilience perspective is more applicable in urban systems as it implies reorganizing and transforming more than the original engineering resiliency concepts that rely on only adapting and focusing on returning to the pre-event state – adaptive cycle, figure 5 b; Adaptive renewal cycle (Wu, 2013, Childers et al., 2014, Berkes et al., 2003, Adger, 2000, Hollings & Gunderson, 2002).



a: Adaptive cycle b: Adaptive renewal cycle

Figure 5: The adaptive & adaptive renewal cycle. (Adger 2000, Berkes, et al. 2003)

Having a domain of stability within ecological systems does not imply going back to equilibrium, as there is no equilibrium to go back to. Instead, systems undergo cycles of periodic, constant change. The stability domain implies maintaining stable function before positively transforming into a new domain of stability, whether by changing function or structure. (Walker, 1981, Westoby et al., 1989, Dublin et al., 1990, Hollings, 1973, Folke et al., 2004, Walker et al. 2006, Gunderson et al. 2002, 2010, Scheffer et al. 2001, Folke et al., 2004, Scheffer, et al. 2003). This applies from the perspective of urban ecology, where the urban system is considered integrated with its ecological and social components withholding adaptive capacities to shift from one functional domain to another in a cycle. (Vale et al, 2006, Redman, et al. 2000, Pickett, et al. 1997, Pickett, et al. 2014, Gunderson et al 2010), figure 6 a-b.

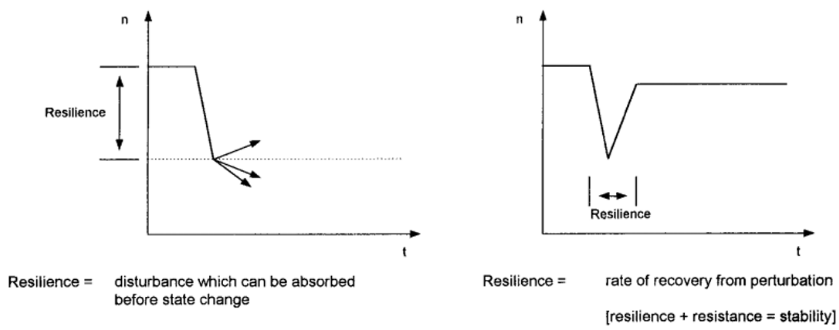


Figure 6: Two alternatives to ecological resilience as derived from Adger 2000.

Ecological & social systems demonstrate different abilities towards disasters, highlighting the main difference of resiliency concepts in both systems – disaster anticipation & learning "experience," which builds adaptive capacity. Sudden unanticipated disaster increases vulnerability in systems. (Hollings, 2001, Carpenter et al., 1999, Gunderson, 2010). The adaptive cycle here is a fundamental measurement of resiliency; they refer to the system's components' response. The processes that undergo each adaptive cycle are the main contributor to resiliency and differ from one system to another (Ostrom, 2005). Within a social system, the adaptive processes refer to technology, resources, capital, etc. (Adger 2006, Folke 2006, Nelson et al. 2007, Walker et al. 2004), whilst for an ecological system, they refer to evolution, functions, populations, etc. (Gunderson et al. 2002, Walker, et al. 2004, Scheiner, et al. 2011). However, both ecological and social resiliency share the same components of resistance and recovery over time (Tilman et al. 2002, Kates et al. 2006).

Yet, the view on the related literature showed that limited studies focus on both (Gunderson et al. 2002, Walker et al. 2004, Scheiner et al. 2011), which is essential to draw attention to, especially when studying an ecosystem that is inhibited by human communities. It is also important to note for the significance of this study that well-integrated attributes of resiliency help improve the restoration/rehabilitation practice of ecosystems & increase adaptive capacities towards climate change and natural disasters. From this perspective, resiliency characteristics are discussed in terms of recovery & resistance (Beechie et al., 2013, Hansen et al., 2003, Beatley, 2012, Seavy et al., 2009, Padgham et al., 2017). This is why this study will focus on the urban system as an integrated system with social/ecological components and focus on their adaptive processes and capacities when setting attributes for assessment and measurement of resiliency, leading this literature to overview resiliency thinking from social-ecological science studies, see table 4.

Within a social-ecological system, there is a relationship between the two systems. Even though, as stated by Norgaard (1994) and Adger (2000) that it is still not clear how social and ecological resiliency relates to each other, it is highly emphasized that they are linked as social systems which are embedded with ecological systems, and they both rely on each other's capacities to function and respond to stress.

Table 4: Adaptive capacity processes in complex systems. Derived from Pickett et al. 2014 and developed by the researcher.

Complex System	Adaptive Capacity Processes	Reference/s
Social	- Available technologies - Resources location and availability - Structures and institutions – decisions - Human capital /Individuals - Social capital and resources - Accessibility - Effective management / analyzing information - Public Response to stressors	Adger 2006 Folke 2006 Nelson et al., 2007 Walker et al., 2004
Ecological	- Evolution and variations - Flexibility of organisms - Rich functional groups of species - Population feedback - Resources - Spatial heterogeneity - Dividing up stressors - Connecting is scales	Gunderson et al., 2002 Walker et al., 2004 Scheiner et al., 2011

Non-resilient ecological systems increase human vulnerability – a more complicated response due to lack of capacity. While also, a resilient social system with resiliency capacities is crucial. (Gunderson, 2000, Gunderson, 2010, Pelling, 2006, Adger et al. 2005, Elmqvist et al. 2003, Adger in 2000, Westley, et al. 2002). It is also emphasized how human activities can cause stress to the ecological system, e.g., urbanization disturbs the ecological system (Gunderson et al., 1995). Drawing from the previous arguments, understanding the link between society/ecosystem in SES and how they interact to achieve resiliency in both is needed , figure 7. It is acknowledged that they rely on each other. It is also essential to understand that building the capacities within a social-ecological system is crucial to it being resilient. As mentioned in the literature, those capacities are the capacities to absorb disturbance, maintain process/structure to buffer, self-organize, learn and adapt (RA. 2002, Berkes et al. 2003, Berkes &Folke. 1998). (Folke et al.,1998a, Folke et al., 1998b).

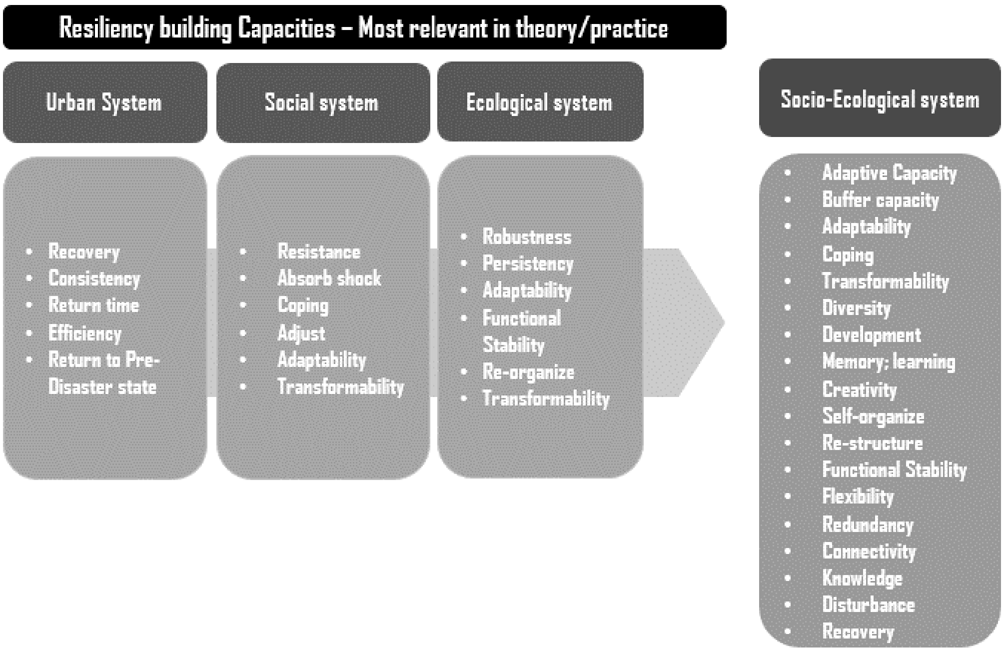


Figure 7: Summary of resiliency building capacities for urban systems, social systems, and ecological systems.

For this study, an overview of all resiliency for disaster risk reduction DRR was viewed with a focus on those specially tailored for urban areas as social-ecological systems. The review showed that DRR for resiliency building for complex systems frameworks is very limited, see figure 8. And were found as follows;

- Resilience alliance tried to bridge theory to practice in managing natural resources, taking into account both social/ecological influences at all scales incorporating continuous change and uncertainty levels to increase the system's resilience & capacity to adapt. (Resilience Alliance org. 2016). However, the RA approach to building the R framework for SES can't be generalized –context-sensitive. Compromises both slow/fast-changing components in SES, other models of assessing SES have the same limitation – context/time-sensitive (Resilience Alliance 2010, Chapin et al.., 2006).
- Others are focused on one specific disaster, such as NaHRSI, which focuses on DRR to natural hazards/ limited to flood resiliency. On the other hand, it introduces ecosystem services indicators focusing on multiple indicators; Built/Natural environment, governance, society, and risk. Introduced environmental indicators explored the relationship between ecosystem services & community (Abenayake et al., 2018), which is seen as promising and complementing.
- Most applicable and comprehensive information in the literature is an index with attributes for recovery from natural disasters & enhancing R; Natural/Built environment, social, governance addressing events, examining the risk of events (Summers et al.2019). Yet, it is very theoretical and does not provide bases for practical implementation strategies.

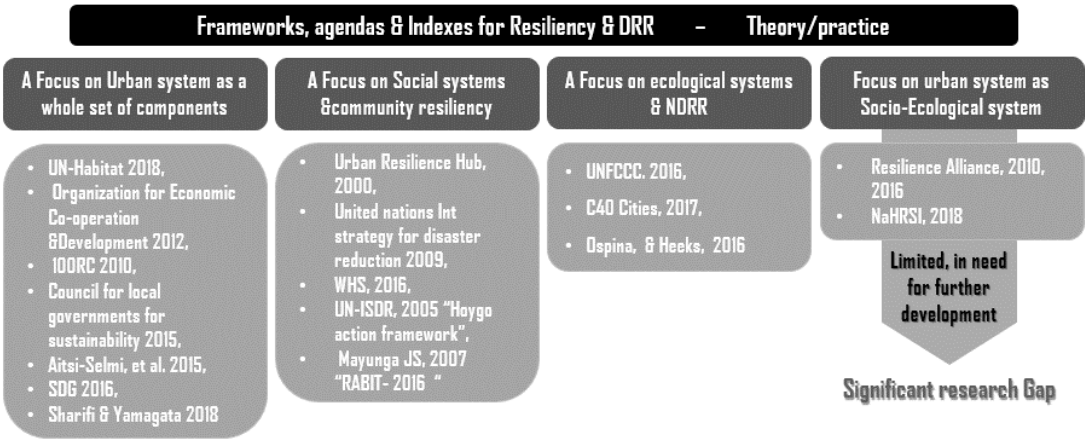


Figure 8: Summary on frameworks between theory / practice on resiliency and DRR.

After the overview of the social-ecological systems approach in resiliency, the next section focuses on resilience in green infrastructure.

2.2.3 Resilience in Green Infrastructure

Green infrastructure GI has been acknowledged within some studies as a contributor to building resiliency towards climate change and related disasters. GI is understood as a healthy relationship between communities, natural environment, and built environment (Rogers, Trust for public land National Urban Agenda 2006, Ahren, 2011, Lennon &Scott, 2014). However, as reviewed by Ahren (2013), most studies highlight the link between resiliency and GI from a single perspective, mainly from a storm water management approach.

All interpretations of GI convey a similar understanding of the concept; networks of connected natural or semi-natural areas that are planned and managed, implying maintaining ecological processes & contribute to human health/wellbeing by delivering ecosystem services benefits (Wang &Banzhaf 2018, Benedict & McMahoon 2002, the Conservation fund, 2004, Benedictt et al., 2006, Natural England Organization, 2009, Barlow in 2009, Davis, 2011, ECC - European Commission communication, 2013, Pazkad, 2019, Cohen-Schacham et al., 2016, Pakzad, 2019).

However, some definitions emphasize GI as a contributor to urban sustainability and resiliency; (Mell et al., 2009, Beauchamp &Adamowski, 2013, Staddon et al., 2017, Resilience shift, 2017, Tzoulas et al., 2007). For purposes of this study, GI was also reviewed from a social-ecological urban system's perspective, and relevant studies (Godschalk, 2003, Wilkinson, 2011, Koc et al., 2016) argue that GI increases urban resiliency characteristics in SES – by enhancing urban resilience capacities "diversity/redundancy/flexibility". It is also noted that GI is multi-functional; provides multiple functions, making it efficient, appealing, and cost-effective. Those benefits are referred to within literature as ecosystem services which are the benefits GI delivers to people, whether directly or indirectly (Sandstrom, 2002, Madureia & Andersen, 2013, Kabisch et al., 2016, Pazkad, 2019, MA, 2005, TEEB, 2010).

GI strategies/elements vary in scale, type, and context and are mentioned differently between theoretical studies and practical publications. However, and for this study, the following are the most relevant inner-city GI found from the reviewed literature, see table 5;

- Urban gardens. (Cameron et al., 2012, Hunter and Brown, 2012, Ranjha. 2016)
- Green roofs. (Carter and Fowler, 2008, Williams et al., 2014, Dagenais et al., 2016, Koc et al., 2016, Barlow, 2009, Staddon et al., 2017, Pakzad, 2019, Cole et al., 2017, Gallet, 2011)
- Green space. (Banzhaf et al., 2014, De la Barrera et al., 2016, Koc, et al., 2016, Pakzad, et al. 2017, Ranjha. 2016, Pakzad, 2019)
- Vertical greenery/green walls. (Koc, et al., 2016, Barlow, 2009, Pakzad, 2019)
- Tree canopy, street tree. (Koc, et al., 2016, Barlow, 2009, Staddon, et al 2017, Pakzad, 2019, Gallet 2011)

Other literature highlights other types of inner-city GI that can be important to this study such as; Residential gardens (Barlow, 2009, Pakzad, 2019), recreational areas (Barlow, 2009), permeable pavements (Staddon, et al 2017, Gallet 2011, Pakzad, 2019), terrestrial surfaces: Vegetated/Bare, Artificial/Natural. (Koc et al., 2016), sports fields, (Pakzad, 2019), community gardens (Cole et al., 2017) and urban farming (Pakzad, 2019).

Table 5: Summary of most common mentioned components/elements/features of GI. Developed by author.

GI Element	Context	Reference
Green Corridors Green belts Riparian corridors	Urban – Outer city	Van der Windt and Swart, 2008, Shwartz et al., 2014, Snäll et al., 2016, Panzacchi et al., 2016, Ranjha. 2016, Pakzan, 2019
Urban Gardens	Urban – Inner city	Cameron et al., 2012, Hunter and Brown, 2012, Ranjha. 2016
Urban Parks Public Parks	Urban - Outer city	Voigt et al., 2014, Barlow, 2009 Ranjha. 2016, Pakzad, 2019, Cole et all 2017
Green Roofs	Urban - Inner city	Carter and Fowler, 2008, Williams et al., 2014, Dagenais et al., 2016, Koc et al., 2016, Barlow, 2009, Staddon et al., 2017 Pakzad, 2019, Cole et all 2017, Gallet 2011
Urban Forest	Urban – Outer City	Pakzad, 2019
Green Spaces	Urban – Inner city	Banzhaf et al., 2014, De la Barrera et al., 2016, Koc, et al., 2016, Pakzad, et al. 2017, Ranjha. 2016, Pakzad, 2019
Tree Canopy/ Street tree	Urban – Inner city	Koc, et al., 2016, Barlow, 2009, Staddon, et al 2017, Pakzad, 2019, Gallet 2011
Vertical Greenery/ Green walls	Urban – Inner city	Koc, et al., 2016, Barlow, 2009, Pakzad, 2019
Residential garden	Urban – Inner city	Barlow, 2009, Pakzad, 2019
Recreational area	Urban – Inner city	Barlow, 2009
Natural Vegetated Surfaces	Urban – Inner-city – Outer City	Koc et al., 2016, Barlow, 2009
Preamble Pavements	Urban – Inner city	Staddon, et al 2017, Gallet 2011, Pakzad, 2019
Terrestrial Surfaces: Vegetated/Bare, Artificial/Natural	Urban – Inner city	Koc et al., 2016
Water bodies	Urban – Inner-city – Outer City	Koc, et al., 2016, Staddon, et al 2017
Swales	Urban – Inner-city – Outer City	Staddon et al. 2017, Ranjha. 2016
Rainwater harvesting units	Urban – Inner-city – Outer City	Staddon et al. 2017, Gallet 2011
Wetlands/ constructed wetlands	Urban – Inner city – Outer City	Staddon, et al 2017 Pakzad, 2019
Bio retention treatment systems	Urban – Outer City	Pakzad, 2019, Gallet 2011
Sport Fields	Urban – Inner city	Pakzad, 2019
Community Gardens	Urban – Inner city	Cole et al. l 2017
Urban farming	Urban – Inner city	Pakzad, 2019

As mentioned frequently in the literature, green spaces are considered as one of urban GI's most popular strategies (Banzhaf et al., 2014, De la Barrera et al., 2016, Koc, et al., 2016, Pakzad, et al. 2017, Ranjha. 2016, Pakzad, 2019). Worpole & Knox

(2008) emphasize the social value of GI with green spaces, Banzhaf et al. (2014), De la Barrera et al. (2016), EEA – European Environmental Agency (2017) highlight how green spaces are the places where humans physically interact with the ecosystem and receive its benefits. Similarly, Tzoulas et al. (2007), Takano et al. (2002), and De-vries et al. (2003) shed light on the promoting relationship that humans and ecosystems have within any urban area and emphasize how crucial it is for cities to overcome their growing challenges in maintaining their green spaces.

Reviewing GI from a human ecology perspective, it can be argued that the health of social and ecological systems showing resiliency as ecosystem health had been defined in terms of resiliency and self-organization (Rapport et al. 1998, Mageau et al. 1995, Lu et al. 2003, Costanza. 1992). At the same time, others define ecosystem health by the future potential for managing a resilient ecosystem (Brussard et al. 1998), and another from a perspective emphasizing how society values directly impact on healthy ecosystems, see figure 9 (Lackey in 1998). Similarly, it has been noted that healthy ecosystems/communities share integrated factors from several perspectives, such as policy and economy, and most importantly, socially and ecologically. Importance needs to be placed on the social/ecological systems in the urban system (Lu &Li. 2003, Grimm et al., 2000, Kinzing &Grove, 2001, Yli & Kohl, 2005).

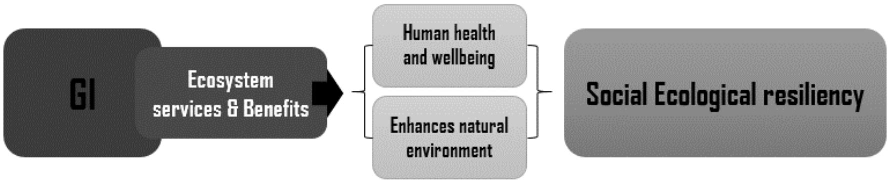


Figure 9: Illustrating the relationship between GI and Socio-ecological Resiliency.

However, the recognized link between GI and human wellbeing is affirmative, but the evidence is relatively weak (De-Vries et al. 2003, Takano et al. 2002). In this matter, numerous studies attempted to find the link between socio-economic conditions of communities & their well-being in terms of poverty & other social factors. Yet, no links to environmental factors were found in these studies (EC – Environment Conference. 2003).

When GI was first introduced in the late 1990s, it was an idea with a potential to benefit sustainability in practice. Since then, sustainable development has started adopting resiliency concepts. At the same time, GI is seen as an advance toward resiliency, climate change mitigation, disaster reduction, and disaster risk resiliency. Then it fits both sides of the equation (EEA,2011, Ignatieva et al., 2011, Demuzere et al., 2014, Cole et al. in 2017, Ramos et al., 2014, Demuzere et al., 2014, Wang &Banzhaf, 2018, UCCRTF, 2019 Urban Climate Change Resilience Trust Fund, Tzoulas, et al. l 2007, Norton, et al. 2015, Newton, et al. l 2013).

However, Pauleit et al. (2011) and Mazza et al. (2011) argue that even though there are efforts in putting theoretical and practical approaches toward GI, there is still a need to develop the most effective ones into implementation. It is also highlighted by Beauchamp &Adamowski (2013) that there is not sufficient literature addressing the practical, theoretical framework of an integrated GI to be bridged into planning. Existing frameworks truly focus on usually individual aspects of GI; as summarized in the following table;

Table 6: GI ecosystem services, related benefits & assessment indicators/attributes as retrieved from literature and developed by the author.

Associated Ecosystem Services Benefits	Ecosystem Services Categories	Possible Indicator/Attribute	References
Stormwater Management	**Regulating; Provisioning**	- Surface floods and stormwater runoff average - Condition of existing grey infrastructure - Water pollution levels - Quality and quantity of water levels - Stormwater harvesting techniques - Coasts of regular water management - Water storage and retention conditions. - Peak water runoff rate.	Jaffe et al., 2010 Voskamp, et al 2015 Casal, et al. 2015 Beauchamp &Adamowski, 2013 Gyurek, 2009 BCWWA, 2005 Hoang & Finner, 2016 Staddon et al,. 2017 Pakzad, et al. 2017

			Ranjha. 2016 Pazkad, 2019 Gallet 2011
Social Vulnerabilities Reduction	**Cultural**	- Human health and well-being conditions - Individuals living near green space - Crime rates - Place attachment - Social capital level - Aesthetics level - Economic status - Recreation opportunities - Property value near GS	Cutter, 1996 Kuo Sullivanan, 2001 Kardan et al., 2015 Douglas et al., 2007 Maas et al., 2011 Staddon et al., 2017 Pakzad et al., 2017 Pakzad et al., 2017 Ranjha. 2016Packardd, 2019 Cole et al. l 2017 Gallet 2011
Increased Accessibility to Green Spaces	**Cultural**	- Available green spaces - Estimate the population with no access to GreeSpacece - Quality and Quantity of Green spaces - Socio-economic status of the population (Park Poverty) - Community livability	Heynen, 2006 Wolch et al., 2014 Dunn, 2010 Hoang & Finner, 2016 Staddon et al., 2017 Pazkad, 2019 Gallet 2011
Urban Heat Island Effect Reduction	**Regulating**	- Toula	Tzoula et al., 2007 Koc et al., 2016 Staddon et al., 2017 Pakzad et al., 2017 Grimm et al., 2008 Pazkad, 2019 Gallet 2011
Improved Air Quality	**Regulating**	- Air pollution conditions - Particular matter - Traffic emissions - Traffic levels - Noise pollution level - Odor levels - Carbon removal and storage	Pugh et al., 2007 Hoang & Finner, 2016 Ranjha. 2016 Pazkad, 2019 Gallet 2011
Increased landscape Connectivity	**Supporting**	- Wildlife habitat physical connections in a specific area (Urban ecological matrix) - Ecological land-use patterns - Habitat wellbeing - Species	Kong et al., 2010 Colding, 2007 Ranjha. 2016 Weber et al., 2006 Gallet 2011
Increased Independence of Natural resources and Energy	**Supporting Regulating Provisioning**	- Water resource capital - Food ResourcCapitalal - Urban farming - Community Gardens - Building energy consumption levels - Building conditions that can withstand green roofs and green walls - Urban agriculture opportunities grey and greyand , red fields)	Hoang & Finner, 2016 Staddon et al., 2017 Pakzad et al., 2017 Ranjha. 2016 Grimm et al., 2008 Pazkad, 2019 Gallet 2011

GI is sometimes integrated within other infrastructures; Green-blue infrastructure (Pazkad in 2019, Ranjha. 2016, Pakzad et al., 2017, Beauchamp &Adamowski, 2013, Wong, 2006), and Green-Grey Infrastructure (Pakzad, 2019, Liquete, et al. 2015, Wang & Banzhaf, 2018). Those studies highlight that integrating GI into conventional non-resilient blue or grey infrastructure enhances their functionality cost-efficiently while simultaneously improving sustainable, resilient infrastructure planning and management. Staddon et al. (2017), Pitt (2008), Pazkad (2019), and Climathon

Initiative (2020) also highlight this notion, in addition to an emphasis on resiliency being built due to community engagement with GI. As there is clear evidence in the literature of how social system becomes vulnerable when ecological systems are compromised, thus, it is vital to reduce the ecosystem loss as it harms the population & increase the risk of climate change and natural disasters. (Gunderson et al. 2010, Folke, et al. 2004, Walker &Salt, 2012, Beechie, et al. 2010).

However, planning for, managing, and implementing GI withholds many challenges and barriers. The most commonly agreed ones from literature are planning, institutional, technological, environmental, and perceptual barriers (Elmqvist et al. 2016, Resilient Shift, 2017, Staddon et al. 2017, Baptiste et al. 2015, Wong &Jim 2017, Bhaskar. 2016) as stated in Table 7. It is noted here that local governments, stakeholders, and community members need to be aware and engaged with GI-oriented approaches for successful implementation in urban practices. Complementing this note and drawing on the critical relationship between GI and resilient urban planning; (Ranjha, 2016 and Pazkad 2019) agree that GI is very context-sensitive, but when appropriately integrated, it enhances resiliency.

Similar discussions about challenges towards integrating social-ecological systems into a city in urban planning and managing land use argue that it is only challenging due to the lack of sufficient theories to support it. However, from the reviewed literature, it is observed that methods are rather complex, emphasizing the enhancement of networks of green spaces in and around urban areas as an approach (Moss. 2000, Massa.1991, Sandstrom, 2002, Turner. 1996).

From this perspective, critical planning and maintenance of networks of urban GI can guide positively growing urban systems such as the natural, economic, and social systems. Moreover, preventing fragmentation due to urbanization is also important

(Vander & Cowan.1996, Bratton.1997, Opdam et al. 2006, Jongman & Pungetti, 2004). Hence, this study will further look into ecosystem connectivity theories and mapping approaches to construct the methodology of research.

Table 7: Urban GI Challenges, Barriers. Developed by the author.

	GI Challenges/Barriers				
Type	**Institutional**	**Technological**	**Perceptual**	**Environmental**	**Planning**
Detail	Political support concerns	Maintenance concerns	Individual /SociaConcerns ns	Design/planning	Design / planning concerns
Example	Politicians do not support GI Lack of collaborative actions to support GI Discontinuity in implementing GI projects Non-sufficient coordination between government and organizations Lack of GI policies	Lack of maintenance Increased costs of maintenance Reduced effectiveness of GI due to non-effective maintenance Poor knowledge and experience Irrigation system difficulties Unavailable new engineering practices Buildings subjected to increased loads in case of green roofs	Increased crime Budget concerns GI solutions could cost more Lack of education and awareness – Social acceptance New responsibilities Lack of participation and involvement in GI projects	Storm water infiltration into the underground water happens when green infrastructure lies above thin aquifers. Expand borne diseases as GI provides habitat for insects and mosquitoes. Accumulated Pollutants Increased debris Wildfire risk Increased Allergens Water-related risks Health Issues	Defining with applicable context-sensitive design Operational standards Insufficient guidance Socio-economic related concerns – non-inclusive planning due to socio-economic distribution of contexts Poor neighborhoods and communities Non-sufficient financing for GI projects Non-Sufficient capacity for GI
Reference	Resilient shift 2017 Staddon et al., 2017	Resilient shift 2017 Staddon et al., 2017	Resilient shift 2017 Staddon et al., 2017 Baptiste et al., 2015	Bhaskar. 2016 Wong &Jim, 2017	Resilient shift 2017 Staddon et al., 2017 Elmqvist et al., 2016

In concluding this vital part of the literature review, some cities develop their GI through research with the assistance of governmental agencies, and organizations. However, despite the efforts, there are challenges in developing tactical strategies to benefit urban practices toward the integration of GI within urban areas (Figure 10).

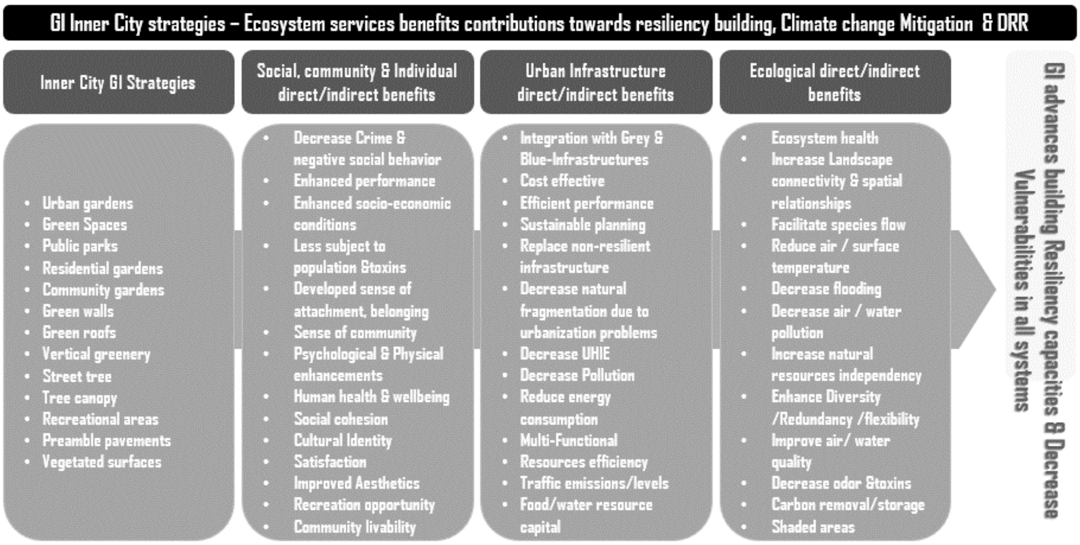


Figure 10: Summary of resiliency regarding GI Inner city strategies and GI advances.

The existing theory and knowledge which is reflected in urban practices are vague and not sufficient, especially due to standard and single perspective GI approaches e.g., storm water management only, and is acknowledged as a research gap (Berkooz in 2011, Mell in 2016, Meerow et al. 2016, Newell et al. 2013, Ranjha, 2016, Pazkad in 2019). Similarly, evidence on how GI contributes to the enhancement of human communities for creating more sustainable/resilient urban systems is rather weak in academic research and practitioners' publications and reports (Frantzeskaki et al., 2017, Haase et al., 2017).

As noted from the reviewed literature and highlighted by Staddon et al. (2017), building social-ecological resiliency is very challenging, as urban systems are very context-sensitive. Identical communities might have a similar infrastructure but require different resiliency measures. Resiliency thinking must take into consideration Inclusive appropriate approaches. Linking GI to create resiliency is challenging and the link between theory and practice needs further reinforcement.

2.3 The Summary Of The Literature Review

Resiliency thinking has become crucial as we live in a world of unpredictable change. Non-resilient components of the urban system withholding low resiliency capacities increase its vulnerability to facing stress. From the perspective of this study and the reviewed literature, it is important to consider;

- Conventional infrastructures, are acknowledged to be non-resilient. Integrating or replacing them with GI improves efficiency and promotes resilient infrastructure planning and management.
- Due to urbanization's degraded unconnected natural environment, fragmented patches of nature within the urban context lower its connectivity, decreasing its efficiency in delivering ecosystem benefits and services to the communities within. Compromised ecological systems negatively affect social resiliency. Both systems rely on each other's resources and capacities to thrive through stress.
- Communities with weak engagement with their natural resources lack a strong relationship with the natural environment and are unhealthy, non-resilient, and vulnerable to natural disasters. As well as diversity, diversity in cultures within communities scatters society, Hence increasing social vulnerabilities.

Strong relationships between the components of the urban system, the natural environment, and individuals are essential to achieving resiliency. Urban resiliency hence enables DRR. However, the various definitions of resiliency make the concept vague and unclear, creating disconnection in the link between theory and practice. This is acknowledged in the literature as a gap that must be filled.

To prove the existence of this gap, multiple resources between theoretical studies and practitioners' publications have been reviewed, concluding with the following;

- Resiliency derives from several branches of theoretical studies; ecology, social ecology, and engineering. Each field sets different characteristics and focuses on resiliency, resulting in various definitions.
- Similarly, there are multiple frameworks to assess resiliency practically. However, each framework approaches resiliency from a different perspective. For example, while most frameworks divide their focus between urban, ecological, or social resiliency approaches, minimal frameworks focus on social-ecological resiliency and look at urban contexts as complex SES. Moreover, the first framework by the Resilience Alliance organization is acknowledged to be very limited, context-oriented, and cannot be generalized. Another notable framework by NaHRSI focuses on disaster resiliency for SES. However, it is concentrated in a specific climate-related disaster; flooding.
- On the other hand, reviewing literature from the theoretical studies showed that there is also some notable effort into building a comprehensive index towards approaching resiliency from an SES perspective by Summers et al. (2019). However, it is very theoretical and does not provide the basis for practical tools for implementation.

This underlines the significance of this study as it overlooks the urban system from a social-ecological perspective because, as concluded from the literature, resiliency thinking from a social-ecological systems perspective is seen to be more applicable to urban tactical scenarios. After all, it implies re-organizing / transforming the original engineering resiliency concepts that rely on only adapting and focusing on returning to the pre-stress state. Addressing the gap, the study intends to develop a comprehensive framework with a theoretical base and practical tools for social-ecological urban resiliency assessment – adopting knowledge in the theory to practice. Approaching the resiliency of urban areas from their social and ecological systems towards DRR is critical and seen as a field needing research and development. Evidence towards this notion has been found within the literature review process as follows;

- It is acknowledged that with all the optimism of what community resiliency can offer as a guideline to DRR and recovery, efforts are still needed to clarify concepts of how to bridge theory to practice as it is considered a forgotten dimension of DRR, lost, misguided, or minimized at best. Similarly, social resiliency as a concept lacks clear indicators within studies, as available indicators are minimal, different, and not strongly stated.
- Multiple frameworks/indexes with different domains which measure community resiliency precisely including the "Social" domain. In contrast, those with both "Social and Environmental/Ecological domains are very limited".
- From the scientific studies, it has been noted that there are two main approaches to social resiliency. The first approach comes from ecology/social-ecological sciences. The second derives from social sciences. The first approach is fundamental, yet more research is still needed.
- Measuring social resiliency is challenging due to the vast properties of measurement "cost/time/assets/level of change/scale of vulnerabilities". Moreover, most available frameworks lack flexibility – flexibility to context/society, which is why there is a significant need to build a proper framework to develop an inclusive way to measure social resiliency to disasters that is flexible, adjustable, and easily generalized.

- It is yet not clear how social and ecological resiliency are related even though studies highly emphasize how they are linked. The relationship between the two has been emphasized to be complex and challenging because they have a complex non-linear relationship. Natural disasters within ecological systems disturb the human system and cannot be easily predicted by urban practices. Non-resilient ecological systems increase human vulnerability – harder response due to lack of capacities. However, a resilient social system with resilience capacities is crucial. While on the other hand, within SES, human activity can be a cause of stress, e.g.urbanization. The ecological system must respond to disturbance "change in resources" – S.E relies on each other. Drawing from those arguments, researchers must understand the link between society/ecosystem in SES and how they interact with each other to achieve R within an urban context.

Global attention has been raised towards finding strategies and solutions for disaster mitigation, reduction, and prevention. Drawing from Green Infrastructure-related studies, publications, and international guidelines, It's been noted that;

- GI holds potential in enhanced and advanced urban resiliency. It is crucial for climate change mitigation and natural disaster prevention, DRR. Increased GI contributes to successful resiliency planning &management strategies. However, most studies focus on the link between resiliency characteristics and GI from a single perspective even though it is a multi-functional infrastructure that delivers multiple benefits – making it very appealing for building resiliency. Yet, it is mainly approached towards one specific function, usually from a stormwater management approach. This highlights the significance of this study aiming at implementing urban GI as an integrated connected network to achieve most of its benefits.

- Similarly, there is not sufficient literature to present an adequate theoretical framework of an integrated GI to be bridged into engineering sustainable, resilient planning. Existing frameworks truly focus on individual aspects of GI, such as human health, landscape, and water management.
- There is no single definition of GI in theory/practice. However, all descriptions resemble a similar understanding of the concept; networks of connected natural or semi-natural areas are planned and managed, implying maintaining ecological processes &contribute to human health/wellbeing by delivering ecosystem services benefits. However, some definitions emphasize GI as a contributor to urban sustainability and resiliency, which highlights the significance of providing proof of resiliency building and DRR through GI by drawing the connection between all GI contributions towards resiliency building in all components of the urban system, see figure 11.

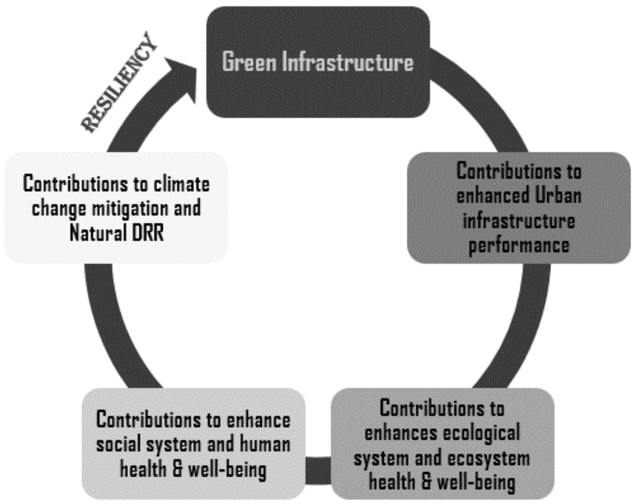


Figure 11: GI contributions towards resiliency. (Developed by the author)

- GI engages both social and ecological systems and integrates them. Enhancing GI can strengthen the relationship between individuals and the natural environment. GI delivers multiple benefits to communities within an urban context. Individuals' engagement with nature improves their health and wellbeing. At the same time, ecosystems need solid and resilient communities to thrive. Both systems rely on each other. At the same time, GI is acknowledged as a promoter of urban resiliency, especially when replacing/or integrating with conventional non-resilient grey and blue infrastructures. Hence, GI enhances social-ecological urban resiliency and is crucial for climate change mitigation and natural disaster risk prevention and reduction.

- Within the literature review, we can highlight various arguments about Urban GI's contributions to human health. Very few studies focus on that concept from the scope of building resiliency instead complementing human and ecosystem wellbeing. Some highlight GI's effect on natural DRR – Disaster risk reduction- while others discuss the vulnerabilities it may help overcome, especially in the scope of climate change and degradation of ecosystems. Some non-scientific publications for practicing this issue also deal with the concepts of GI.

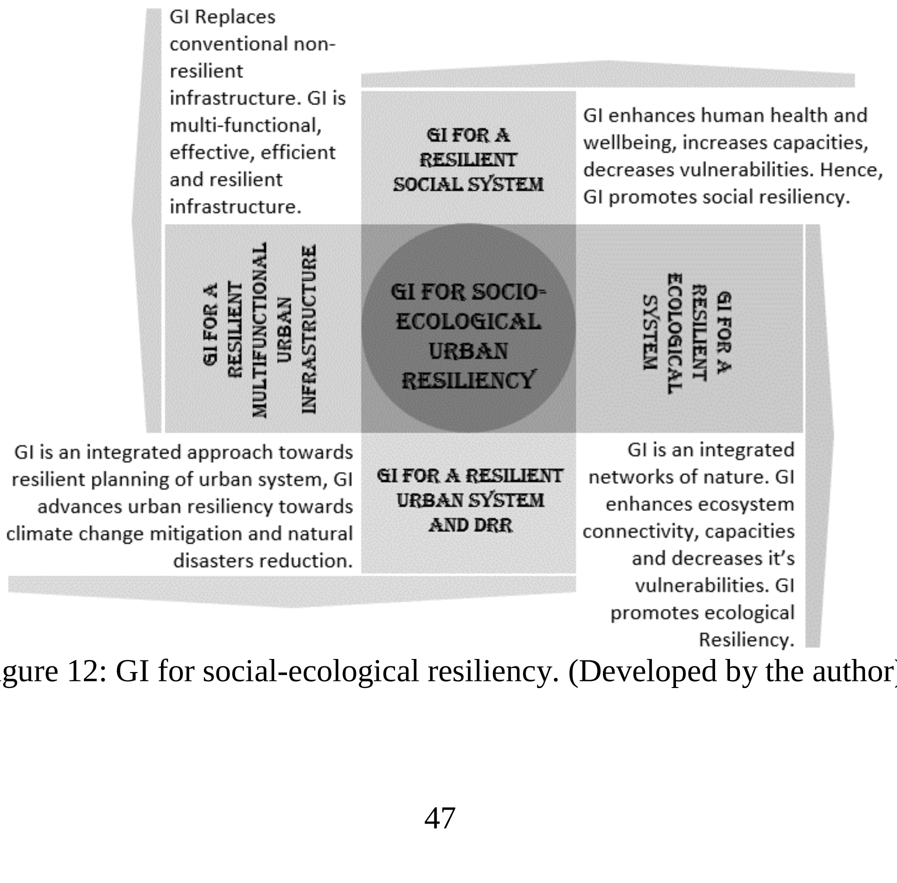


Figure 12: GI for social-ecological resiliency. (Developed by the author)

- GI within theory and practice is focused on from a single functional perspective. There is not any comprehensive planning or management approaches for multiple GI benefits as an overall multi-functional network integrated within urban contexts. GI is considered as infrastructure and is acknowledged to be more efficient than traditional infrastructure. However, planning for urban GI on a large scale is still limited and faces many barriers and challenges for actual implementation. The most acknowledged barriers that need attention are; Planning, institutional organization, perceptual, technological, and environmental issues.
- Some cities expand their GI through research, governmental agencies, and organizations. Despite the struggles, there are challenges in developing research, strategies, and policies for integrating GI within urban areas. What exists is vague and insufficient, especially since traditional planning only approached GI from a single perspective, e.g., stormwater management. This is acknowledged as a research gap. Even the GI is multi-functional & offers excellent benefits, and this has been recognized, proof of GI being planned and used for specific functions and help has been noticed within the literature. Particular studies with combined functions and benefits for GI being used within the scope of this study, however are limited, and are as follows;
    - GI for enhancement of human health/wellbeing as well as socio-economy – decreasing social vulnerabilities.
    - GI for regulating and managing stormwater and floods, enhancing grey-infrastructure conditions.
    - GI for increasing human/ecosystem interaction – enhancing human/ecosystem health – climate change mitigation & NDRR.

- GI for resource diversity, water/food independence, decrease energy consumption and building human/ecosystem resiliency capacities.

- Planning for GI is very context-sensitive towards many issues such as social acceptance and willingness to be engaged, local planning and management policies, whether by the government or local stakeholders and non-profit organizations, as well as the nature of the area where specific GI strategies might be suited better than others in terms of original greenery present, and landscape connectivity conditions.
- As for GI strategies, elements or features, however, are mentioned within the literature. Literature has acknowledged that when GI is adequately integrated, it highly enhances resiliency. In this matter, there had been a diverse variation between their scale, type, and context. For this study, inner city urban GI had been filtered through the studies found and are as follows; Urban gardens, Green corridors/belts, Urban parks, Green walls/roofs, Green spaces, and street trees. However, there had been some other less popular features of urban GI which withhold great potential for inner-city context implementation that engages community members with GI, which are; community gardens and residential gardens. Preamble pavements, Artificial, and natural surfaces are some features that are highly cost-effective, efficient, and relevant.
- Healthy ecosystems are characterized by diversity. Diversity in ecosystems increases their abilities to resist stressors due to their diverse resources, which their communities can use efficiently to cope, maintain function, and re-organize. There is a clear link between a healthy ecosystem/healthy human system and GI. However, the recognized link between GI and human wellbeing is affirmative, but the evidence is relatively weak. In this matter, numerous studies attempted to

establish the connection between socio-economic conditions of communities & their well-being in terms of poverty & other social factors. Yet, there were no links to environmental factors within these studies.

- Individuals' performance is enhanced when they are part of a community living close to green spaces. – social economy perspective. Psychology. becoming relaxed, active, subjected to fewer toxins &pollutants, develope an increased sense of attachment to their urban context and their communities, & generate an enhanced sense of community. However, on the other hand, increased open green spaces can contribute to negative social behaviors "crime" especially when segregated- which can make them hard to manage, which is a point worth considering when planning for GI, especially within residential areas.
- Evidence on how GI contributes to enhancing conditions of urban systems with their human communities and contributes to sustainability/resiliency found between academic research and practitioners' publications and reports are very weak.
- Building social-ecological resiliency is very challenging, as urban systems are very context-sensitive, and identical communities might have a similar infrastructure but yet require different resiliency measures. Resiliency thinking must take into consideration two main strategies; Inclusive/Appropriate resilience strategies, which is Challenging - Therefore, the linkage of GI to resiliency has not been the subject of focus in research and therefore not reflected to practice.

From this perspective, this study aims at developing a theoretically based framework that contributes to integrating urban GI with a practical assessment and implementation tool toward achieving social-ecological urban resiliency that enables DRR through the human-ecosystem spatial networks of the urban communities.

2.4 The Theoretical Framework of the Research

The study focuses on both social and ecological systems within the urban context. As such, relevant theories are approached toward choosing methods for measuring and implementing GI properly are as follows for each system;

Firstly, for the <u>social system</u>, there is a need to examine the urban context for networks of spatial patterns such as where people move, where they connect and centralize, and where they connect. This is highly important because the GI delivers ecosystem services and benefits that enhance human health and wellbeing, consequently improving the individual, community, and social resiliency capacities. Knowing the spatial patterns of their movement, flow, and centralization helps choose where to locate GI for direct social engagement. In addition, it will further help know which GI strategies and features are best suited for the specific location within the urban context.

Doing this by the traditional methods such as site observation is very time-consuming and difficult, especially within large scale dense urban contexts. For this reason, the study investigated space syntax theory and its methods as tools for mapping out the urban context from a human perspective. Noting from literature about space syntax theory;

- Relations between people & settlements are defined by architectural/urban space. In this matter, space syntax analysis, either architectural layouts "inside buildings", or urban areas and street networks, thus it grew popular in the field of architecture, urban planning, and design. (Cutini et al., 2010, Hiller and Hanson, 1989, Dawes &Ostwald. 2013)
- Space syntax presents a group of theory-based quantitative, mathematical and graphical techniques that analyzes urban forms with their social patterns, provides

a visual representation of space, and explore spatial layouts/phenomena. It identifies where people move, how they adapt, and develop & talks about the spatial form. (Netto, 2016, UCL, 2010, Spacesyntax.net, 2021, Batty. 2004, Hiller, 2007, Osman &Suliman. 1994, Hiller & Hanson, 1984, Hanson. 1998, Hiller. 1999, 2007, 2016, Spacesyntax.com. 2021, Yamu et al. 2021).

- The space syntax theory sets tools used to read, describe and compare the patterns of buildings and street networks to understand the social norms embedded within the built environment. It is acknowledged to be a method for operationally analyzing the relations between the built environment and the people inhabiting it, with an emphasis on its capability of measuring cultural relations within urban settlements (Hiller and Hanson, 1989, Yamu et al. 2021, Hiller. 1999, 2016). In contrast, it has been mentioned that the space syntax theories and methods are still being investigated and criticized for reasons as being inadequate to explore social patterns as an actual projection on their own as they can be culture-based (Lawrence. 1990, Leach 1987). Approaching this concern, the study explores models of pro-environmental behavior, where related literature explain how they are essential in assessing human-environmental psycology (Steg & Vlek, Kollmuss, &Agyeman, 2002). Moreover, visualizing human spatial patterns through space syntax methods alone does not give a clear measurement/assessment of factors based on cultural norms or individual values and beliefs, which are factors that are very context-sensitive and differ from one individual to another, community to another, mainly where communities are scattered within one social system for many reasons such as different educational levels, cultural backgrounds, or even socioeconomic status. This brings the importance of evaluating the social system from a pro-environmental behavior perspective. Notes from the literature on this matter are as follows;

- Pro-environmental behavior, based on human-environmental psychology is crucial towards resiliency and climate change. This is why there has been a focus on the literature to identify its motivations and barriers to minimize the negative impact of people on nature and highlight strategies that influence it. However, the latest models for pro-environmental behavior acknowledge that there is always a gap between the concern and the action, which is why it is significant to assess local communities within any urban context for case-sensitive accurate data. (Kollmuss, &Agyeman, 2002, Balundė et. Al. 2019, Stern et al., 2016, Steg, et. Al. 2014).
- Assessing the local communities within any urban context through understanding their relationship to the environment is essential for the study as it will give a clear evaluation of their motivations and barriers towards engaging a people-oriented GI for it to succeed positively as it highly relies on their acceptance, awareness, and participation at all scales "individual, community, society". (Nordlund and Garvill, 2002, Balundė et al., 2019, Grun. 2009, Milfont et al. 2006)
- Pro-environmental behavior has been developed through several models, which are almost always linear. The latest models show multi-dimensional ways of interesting an individual's behavior towards the environment. However, the most commonly used are the traditional linear models, though somehow criticized, which are most celebrated as it gives a clear idea of the progression that leads towards positive behavior simply. (Owens, 2000, Kollmuss, &Agyeman, 2002, Rajecki in 1982). To this end the study uses pro-environmental behavior model based on linear theoretical models, shown next in figure 13;

Figure 13: Pro-environmental behavior progression simple model. As adapted from literature by Burgess et al. (1998). Developed by the researcher.

Secondly, for the <u>ecological system</u>, there is a need to examine the natural environment in terms of integration, connectivity patchiness, and fragmentation. In this matter, the study reviewed graph based theories for landscape connectivity and its practical tools for visualizing ecosystem spatial patterns. Notes from the literature on the graph theory are as follows;

- landscape connectivity is the functional relationship between patches of nature in which organisms move, showing response to landscape structure – how nature facilitates spatial patterns. In other words, landscape connectivity shows function "response/movement" and structure "patches of landscape". **(**Levin 1974-6, Roff 1974, Marriam, 1984).
- Landscape connectivity is a measurement of the extent that allow species flow within the natural landscapes. The loss and fragmentation of natural landscapes thus threaten this process. This became the primary concern when examining population dynamics and the effect of the spatial structure on them. (With et al., 1997, Taylor, 1993, Rudnick et al. 2012, Tischendorf & Fahrig 2000), Lefkovith in 1985, Fahrig in 1988-90, Colling & Forman 1998, With et al. 1997).
- From a human perspective, even though they have the means to navigate fragments of nature easily, other species can not. Here, human activities consistent with urbanization increase patchiness, ecosystem vulnerabilities – decreased capacity to remain functional increases risks of natural disasters, e.g., climate change,

pollution, and species extinction-. This requires efforts to be avoided – approaches for recovering and conserving landscapes. Thus, visualizing connectivity and setting up methods for strengthening the connection is critical Resiliency. (Laliberté, & St-Laurent. 2020, Urban & Keitt. 2000, Rudnick et al. 2012)

- As landscape connectivity became a significant priority within emerging conservation and management efforts, many studies focused on modeling how functionally species respond to their landscape in network analysis – or functional connectivity- based on graph theory. Landscape connectivity models based on the graph theory are popular due to their influential representation of spatial patterns, which are commonly used in the analysis of the given land use. (Urban &Keitt, 2001, Urban et.al. 2009, Galphern et. Al. 2010, Laliberté, & St-Laurent, 2020)

Despite all the notable attempts to theoretically study and assess resiliency in all systems, the literature review proved that there is a lack of fundamental theoretical frameworks on tools/approaches that can be utilized to assess social-ecological urban resiliency from an urban greening – GI-oriented perspective. Although crucial, all the assessment frameworks approaching resiliency in urban areas as a social-ecological system towards DRR are found very limited and are seen as a field needing further research.

To conclude the critical literature review, the study proposes the following theoretical - methodological framework to bridge GI-oriented resiliency building within the social-ecological urban system's perspective into practice using modern, up-to-date / theory based methods and tools for assessment and implementation. The results may prove beneficial to propose appropriate building theory based strategies and urban planning practices towards resiliency and DRR. Shown next in figure 14;

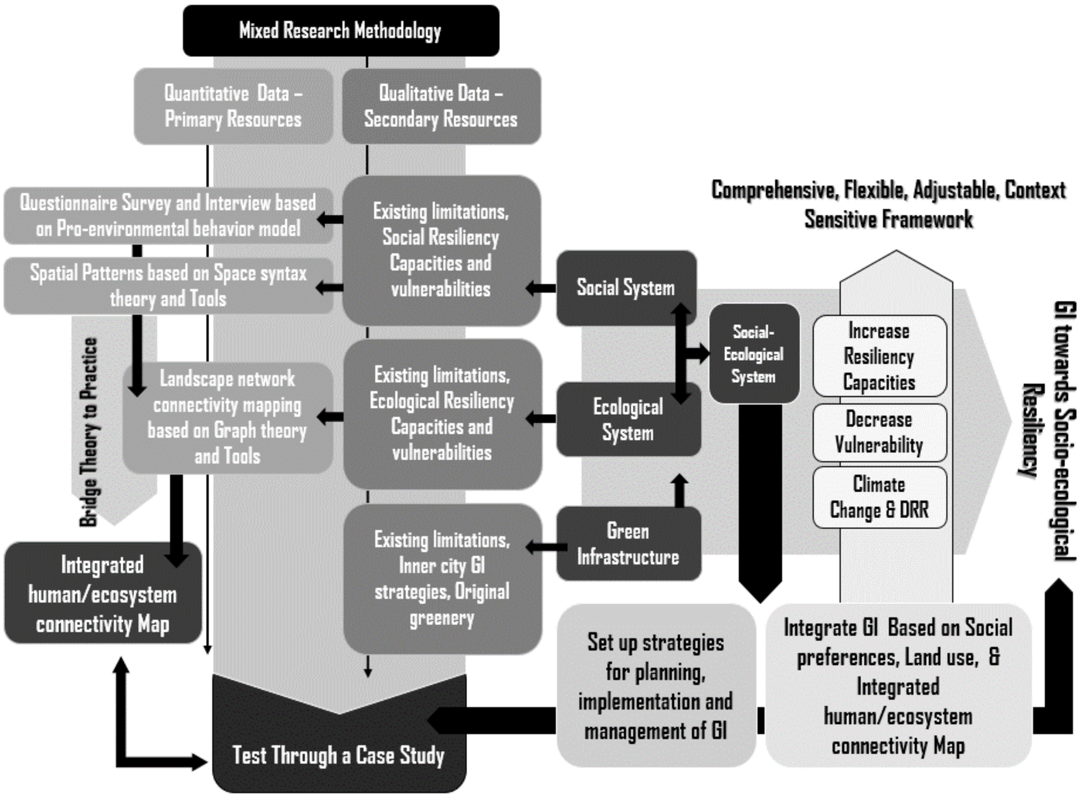


Figure 14: Theoretical framework of the study.

Noting that, as resiliency and GI are both acknowledged to be context-sensitive, the framework is meant to be flexible and adjustable so that it can be generalized through several inner-city urban contexts. For that, data must be case-oriented for accurate results, which will therefore be different from case to case, and as such are distinguished.

The next chapter will focus on the methodology of research based on the theoretical framework developed in this section.

Chapter 3

METHODOLOGY

A mixed research methodology is adopted utilizing both qualitative and quantitative research methods, see figure 15. This chapter is dedicated to clarifying the methodology where the selected approaches will be elucidated with their complementary tools to outline the overall methodological approach of the research. Data resources were collected by both qualitative and quantitative research methods, and are as follows;

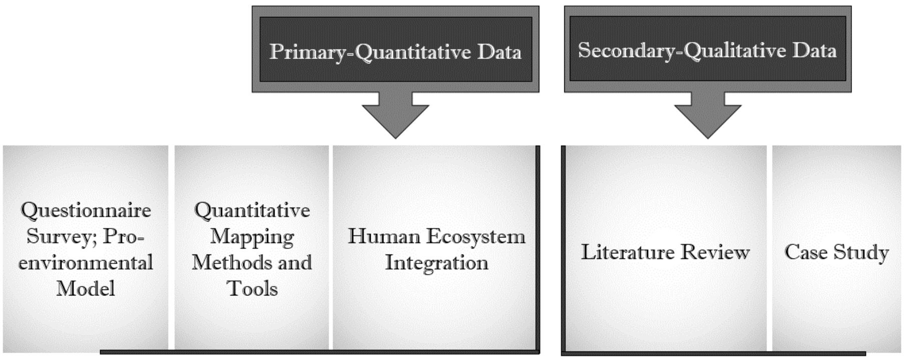


Figure 15: The overall research methodology data by type and resource.

3.1 Literature Review

The literature review went through an integrative critical process, previously discussed in chapter 2. The process concluded into a critical thinking that drew focus on the theoretical framework of this study, as well as helped shed the light on the methodological approach the research further uses to practically assess the relationships within urban communities based on relevant theories by utilizing specific analytical methods in an integrated human ecosystem approach towards a GI oriented social ecological resiliency. The overall logic in critically conducting the literature review is as follows – figure 16;

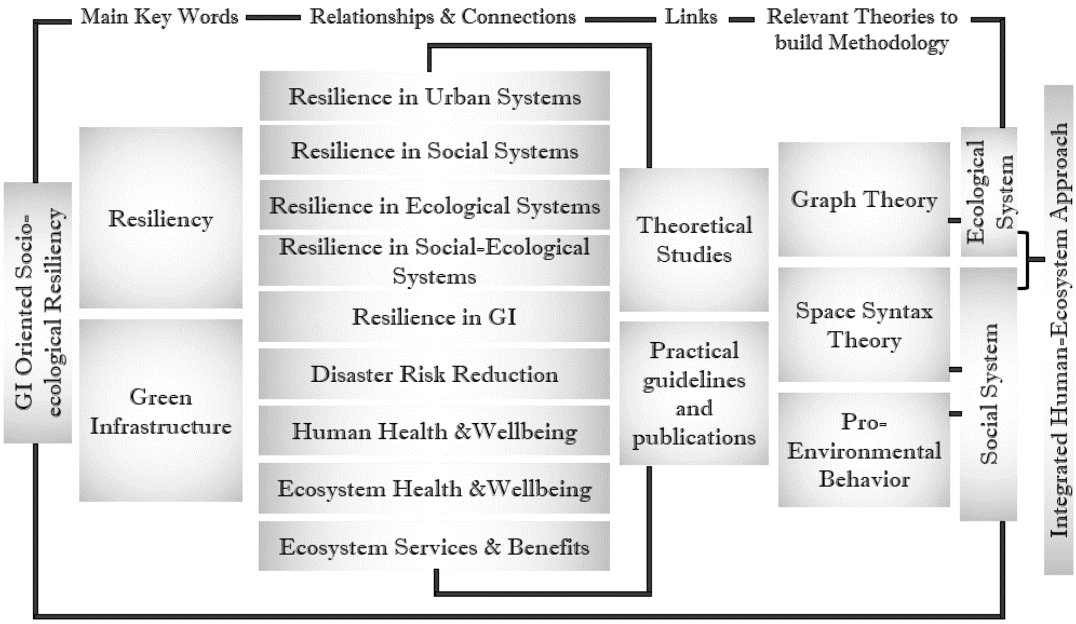


Figure 16: The overall logic in critically conducting the literature review.

Secondary data retrieved from the literature were used to find evidence-based theoretical information essential for;

- Identifying limitations and gaps that need development and further research.
- Defining the limitations within existing frameworks and indexes for building resiliency towards climate change and related natural disaster mitigation and prevention – DRR.
- Setting resiliency capacities for social systems, ecological systems, and urban systems.
- Compare those to urban socio-ecological resiliency capacities, characteristics, and attributes and merge them for a comprehensive, inclusive review.

- Identify the best GI strategies, elements, and features most relevant and suitable within an inner-city context.
- Identify GI advances towards building resiliency capacities in social and ecological systems, urban infrastructure advancements, climate change mitigation, natural disaster prevention, and reduction.
- Identify existing frameworks/indexes for current GI theoretical and planning practices to identify limitations and fundamental approaches to GI-oriented functional infrastructure practices.

3.2 Case Study

When adopting a case study, the choice needs to be justified for suitability to the addressed main aims of the research. While the case study in this research is considered a tool for practically testing the theoretical framework, this process requires quantitative data to be retrieved when applying the methods to the case. Yet, there are vital qualitative secondary resource-based data that is needed, figure 17.

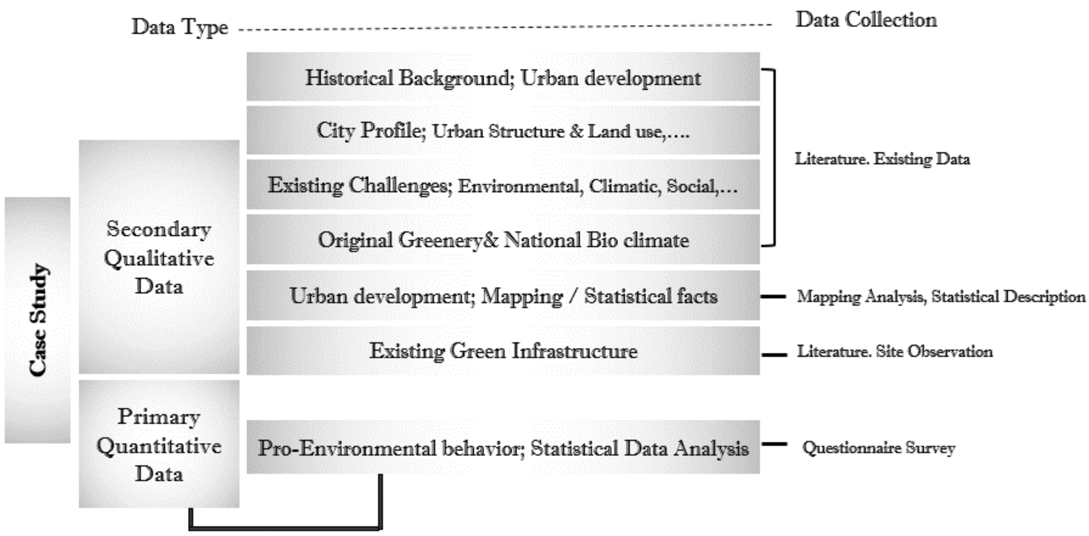


Figure 17: Types and collection methods for conducting case study data.

Firstly; **Case Study Secondary Qualitative data;** data retrieved by case study analysis include;

- Introducing the case study and examining its historical background. Besides investigating its existing challenges as a city of complex dynamics from several aspects; urban structure, environmental, economic, social, climatic, and natural resources, socio-economic structure, social disparities, and urban structure/official land use is also explored in the selected case study. This is done through a descriptive approach utilizing all available data analyzed in the literature including national archives, documents, practitioners publications such as the 100RC Amman city profile, and information from official authorities such as the municipality, GIS royal center, and the local statistical department.
- Historical mapping analysis was mainly utilized to explore the degradation of the natural environment on behalf of the rapid urbanization whereas case study boundaries were investigated using a comparative approach to assess the dominant urban structure layers, street networks, and buildings. Results are shown both as visualizations and as statistical charts and graphics.
- Introduction of some literature on existing public/green space in the case study area. As well as for some data based on site observations reflecting socio-cultural activities between communities and public green space.
- Identify original greenery based on location (different from case to case) for the most effective long-term implementation – as actual vegetation requires less maintenance and is case-oriented), This part of the data collection is flexible and can be adjusted to different urban contexts. This is done by exploring existing databases and available ecological species checklists and reviewing relevant research. Even though the researcher has accuired this data, however, the data is

excluded from the min context of the thesis and are presented in the appendices section under section APPENDIX B. Never the less, such data is highly recommended to be applied if and when the GI oriented resiliency approach suggested by the study is truly implemented.

Secondly; Case Study Primary Quantitative data; for this data a questionnaire survey is used. While this strategy is considered a popular qualitative data collection method, the tools and research design proposed are used to analyze the data retrieved from quantitative and statistical research. IBM SPSS software and MS excel are used in the advanced statistical analysis and presentation of the survey results.

Within this part of the case study methodology, the researcher conducts a questionnaire survey about the local communities inhabiting the study area. This step is crucial for developing an overall understanding of the individual's environmental perception. For this purpose, a set of questions are tailored based on the previously discussed pro-environmental behavior models, which assess people's behavior toward the environment in an interpretive approach. This part of data collection is flexible and must be adjusted to different urban contexts and is retrieved by conducting both action and survey research strategies to collect and analyze data regarding the local communities. A sample of the Questionnaire survey is found under section APPENDIX A.

As parts of constructing and designing the research methodology of the questionnaire survey is based upon data retrieved from the case study analysis such as sample size, type variables, purpose, testing and hypothesis, all concluded from chapter 3; case study, the overall methodology of the questionnaire survey will be presented there. However, a brief introduction to the stages of the process are introduced as follows in figure 18;

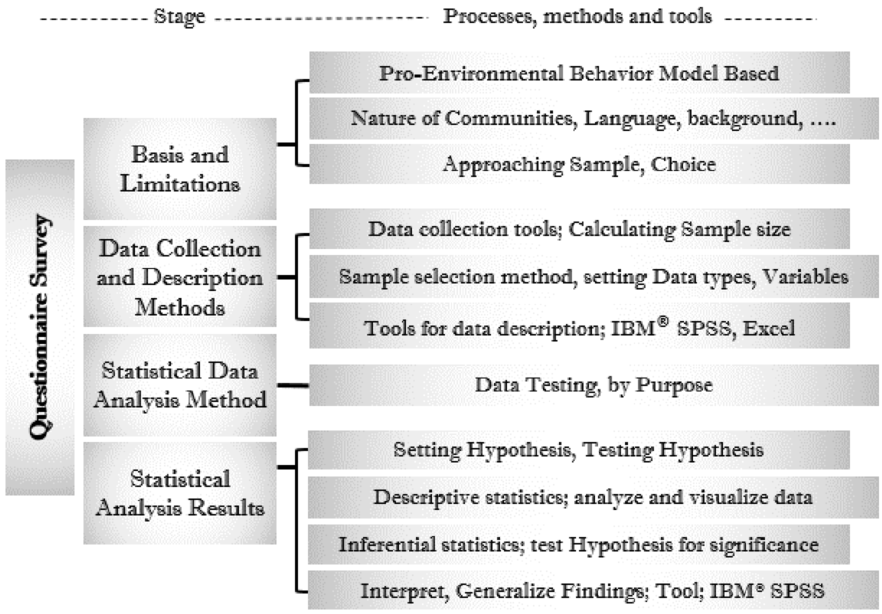


Figure 18: Stages of the process of conducting the Questionnaire Survey.

- In (Section 5.1.1); **Basis and limitations** of the survey where the pro-environmental behavior-based approach is used to tailor the questionnaire addressed to the local communities.
- In (Section 5.1.2); **Data collection and description methods**; Sample size and significance level retrieved by Raosoft online calculator. Sample choice, and data types specified. Data described using Microsoft Excel and IBM® SPSS as a tools to help organize, interpret and visualize the data.
- In (Section 5.1.3); **Statistical Data analysis methods**; At this stage, the variables and main categories are set up to construct the hypothesis, thus leading to the grounds for the statistical data analysis and the choice of statistical testing that addresses both data types available and the purpose of the survey. The choice of the test was Chi-squared as it allows comparison between only categorical variables for descriptive research, meeting the best criteria for this study.

- In (Section 5.1.4); **Statistical data analysis**, this stage includes; Setting the hypothesis, Describing the data using descriptive statistics, Testing the hypothesis using inferential statistics, and Interpreting & generalizing findings. Again, IBM SPSS software is used as a tool for this analysis.

3.3 Quantitative Mapping Methods and Tools

Data retrieved by mapping analysis are used for setting up tools for the assessment of urban areas and implementation of a GI-oriented social-ecological resiliency approach. Bridging theory to practice by building a new up-to-date empirical method, and testing it through a case study was the main aim of the research. The overall methodological approach is presented as follows, figure 19;

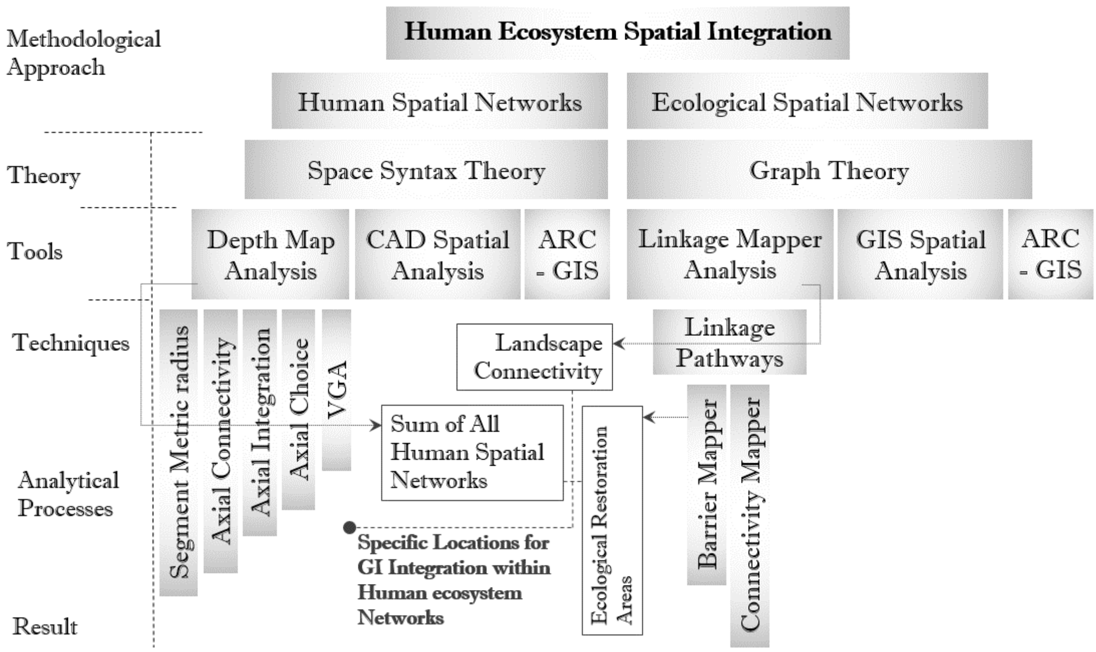


Figure 19: Stages of the process of conducting the Questionnaire Survey.

The main methods used in the analysis of the selected urban context are applied to the case in Chapter 5. The methods and tools are approached as follows;

- In (Section 5.2.1); **For the Human System**; Using space syntax theories and visual representation and analysis tools (CAD spatial analysis, ARC-GIS, and Depth map) for spatial analysis of human spatial patterns and networks. The space syntax methodology is approached in three main steps, and are as follows in figure 20;

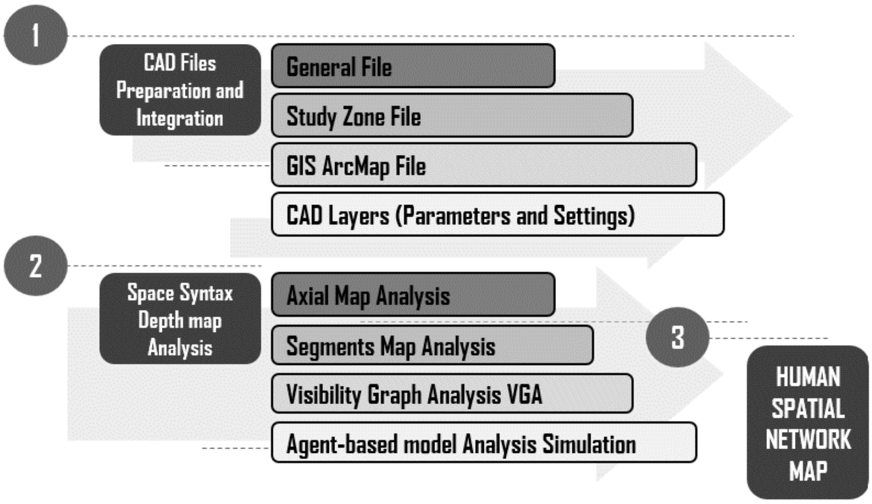


Figure 20: Summary of the Process of File preparation, integration, and analysis for conducting space syntax mapping analysis.

The first step; **CAD Files Preparation and Integration;** This step focuses in preparing the input files to integrate these files into several tools to help analyze all the urban spatial data and information of the study area as follows, figure 21;

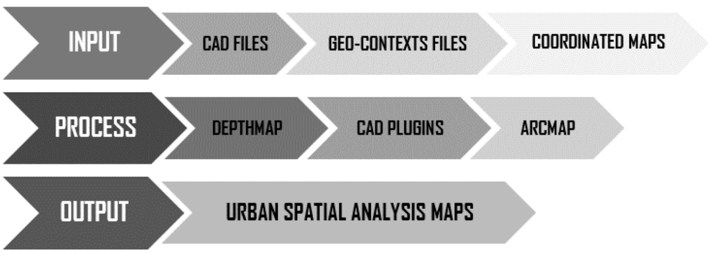


Figure 21: CAD files Preparation and Integration process.

CAD layers for general road networks, buildings and topography were created utilizing different tools in the following process. File preparation started after exploring the study area using Google Earth Pro desktop online software and the online street maps OSM, the map was exported using spatial manager plug-in in AutoCAD.

The Process included using several CAD plug-ins such as the CAD-EARTH, which is designed for an easier importation – exportation of images and other files from Google earth into AutoCAD towards dynamically creating both lines and profiles. Also, the Spatial Manager Plug-in assessed in managing geospatial data and coordination. To determine the accuracy level of all layers, the research exported the original map using Google Earth Pro (. KML file) to (. GPX file) through online tools of GPS visualizer. Files then were imported into ArcGIS (ArcMap) to convert them into an extension suitable for AutoCAD importation.

The file was exported from (. GPX file) into a (. IDW file). Next, the process estimates the values of the data points given towards creating a smooth surface using an interpolation tool. The research uses an extraction tool that allows the extraction of attributes and spatial locations for data. Finally, all the layers are ready to be imported into AutoCAD then geo-located by assigning the exact and accurate coordination system to them, using CAD Earth Plug-In. CAD layers were given parameters and settings for the output files and were finalized as needed for this research to analyze the study area appropriately.

The second step; **Space Syntax Depth Map Analysis.** Space syntax methodology utilizes a set of techniques based on theories that are used as an approach for mapping spaces for human spatial patterns in an analytic visual way. Space syntax theory links space and society by addressing how individuals interact with space from a geometry perspective. Accordingly, spaces are derived through geometry; point, axial line, segment, convex space, and isovist. Also, according to space syntax methodology, each space holds a configuration that defines the relationships between all the elements of this space.

Space syntax maps are generated through Depth Map multi-platform software. The maps are produced according to specified elements and how they are connected through specific relationships, resulting in deriving variables that are either social or experiential significant. While Depth map analysis withholds a substantial potential in performing a visual analysis through a wide range of methods, for the purposes of the study, a limited selection of methods was selected. In the third step; **Human Spatial Network Map**; The researcher further limits the spatial values visualized for those with medium to high human patterns, merge and overlap them to get the final sum of all spatial network. The process for conducting the space syntax methodology is summarized and illustrated as follows, figure 22;

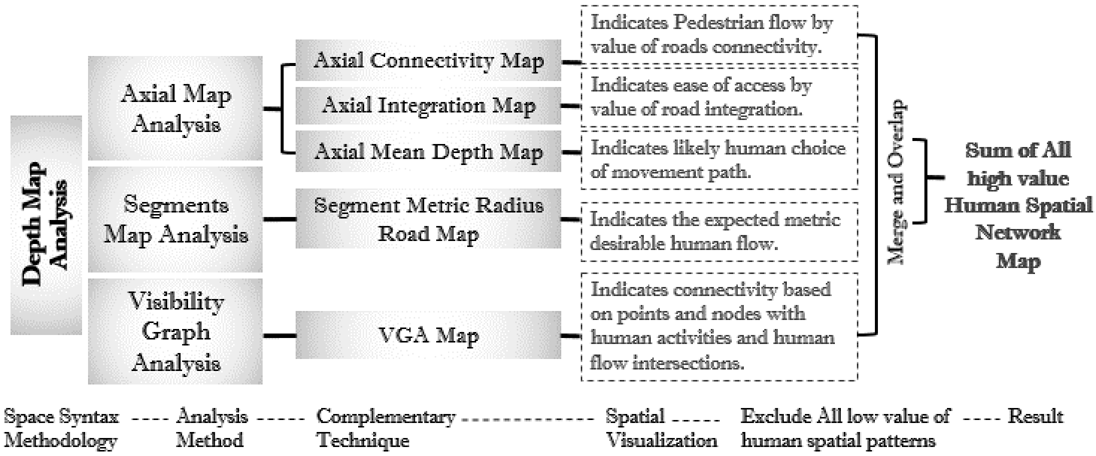


Figure 22: Space Syntax Methodology process.

- In (Section 5.2.2) **For the Ecological System**; Use graph theory and visual representation and analysis tools (GIS spatial analysis, ARC-GIS, and Linkage mapper toolkit) for landscape connectivity visualization and measuring patch integration, functional connections in the ecological network, and ecological barrier areas.

The tools for measuring landscape connectivity are a few developing quantitative approaches that highly integrate massive data on species' behavior within their habitats based on graph theory. Graph theory-based landscape models work within a mathematical framework – using tools and technologies - that quantify landscapes giving an adequate representation of spatial patterns by productions of raster images of landscape connectivity to assess ecological patches at any scale.

The researcher approaches ecological spatial patterns in the study area with the use of Linkage Mapper toolkit which is a landscape connectivity analysis tool that operates within ARC-GIS platform, the tool is set with perimeters that are based on the graph theory. Linkage mapper tools support the analysis of habitat connectivity for spatial ecosystem patterns for six main measures that map and prioritize habitat corridors, pathways, and linkages, among others. The study limits the choice for specific measurements that complements its methodological approach; which analyzes prominent linkage "corridors" between ecosystem patches "core areas" and measures them by the value of LCP "Least cost path" and CWD "Cost weight distance", centrality; that analyzes the centrality between cores and corridors, and barriers; that analyzes ecological barrier areas. As follows, figure 23;

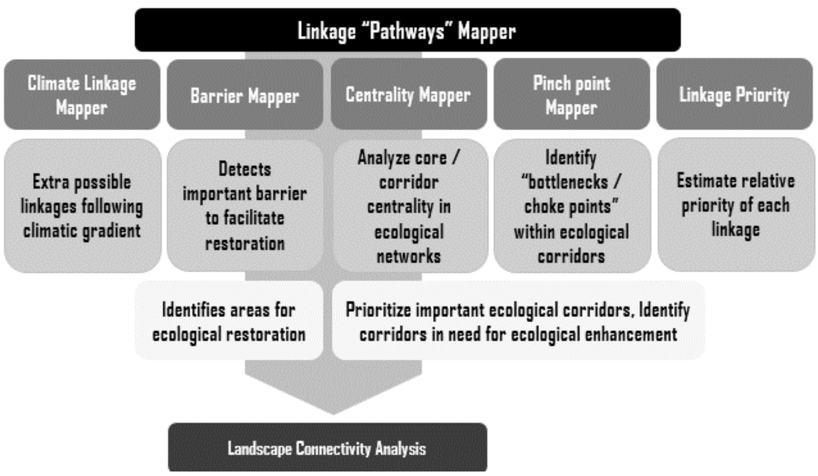


Figure 23: Illustration showing Linkage Mapper tools for landscape connectivity analysis chosen for this study.

The landscape connectivity analysis will be conducted following several steps that will be explained thoroughly at each step while presenting and discussing them in chapter 5. The process is summarized as following figure 24;

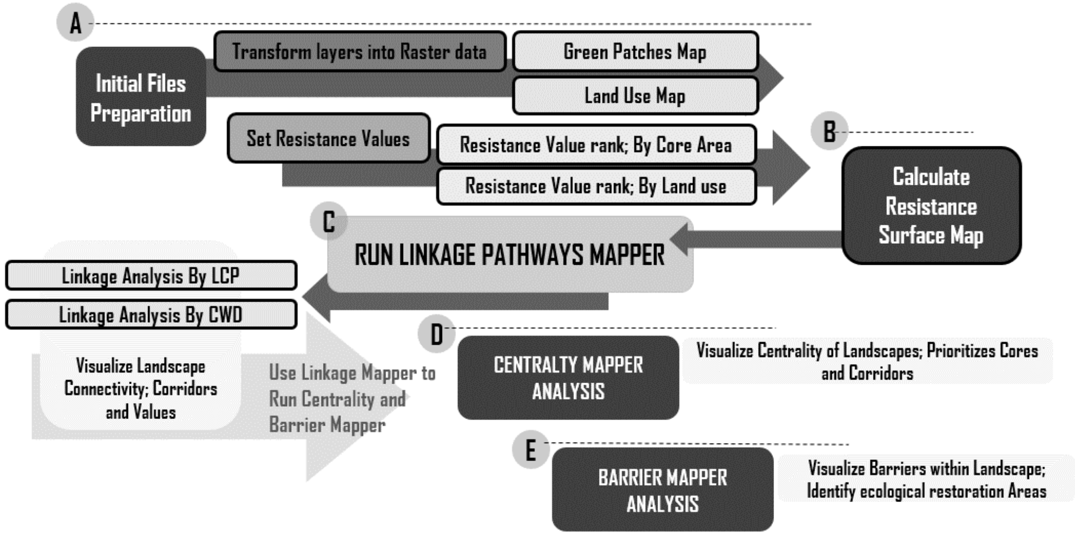


Figure 24: Summary of the process of landscape connectivity mapping analysis.

A. Prepare Files; This is done in two steps where initial layers of ecological patches and land use are integrted into ARC-GIS and are given specific resistance values.
B. Resistance surface map is produced within Linkage Mapper toolkit.
C. The resistance surface map is ran through linkage pathways mapper to produces landscape connectivity values by LCP and CWD.
D. Linkage pathways values are used to run Centrality Mapper to visiualize connectivity networks and priority connections within prior pathways anlysis.
E. Finally, Same values are used to run Barrier Mapper to identify ecological barrier values in the study area.

- In (Section 5.3) **For Human Ecosystem Integration**; The human ecosystem integration is part of the methodology that will utilize the same tools based on space syntax and graph theories as before.

Again, the mapping analysis will be conducted following several steps that will be explained thoroughly at each step while presenting and discussing them in chapter 5. However, the process is summarized as following in figure 25;

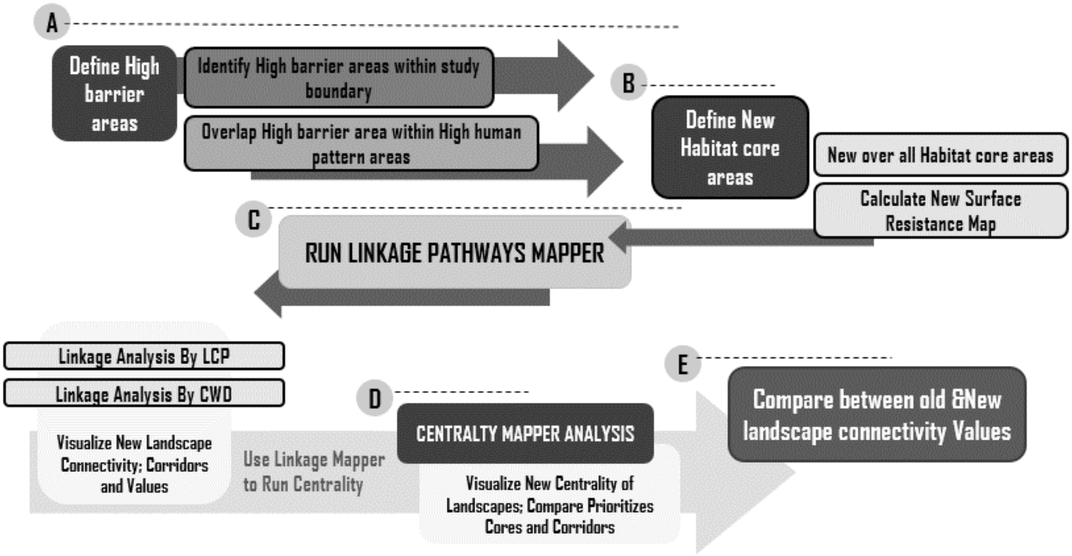


Figure 25: Summary of the Process of Human/Ecosystem mapping analysis.

A. Limit the barrier analysis to high barrier values. And overlap them with the previously conducted high value overall human spatial network, concluding in an integrated human ecosystem network map.
B. Identifying ecological barrier areas “areas that need ecological restoration” within high human activity areas. Considering those areas as new ecological areas “grounds for GI implementation”.
C. Re-calculating ecological networks to provide evidence of improvement of landscape connectivity. Here the new layer of ecologial patches is used and as such, a new resistance surface map area is conducted.
D. Re-Calculate centrality mapper for new network connection values.
E. Comparativly analyze All values to provide evidence of enhancment.

Here, it is suggested that merging those tools offer a significant contribution to providing an empirical practical and effective tool for assessing GI social-ecological resiliency through visual mapping analysis of both systems.

Concluding the methodology chapter, the overall methodological approach utilized for this study will contribute in suggesting planning, implementation, and management strategies that can utilized both by practitioners in the field and by scholars for further research development.

Again, the researcher emphasizes that part of the methodology provides data that can be generalized. However, specific context-related suggestions must be flexible and easily adjusted to different urban contexts. Those context-sensitive data are; Social preferences for GI as retrieved from the survey, and suitable GI according to local regulations and official land use as retrieved from the case study analysis.

- The previous steps of this part of the methodology are summarized in the chart as following in figure 26;

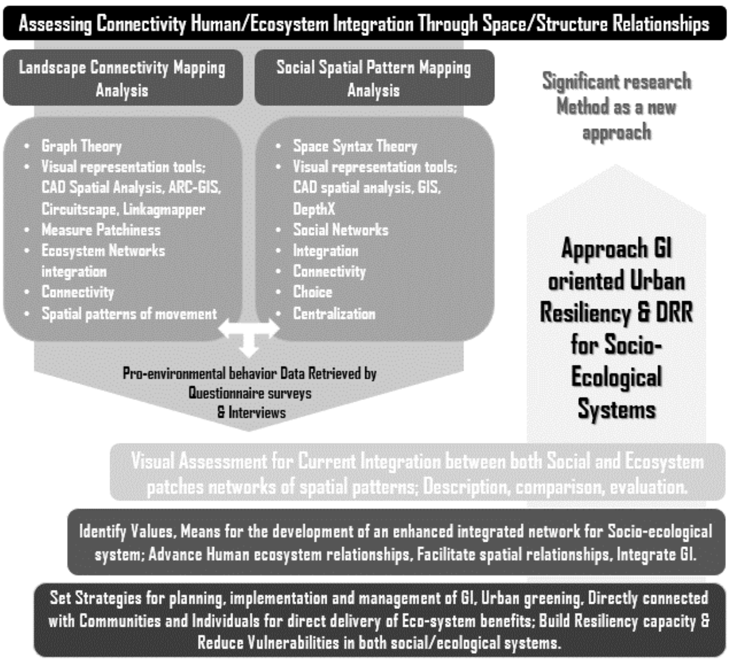


Figure 26: Illustration showing methods merged towards achieving a new research approach for a GI oriented social-ecological resiliency.

Chapter 4

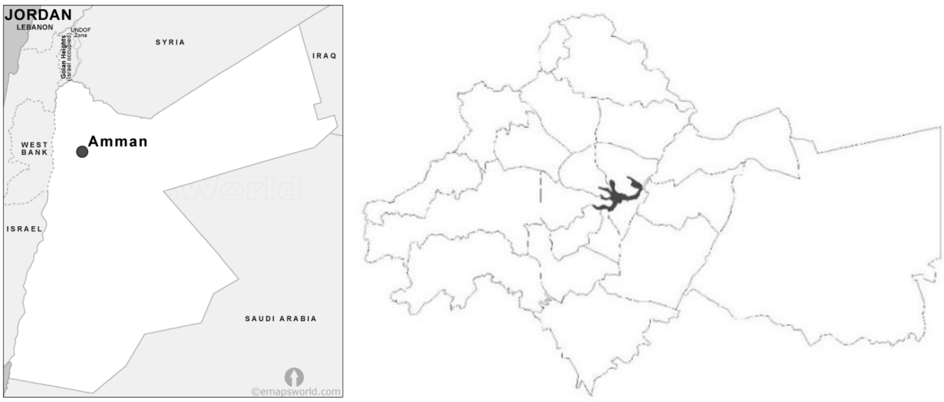
CASE STUDY: THE CITY CENTER OF AMMAN, JORDAN

4.1 Introduction

This chapter focuses on the urban development story of the city center of Amman (Figure 27) through the visual mapping of the area in a timeline using a comparative narrative approach. In addition, the 100 Resilient Cities Initiative overview for Amman will be discussed to understand what emerging strategies are proposed for the creation of a more resilient city (100RC, 2017).

During the visual mapping of the city center, the primary networks of the built environment and natural environment will be identified. Moreover, other research will look into the urban challenges that are putting the city under stress from several perspectives such as physical environment, social structure, land use, and existing land cover, amongst others.

Due to the population increase in Amman, the city was urbanized very rapidly, leaving its natural environment to a densely built city with little and fragmented GI. This has resulted in decreased ecosystem services negatively affecting the inhabitants' quality of life. This also led to disturbances in the natural ecosystem processes causing the area to suffer from increased flooding, pollution, and high temperatures, putting urban practices in challenging positions in tackling natural disasters and taking immediate action regarding DRR. This issue is addressed as the primary concern of the research in regards to climate related stressors.



a b

Figure 27: Amman City, Jordan. (a) Map showing the location of Jordan between adjacent countries, and its capital; Amman city, as retrieved from https://emapsworld.com/jordan-capital-map-black-and-white.html - Accessed on Dec 2020. (b) Map showing the boundaries

4.2 Historical Background of Amman's Urban Development

The city of Amman, Jordan, initially started its urban growth in the area known as the city center "aka downtown Amman". First settlements in the city date back to the Neolithic period and the Byzantine period (Amman Institute of Urban Development, 2005). Amman was part of the Roman Empire and was known as "Philadelphia", one of the Decapolis 10 cities (Khamash, 1986). Amman also became part of the Islamic world under the rule of the Umayyad's. (Figure 28)

Figure 28: The first map of Amman, as surveyed in 1881. (The survey of Eastern Palestine, 1889, pp 29)

During the 1870s, people who fled the Muslim prosecution from the Circassia Mountains settled in the ancient site of Amman around the Romanian remains. (Figure 29) This was the first nucleus of the city, and this period continued until early 1900s when the area started expanding with the arrival of the Ottoman Empire (Khamash,1986).


a

b

Figure 29: Amman – The Valley, Late 1800's, the first settlement by the Caucasians around the Romanian remains and the water stream "Seil- Amman". (Retrieved from History of Jordan web page)

The construction of the famous Ottoman Hejaz railroad drew much attention to the city (Chatelard and de Tarragon, 2006). By 1921, Jordan was founded as an Emirate, with Amman as its capital. It experienced rapid growth in the area and population initially in the early 1900s when it only inhabited an estimated 2000-3000 residents, and by the 1940s, the number reached over 33,000 (100RC, 2017). One of the causes of this urban growth is that the city of Amman became a focal point where it attracted a lot of domestic migration from people moving into it from all around the country (Kadhim and Rajjal, 1988).

The year 1948 marks the Palestinian-Israeli conflict, which resulted in the rapid growth of the city due to the accommodation of high numbers of refugee camps in the area surrounding the city center's valley, figure 30. This conflict continued until 1967, pushing the number of inhabitants of the city to over 500,000 residents. The city kept expanding into the slopes of the mountains, reaching the tops at a remarkable speed, leaving the overall urban texture unplanned, congested, and overpopulated (al-Rifaʿi, T.1996). In the years that followed, reaching the early 1980s, villages and settlements surrounding the area became a part of it as the city's sprawling went far beyond the initial nucleus in the valley and the mountains around it.

a b

Figure 30: Palestinian refugees seeking refuge and settling in and around the center of Amman after the Israeli-Palestinian conflict started in 1948. (Retrieved from History of Jordan web page)

By the late 1980s, the number of Palestinians settling in the city continued rising, making the total number of inhabitants to reach over 1.5 million. Within this period, the city's total area, which was once only 12000 square meters at the beginning of the century, exceeded 530,000 square meters.

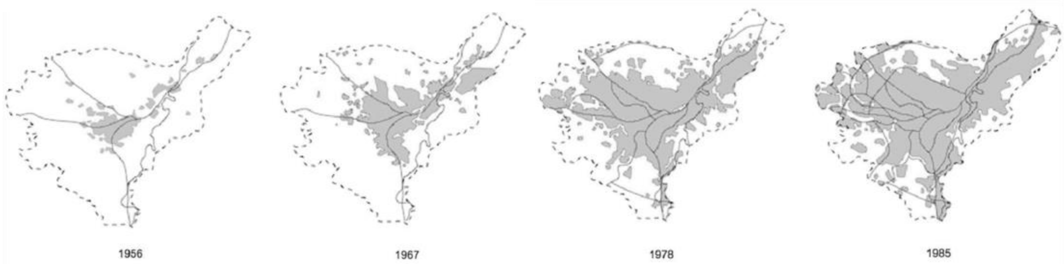


Figure 31: The physical expansion of Amman from the years 1956, 1967, 1978, and 1985. (As retrieved from Potter et al., 2007)

The city continued expanding around the nucleus (figure 31) and growing in total number of inhabitants within the early 1990s until it reached over 680,000 square meters and over 1.5 million in inhabitants. Most of this growth was caused by the gulf war which drove many people back to Jordan from many gulf countries. By the early 2000s, and with the Iraqi conflict, the city's area reached 2000,000 square meters and its number of inhabitants to 2.8 million. Still, city planning and regulations were developed during this period, making newer districts more planned and less likely to resemble the texture of the sprawling older city fabric. See Figure 32.

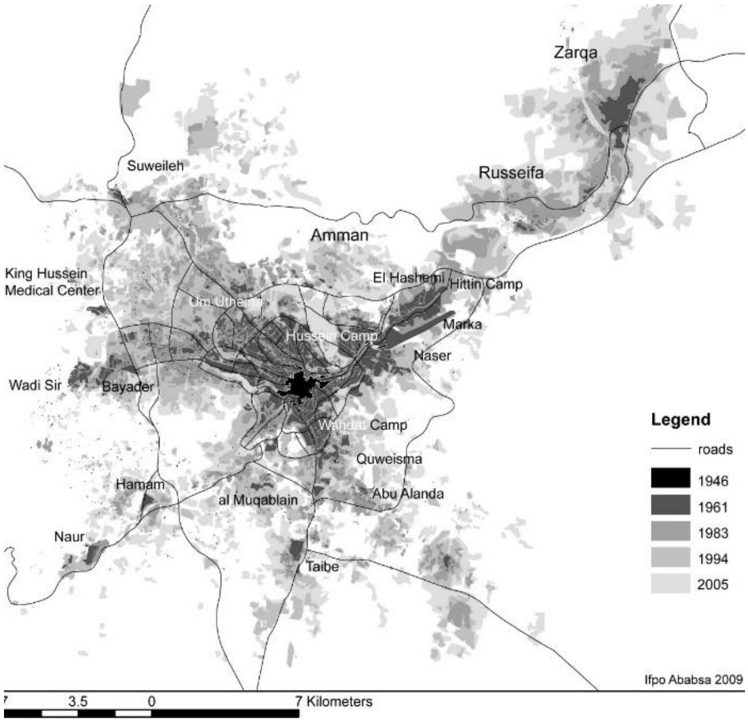
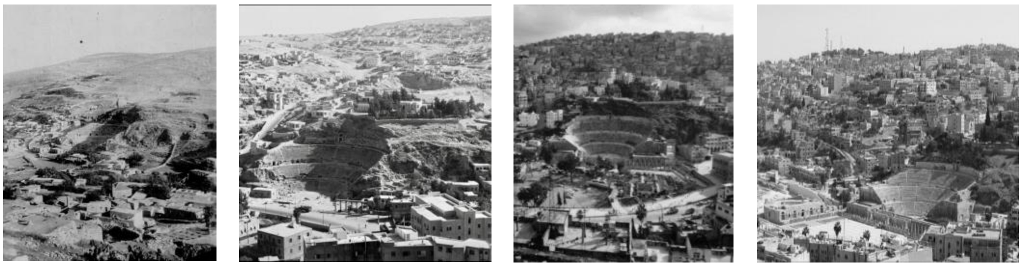


Figure 32: Amman city, showing expansion and growth towards the neighboring city of Zarqa. Satellite Images and Aerial Photographs (1946-2005). IFPO Atlas of Jordan with the Royal Jordanian Geographic Center (2009).

And by 2015, Syrian refugees and asylum seekers from other countries in conflict such as Lebanon, Yemen, and Libya pushed the city's total population towards a significant count of 4 million. Also, as anticipated by the Department of Statistics of Amman, the number is expected to exceed 6 million in 2025 (GAM, 2017). Although the city expanded towards the neighboring settlements, urban growth had an impact on the old city too, inserting the development pressure around the Roman Theater towards the mountains (Figure 33). The following section investigates the urban development in the city center of Amman.



A: Early 1900's B: Mid 1900's C: Late 1900's D: Early 2000's

Figure 33: The development of the study area as retrieved from the following set of references: a: The Australian war memorial archives. b, c & d: History of Jordan web page. Accessed online on Dec 2020.

Figure 34: Scenes from Amman's city center in the last decade. Courtesy of GAM.

4.3 An Overview of Urban Development in the City Center of Amman

Within the last decade, the city's population has grown steadily, leading to fast and uncontrolled development in the area. Due to the rapid population growth, and unplanned urban expansion, the city has exceeded its capacity and failed to provide basic services for its inhabitants, putting acute stresses on its resources, decreasing its urban resiliency, and increasing its vulnerabilities. The city is currently facing many challenges that need well-thought-out urban planning approaches so that it can adapt to dealing with disasters and shocks (Shamout & Boarin, 2019). The intensity of current problems has pushed the local government to take action toward the re-evaluation of its master plan (100RC, 2017).

To understand the dynamics of this development, a historical mapping analysis is done to display how the city expanded over a period of time. Yet, the numbers quoted represent the approximate population for the whole city of Amman. As indicated within the timeline, years of rapid urban growth refers to the sudden rise in the city's inhabitants, leading to a urban sprawl. The years chosen for the mapping analysis are selected based on the limitation of available Ariel photographs, satellite images, and maps obtained during the data collection process. These are explained and summarized in Figure 35.

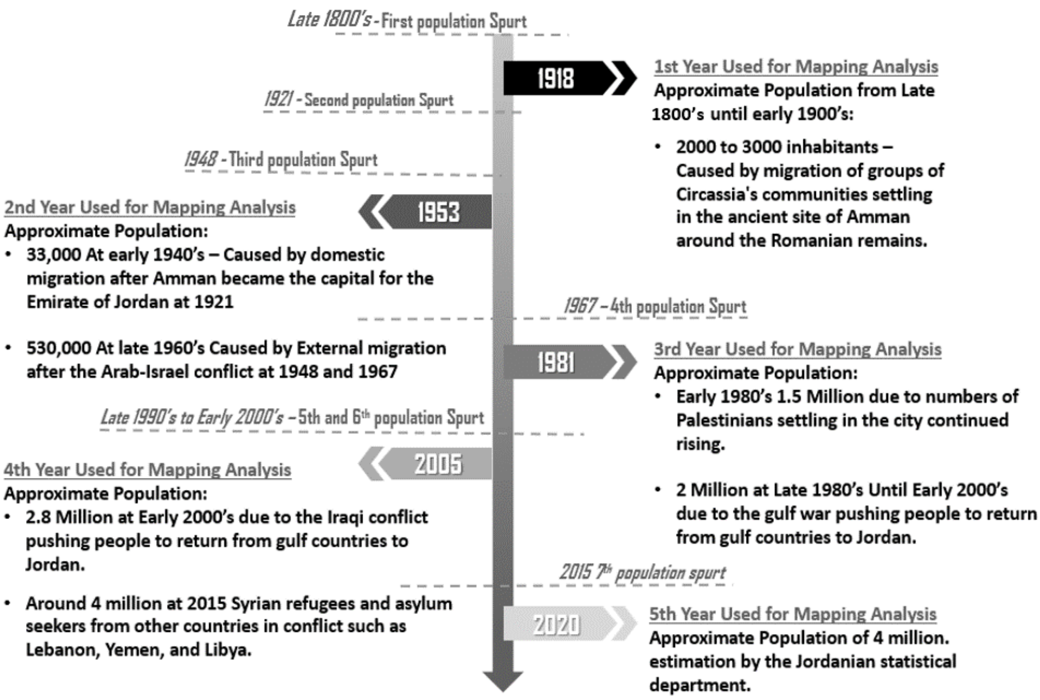
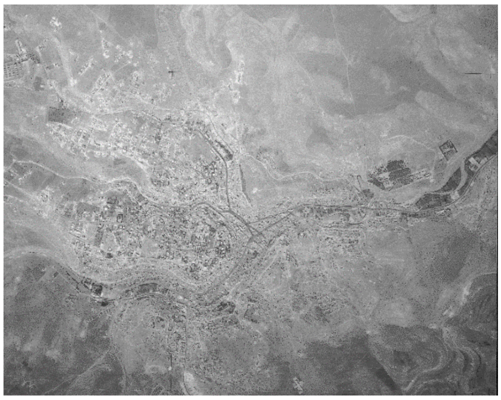


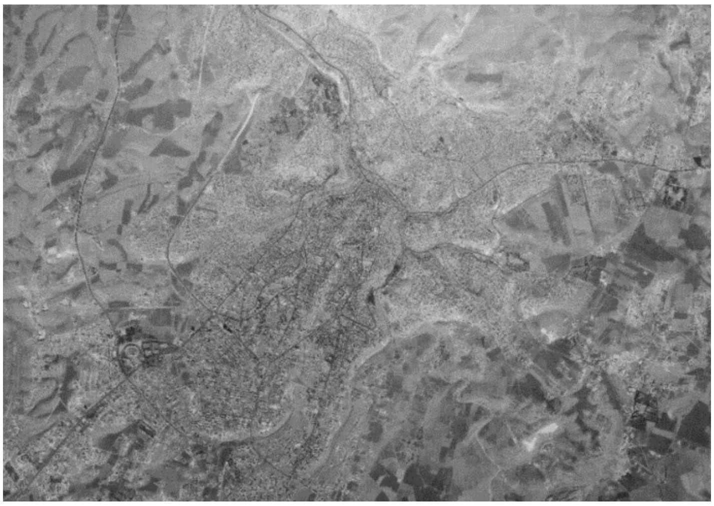
Figure 35: Timeline of the summary of urban expansion in the history of Amman city. (Developed by the Author)

This timeline will help the reader understand the pace of urban development and overlap this information with the maps obtained from the Royal Jordanian geographic center RJGC to visualize the extent of this expansion (Figure 36). Today, the city's grey infrastructure is facing challenges due to its poor condition as it has outgrown its original capacity to withstand the vast population growth leading to other problems.

a: 1918



b: 1953



c: 1981

Figure 36: a,b &c Ariel view of the physical expansion of Amman city center as retrieved from available archives of the royal Jordanian geographic center RJGC.

Figure 37: Satellite image of Amman city center and surrounding urban areas as retrieved from Google earth Pro in 2020.

The following set of maps shows the urban sprawl; unplanned expansion of the built environment. An approximate as-built map of the urban fabric that includes the buildings and the road network as the main elements of development. The leftover areas are what is left of the natural environment, which decreased dramatically between 1981 and 2005. For example, the water stream known as “Seil-Amman,” which existed naturally within the valley of the downtown area, ceased after it was buried and replaced by streets and buildings after the 1980s, see figure 38. The map’s primary purpose was to visually show the degradation of the natural environment on behalf of rapid urbanizaion. Which is more highlighted within the figure 39.

(a): Amman 1918 Ariel view, (RJGISC Archives, 1918)

(b): Amman 2020 satellite image, (Google Earth, 2020)

Figure 38: Sail Amman before &after being sealed. (a) shows Amman’s first nucleus around the natural water stream known as Seil Amman and the Roman theatre in 1918, whereas (b) shows the exact location in 2020. Note how the stream became a part of the urban infrastructure after the city cemented it up in a development project around the early 1990’s & turned it into a part of the street network.

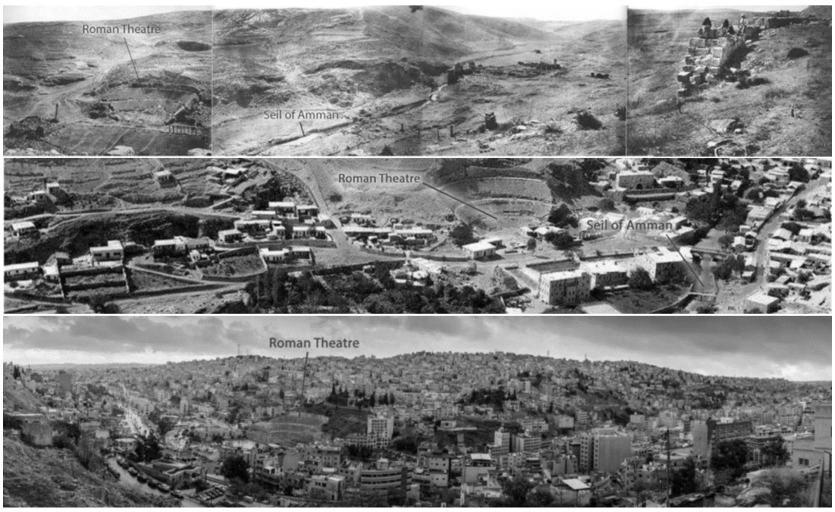


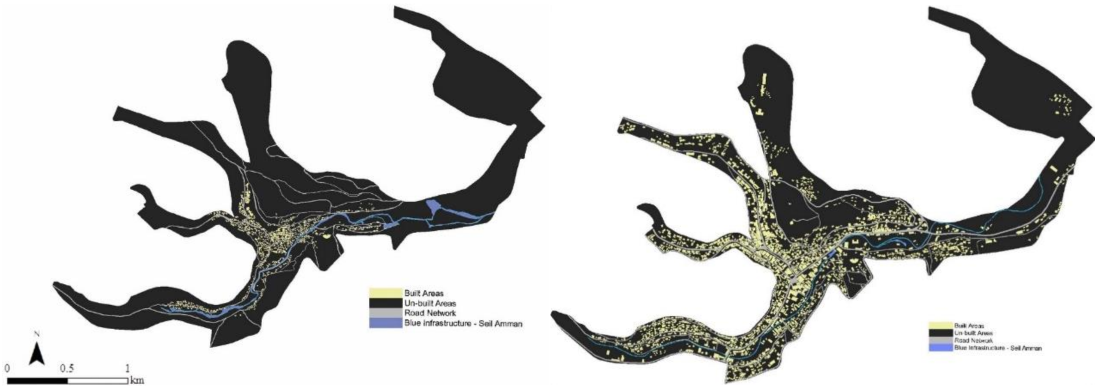
Figure 39: Amman City Center, Seil Amman Site from 1985, 1922 & 2019. (Ahmed, 2020)

As discussed earlier, the chosen years were due to the limitations of the timeline set due to the lack of satellite images existing prior to 2004 on google earth PRO, also the limited availability of clear aerial photographs extracted from the archives of the royal geographic Centre of Jordan. There were no readily available maps to retrieve directly from the municipality of great Amman that will provide a basis for the area's historical development. Also, areas and statistical data needed for comparison and analysis will be calculated from those maps, such as the change in demographics, land area, and the ratio of GS compared to demographics. These other data, such as demographics, will be collected from relevant sources such as the Statistical Department of Amman and the municipality of greater Amman.

Moreover, limitations led to the exclusion of some data, such as the population count per se, from the downtown - study area. For reasons such as, there are no available data on population count at the department of statistics of Jordan before the 1980s. Therefore, an estimated count was conducted by calculating an approximation of the total area of Amman (which was available) and then subtracting the rest of the known populated areas, which leaves an approximate count for the downtown area for the years 1918 and 1953.

The maps are not available in any governmental or private sector within the city; therefore, the methodology used for locating the maps was by retrieving aerial photos from the archives of the Royal Jordanian Geographic Information System Center for 1918-1953 and 1981. While the years 2005 and 2020 were retrieved from satellite images using google earth pro software. The research then worked on developing the maps, which show four main elements; The study area's downtown boundary as the fixed variable of analysis, the built environment – buildings, the road network, and the water stream – natural blue infrastructure.

Maps in Figure 40 shows Amman’s approximate as-built maps from 1918 and 1953; 40 A-1918 shows the nucleus where the first settlers built their dwellings around the water stream after they arrived in the late 1800s and how it developed until the early 1900s. The road network moves parallel to the natural topography surrounding the valley up to the mountain as it was mainly printed by the movement of the animals and carriages of the first agricultural communities in the valley up and down the hills. The general area of the boundaries of the downtown as recently set by Amman’s Greater Municipality is approximately 2.9 million square meters, out of which there is only a rough count of almost 50,000 square meters consisting of built-up area in 1918.



A B

Figure 40: (A) 1918 map. (B) 1953 map –Amman city center. Retrieved from aerial photos of the archives of the Royal Jordanian Geographic Information System Centre, Developed by the author. December 2020

The number of inhabitants accelerated quickly within the following three to four decades, reaching nearly 275,000 square meters of built-up area in 1953 as shown in the map in fig 40 B. The road network now offers lines cutting through the topography where the urban stairs were much used for pedestrian movement as the urban sprawl reached to the mountains.

During those time vehicles were used, which explains the development of the primitive network of roads running through and surrounding the valley. A significant decrease in the water stream area is clearly shown as well, where the water area decreased from almost 60,000 square meters to only nearly 12,000 square meters. The decrease in the area of the natural water stream “Seil Amman” declined dramatically in 1981 to reach only 7,390 square meters. The map of Amman downtown in 1981 highlights how it now withheld a huge amount of unplanned urban development accommodating the big amounts of increasing inhabitants which now reach the boundaries of the city center district as a whole. See figure 41.

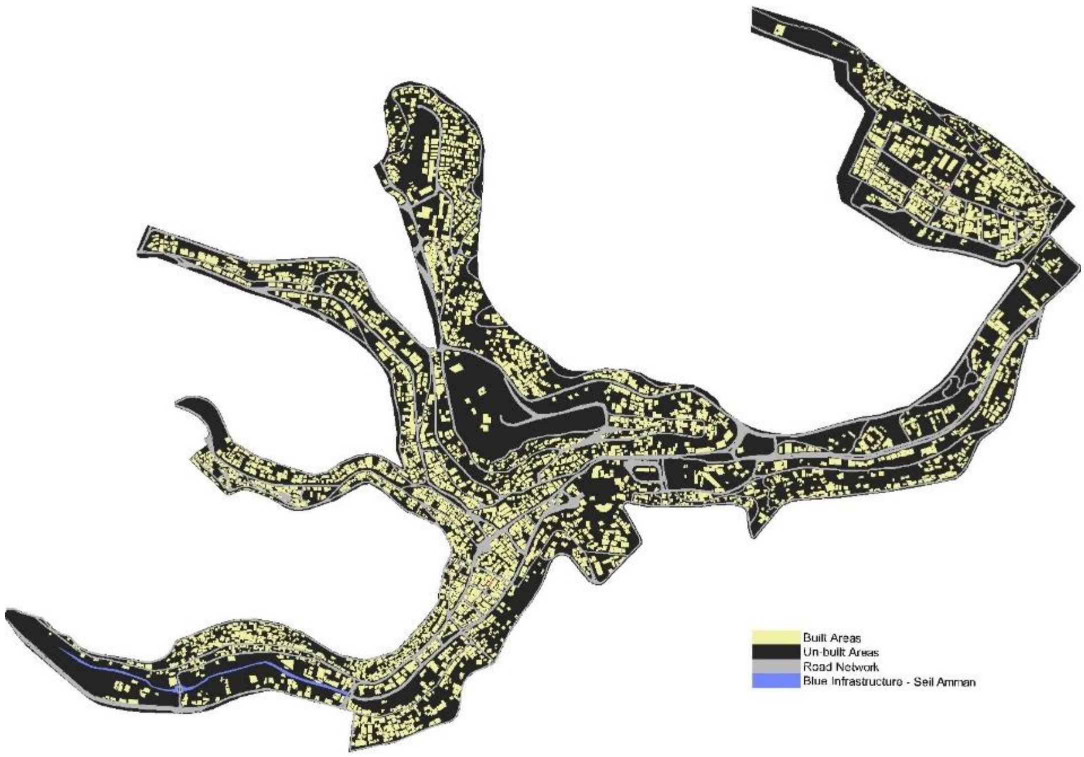


Figure 41: 1981 map –Amman city center. Retrieved from satellite photos from google earth pro software, Developed by the author. December 2020

The urban fabric shows similarities in 2005 and 2020 maps, which are both very dense and complex. The expansion of the urban fabric including buildings and road networks left hardly any space for the natural environment to grow (Figure 42).

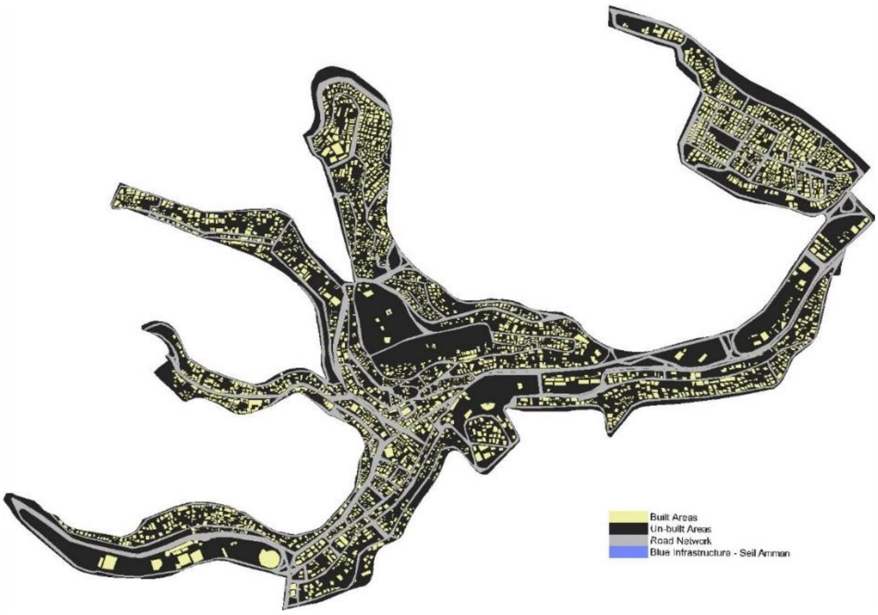


Figure 42: 2020 map – Downtown Amman. Retrieved from satellite photos from google earth pro software, Developed by the author. December 2020

The study defines the unbuilt areas as potential spaces for developing strategies for greening the city, which were about 2.7 million square meters in 1918 decreasing to almost 1.8 million by 2020. The following chart compares the whole set of variables chosen and shown on the previous maps. *Note: Even though built-up areas are almost the same in 2005 and 2020, the population count has increased vastly. This means that green space per capita, even though it was insufficient before, is still decreasing due to the constant population growth. Statistical data for urban development and population ratios are shown as following in the charts below, see figures 43 - 44.

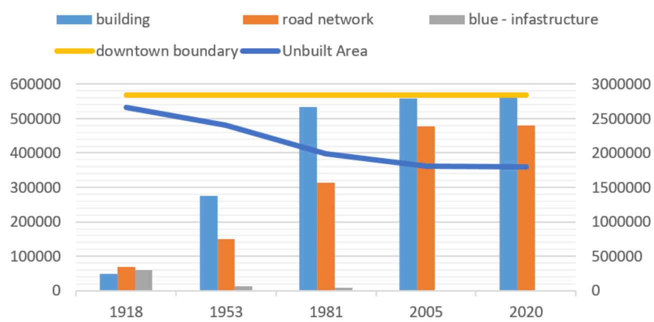


Figure 43: A chart graph showing the elements of comparison presented in the maps in relation to each other. (Developed by the Author)

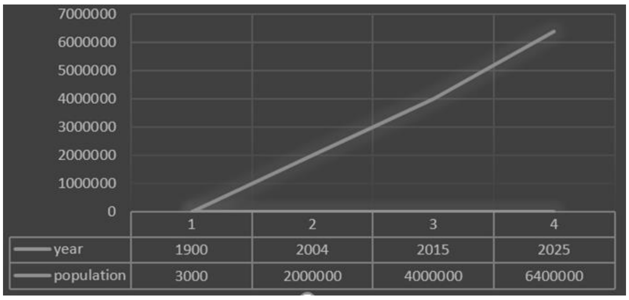


Figure 44: chart graph showing the growth in demographics for the city of Amman between 1900 and 2025. As adapted from the Department of Statistics and Greater Amman Municipality and Developed by the author.

According to the World Health Organization (WHO), the ratio of the area of green space to the demographics should be a minimum of 9 m2 per capita, with an ideal percentage of 50 m2 per capita (Russo & Cirella, 2018). Other publications on this matter suggest that a healthy city should provide around 20 square meters of green space per person. Yet, in the city of Amman, this is around 12 square meters per person according to Amman's latest publication on Green 2020 Strategies (Green Amman 2020, GAM, 2017). While this number was calculated for the whole area of Amman, the reality within the city center is worse due to being so overcrowded and consisting of an approximate count of almost 53,000 people according to the General Statistics Department of Amman in 2020.

When compared to the area of the unbuilt spaces within its boundaries, it gives 34.34 square meters of free space per person, out of which, there are only 168,500 square meters of green space - which are genuinely existing due to plans. This adds up to an accurate ratio of 3.2 square meters per person where the free space was found as 34.34 square meters. However, one needs to keep in mind that the healthy range varies from 20 to 50 square meters. The free spaces this research refers to do not consist of buildings or road networks. It counts for the planned and defined green spaces as well as every neglected spaces, lost spaces and the spaces between buildings.

Table 8: Summary of GS ratios from the mapping analysis of Amman city center in 2020 compared to internationally recognized healthy and ideal minimum GS per capita ratios. (Developed by the Author)

Current GS ratio	**Healthy ratio / Ideal Minimum**	**Available Spaces – free of built-up area and road networks**	**Spaces for further development**
3.2 sqm/person	20 to 50 sqm/person	34.34 sqm/person	31.14 sqm/person

The following parts of this part of the study discusses physical, social, ad environmental challenges. Highlighting resiliency and DRR need in the city center of Amman where the negative impact of the vast elimination of the natural environment consisting of green spaces and water streams left the city center borne to naturally accruing hazards like flash floods as there were not enough green spaces left to act as sponges to the storm water, and other related problems such as air pollution, and increased temperatures.

4.4 Land Use and Urban Structure

In this section of the case study chapter, a general identification of the land use patterns and the urban structure of the city center of Amman will be presented. The study area is significant and comprises several districts withholding mixed patterns of economic activities, residential areas, governmental buildings, public spaces, and heritage/historical sites. The location of the study area to all other districts of Amman city is very central and is considered the nucleus of the whole city (figure 45), explaining the significant patterns of activities it withholds. It is a major center for socio-economic activities that attract investments as well as withholding important governmental buildings like greater Amman Municipality, cultural facilities and heritage/historical sites, which in return attracts people to the area as well as tourists all year long. Moreover, main public transportation networks pass through the city center, especially after adding the main terminal for the new fast bus project, which made it more accessible for the public from all surrounding districts. (GAM,2020)

Figure 45: Boundaries of Amman city, Highlighting the Al-Madinah district as the central – focal point to all other districts. As retrieved from GAM 2020.

Amman city is characterized by complex communities that causes many social disparities. Currently, the city center of Amman lies within several land uses and social-economical structures as it had always been. As the city developed grew from its downtown nucleus, it was categorized into two main areas: Eastern/Western Amman. Both areas have different classifications of urban fabrics; The Eastern parts of the city withhold the urban poor, lacking services to low-income residential areas, refugee camps, and informal settlements, as well as for some light industrial areas and institutional uses, as well as for several touristic cultural heritage and historic areas. On the other hand, Western Amman districts possess modern - to an end well planned / socio-economic privileged - urban areas, figure 46. (Ababsa, M 2011, GAM, 2020)

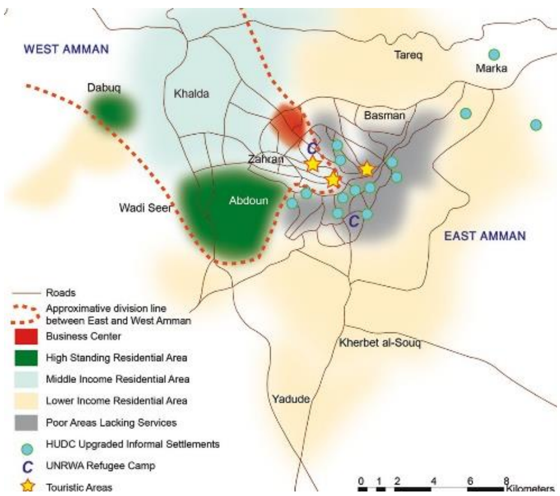


Figure 46: Map showing Social Disparities in Amman. As retrieved from the Atlas of Jordan. (Ababsa, M 2011)

While the business center is shown to be within modern Eastern Amman's boundaries, the previous map does not account for the old main center of economic activities composed of "traditional commercial areas such as furniture, textile & souvenir shops" and light industries and workshops that serve to the poor areas which are at the study area in the downtown, as well as attracting tourists and Western Amman communities for the traditional market goods and experience. The following map (figure 47) of the structure of the whole city of Amman highlights area number 2; where downtown Amman is seen as a mix of all uses and urban structures in a condensed congested complex pattern.

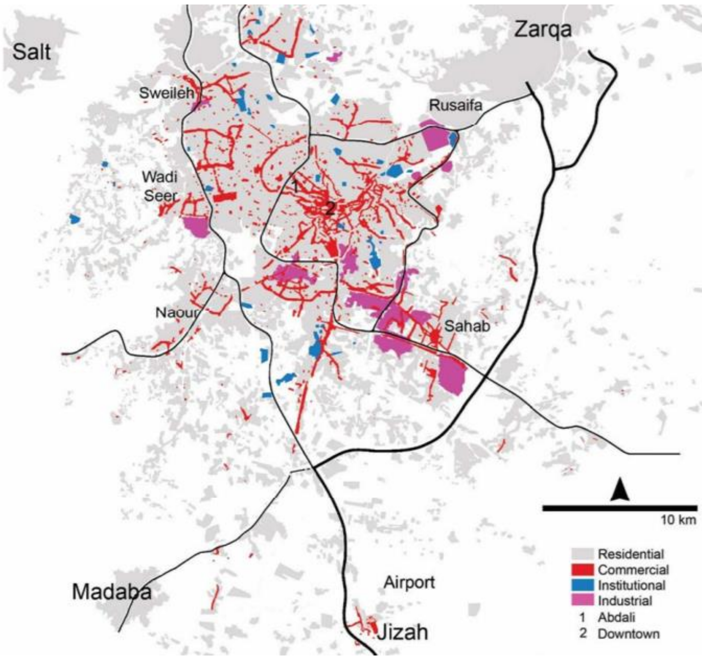
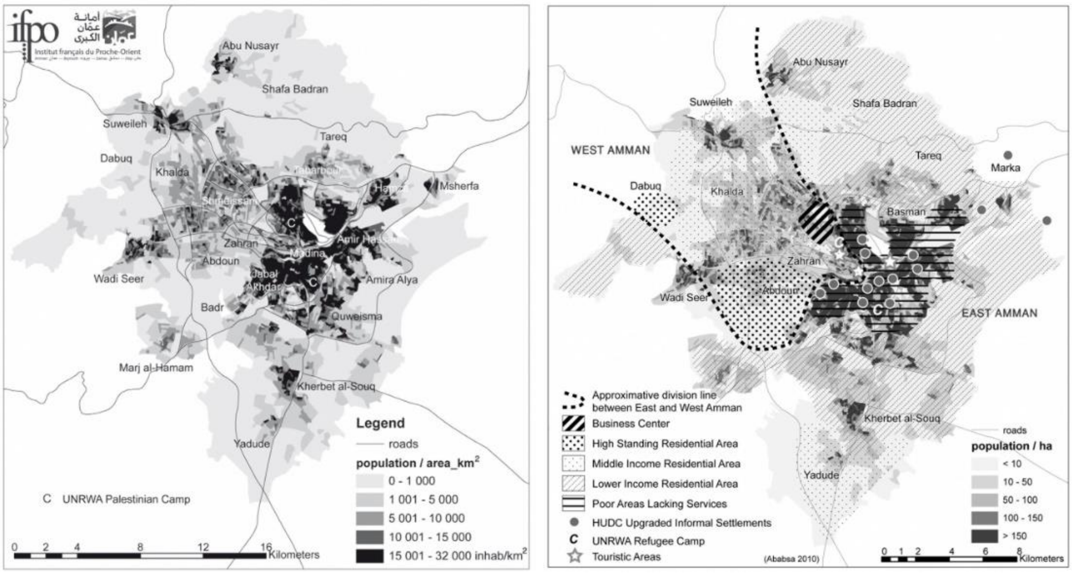


Figure 47: The urban structure of Amman. As retrieved from The Amman Plan by GAM in 2008.

4.5 The Challenges Faced by the Urban Environment – Physical, Social, and Environmental Challenges

This study focuses on the city's oldest, most vulnerable part, the city center of Amman, which is overpopulated, unplanned, underdeveloped, and facing decay. The city center is currently facing a lot of social and environmental challenges that are reflecting poorly on its urban structure due to three main reasons:

- Firstly, from the social aspect, the location is challenging due to its degrading physical environment, and its high population density, as highlighted in the map shown in figure 48. Also, the area and its surroundings withhold inhabitants from very mixed cultural backgrounds as this part of the city has been hosting many refugees, migrants, and relocated communities and individuals since the last century, leading to a constant population growth that is expected to keep rising. It also withholds a lot of high density urban poor residential areas. See maps in figure 45 where they are highlighted.



a b

Figure 48: (a) Amman population density at the block level in 2004. As adapted from the Department of Statistics and Greater Amman Municipality by Ababsa, IFPO, 2010. (b) Amman Urban Morphology and Approximate Division Line Between East and West Amman (Ababsa, IF

The significant urban growth and the vast population rise due to the growing number of migrants and refugees created a challenging urban environment where basic services such as education, transportation, housing, and health had to be provided with limited resources. As a result, the dwellers' socio-economic conditions were negatively affected in many ways, such as decreasing employment opportunities, rising rents, and increasing demand for water supply, among others (100RC, 2017).

Secondly, and moving on from the social structure, the nature of the urban fabric has greatly been under the influence of unplanned, overpopulated, and poor infrastructure.

Thirdly, the city center imposes a low percentage of open spaces, as shown in the maps in figure 49. From the environmental point of view, the city also suffered from inadequate surface/groundwater which created management problems too. From the governance aspect, these problems led to communication issues affecting corporations between local citizens/private sectors and local government bodies, resulting in community resistance (Alshawabkeh & Alhaddad, 2018).

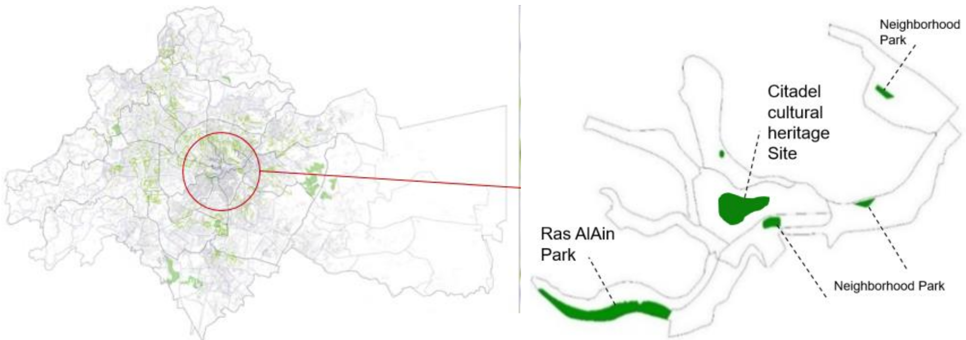


Figure 49: Maps of the study area showing the planned and existing green spaces. As adopted from GAM - developed by the author.

Regarding the layers of open green spaces within Amman's urban environment, it is essential to note that the aforementioned factors impose huge problems on the assessment and implementation of GS in public spaces. Studies in this field had shown that planning for open urban areas is negatively affected by the city's political and socio-economic dynamics. This creates a great challenge in the planning of contemporary Amman (Aljafari, M. 2014). Moreover, the open space network within the city center of Amman is highly inconvenient, as there is no constant pattern of open spaces due to the unplanned and overpopulated nature of the urban fabric and its long history of uncontrolled urban growth. A recent study elaborated on the fact that the city of Amman had been giving priority to vehicles over trees which affected the urban fabric and cultural life in the city, not to mention the negative environmental effect of insufficient and almost nonexistent vegetation within the dense urban environment (Alamoush et al., 2018).

While the study area consists of several public spaces that withhold some sort of greenery that vary in scale. The study within its theoretical and methodological approach focuses of the interaction between human communities and natural ecosystem. In this perspective, the traditional markets, public plazas, and cultural heritage sites within the study area are not considered a type green public space. The only public spaces in the study area that consist of a sufficient amount of green spaces with social accessibility are those at the cathedral mountain cultural heritage site and the public park of “Ras al Ain”.figure 50. Highlighted previously in the map in figure 49.

a b

Figure 50: a; showing cultural heritage site at the citadel mountain, b; cultural, civic site at Amman's municipality complex. Retrieved online from Amman.net official webpage, accessed April 2022.

The citadel mountain area, descending to the valley towards the Roman theater area, reminiscent of the cultural heritage sites towards the middle of the downtown. Due to the regulations, urban sprawl was prevented within the site as it withholds remains from the Byzantine empire, Roman empire and the Umayyad Islamic dynasty. The area being considered a touristic site with entrance fees, prohibited car access and limited public facilities however made local communities refrain from adequately benefit from it as a green public space. Scenes from the site are shown in figure 51;

Figure 51: Scenes from the cultural heritage site at the citadel mountain. Courtesy of the Researcher.

Furthermore, the cultural and civic site around the complex of Amman Municipality at Ras Al-Ain, "translated to the origin of the water spring," consist of several buildings for public use, such as the city hall and the Museum of Jordan, where urban sprawl was prohibited because it is where Amman's water stream "Sail Amman" generates. Unfortunately, public access was prohibited as well for the same reason. However, even though the biggest area of the site is inaccessible, the municipality opened access to some parts and added some valuable activities to attract locals such as a sport field and a playground. Scenes from the site are shown in figure 52;

Figure 52: Scenes from the cultural civic site around the complex at Amman's municipality complex, Ras Al-Ain. Courtesy of the Researcher.

As for Amman's Climate, Topography, Natural Resources and environmentally related challenges; Amman's topographical profile varies, and this creates an impact on the microclimate where immoderations can be experienced, such as the center of the city being subjected to heavy rains. According to Potter et al. (2009), the climate of Amman is well known for its cold rainy winter (Potter, Darmame, Barham & Nortcliff, 2009).

Table 9: Observed Climatology of Precipitation in 1901and 2020, Historical and current mean temperatures and precipitation levels in Amman. - Statistics retrieved from the Climate change knowledge portal. (World bank org. 2021)

Year	1901	2020
Mean Temperature (Celsius)	17.64	20.01
Precipitation (mm)	97.33	109.88

The changing climate, globally and locally, has affected the city of Amman. Studies provide anticipation of more increased temperatures in the future (Figure 53)

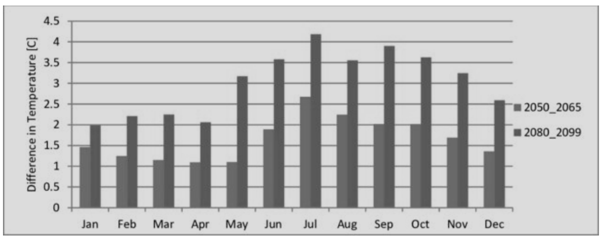


Figure 53: Temperature expected projection. Abdulla, F. 2020.

Also, at its center, floods have become very usual due to the hefty rainfall, which had been elevating and exposing the area with its assets and inhabitants to various hazards on many scales, paralyzing the function of the city's systems such as electricity, transportation, and education (100RC,2017). The main areas experiencing floods are the site of the roman theater with the areas and roads leading to it, as it is the lowest point topographically. See Figure 54. As well as for several main streets, one of which is Quraysh commercial street shown in figure 55.

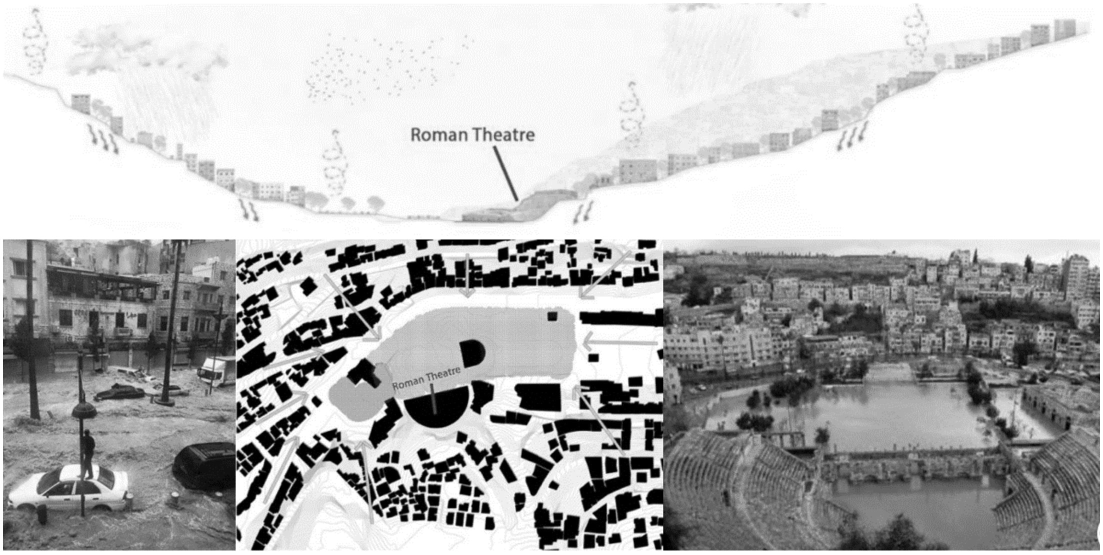


Figure 54: Section, Map and scenes from the lowest point within the city center being subjected to frequent floods due to heavy rain fall. (Ahmed, 2020)

Some studies on Amman show evidence of environmental degradation, one of which is that the city is going through a water stress situation due to climate change (Ray, P. et al. 2012), which can be ironic somehow as the city of Amman has been facing the devastating loss of human life and assets recently due surface floods. Although this had been caused by the poor infrastructure of the city, which is shown at its peak in the city center, a recent study identified and evaluated this situation and concluded that more than 60% of the roadways had poor drainage conditions which led to tremendous environmental problems (Al-Houri, Z. 2012). A recent publication on flood risk management in urban areas analyzed some areas of Amman’s city Centre that had been witnessing major surface floods due to storm water runoff that causes a high rise in the water level in the streets, leading to water breaking into the buildings on the ground and basements levels. See figure 55.

a b c d

Figure 55: Scenes from Al. Quraysh street in Amman city center after water rose above street level due to the February 2019 surface floods. a, b & c; (Al-Washah, 2019). d; Courtesy of GAM.

The study showed that the rainfall amounts –even if intensified due to climate change- are not highly unusual compared to previous rainstorms within the last five years, as stated by Abdulla, F in 2020. However, the poor water management and drainage system in the urban infrastructure are the primary reasons for the elevated severe flooding (Al-Washah, 2019). Furthermore, statistical data on rainfall precipitation mentioned previously proves this intensification which grew from a yearly average of 97 mm in the early 1900s, to 110 mm towards the end of the century (World bank org).

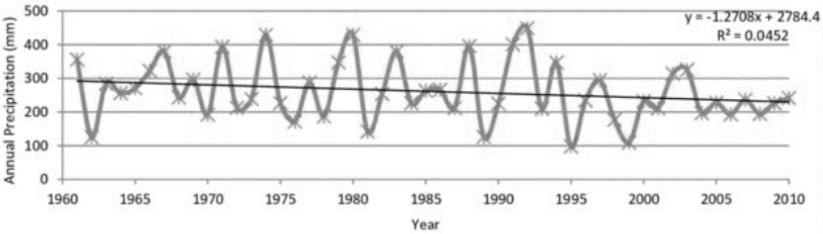


Figure 56: Annual Precipitation for Amman between 1960 and 2010. Abdulla, F. 2020.

Other issues are the overpopulation and congestion within downtown Amman and its surrounding mountains, heavy traffic, air pollution (figure 58), and elevated temperatures (figure 57) due to the increased urban heat island effect (UHIE). The official statistical data on the yearly mean temperatures in the city rose from around 17 Celsius in the early 1900s, reaching 20 Celsius by the end of the century (World bank org, 2020). The degradation of the conditions of the grey infrastructure and the degradation of natural environment, which increases storm water runoff, is a crucial part of this situation. (Liquete et al. 2015; Casal, et al., 2015); Jaffe, et al., 2010).

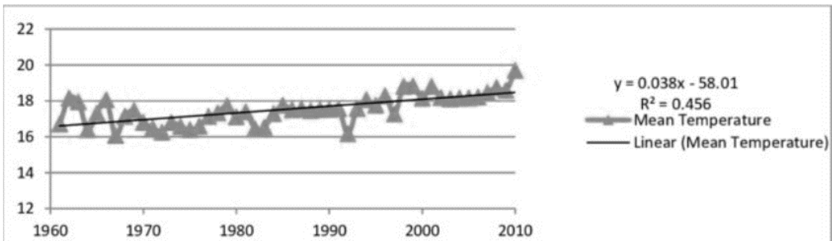


Figure 57: Mean annual temperature for Amman Abdulla, F. (2020)

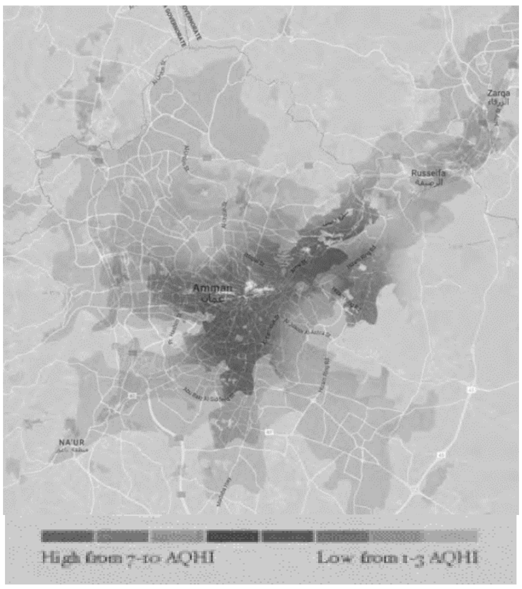


Figure 58: Air Pollution concentration, March 2020 – GAM Resiliency profile.

Moreover, the city lacks sufficient natural resources, such as water sources, food, energy, and green outdoor areas. According to the resilient city strategy for Amman, this issue brings a big challenge for the local government to meet the current and future demand on essential resources, which must be put into planning strategies so that the city can meet the needs of its inhabitants (100RC,2017).

As such, planning for and implementing GI strategies can naturally help bring ecosystem benefits and services to people such as saving energy, promoting human health and wellbeing, storm water management, decreasing of noise and air pollution, and reduction of yearly elevated temperatures with its consequent adverse effects. Where here, GI is seen as a promising alternative to traditional infrastructure which is able to provide naturally inspired solutions in a dense urban context where natural environment is highly degraded and is very challenging to traditionally restore.

To this end, and as the previous discussions suggests that the city is now under a lot of pressure due to the changing climate and its limited economic, physical, and natural resources. Preparing for DRR and resiliency must take into consideration the various challenges currently facing the city with its urban, social and environmental systems, which were classified into two main categories by 100 resilient city organizations in 2017 as follows;

I. Infrequent acute events include surface floods, drought, heatwaves, infrastructure failure, and others.

II. Frequent chronic stressors include the lack of natural resources, fast-changing demographics due to the ongoing urban sprawl and the refugee/migration influx, heavy traffic, and high energy cost, amongst others.

However, and as Amman was chosen as one of the cities for 100RC, yet the strategy set by the official resiliency officers at the local municipality is still limited to it enhancing its urban infrastructure and does not withhold any focus towards enhancing social or environmental components of resiliency at this stage

(Unofficial interview at GAM resiliency office) implies the need to tackle specific analysis of the city towards these aspects.

To highlight this limitation, Amman's resilient city vision withholds specific strategies being developed for implementation and are summarized into specific goals as follow; Improving the mobility system, promoting walkability, institutionalize planning in the city, digitally connecting the city, improve energy efficiency, apply green building codes, improve waste management, enhance employment, support local business, empower women, support youth, promote sense of belonging amongst citizens as well as promoting participation and engagement. (Resilientcitiesnetwork.org/ResilientAmman).

Chapter 5

FINDINGS AND DISCUSSION

Within this chapter, the quantitative data will be analyzed and discussed. In the first section the pro-environmental behavior questionnaire survey will be discussed for its case sensitive based methods. In the second section space syntax and graph theory based analysis is conducted and in the following section they will be merged for an integrated approach towards human ecosystem spatial analysis. Results then discuss proper GI oriented approaches in the final section.

5.1 Pro-Environmental Behavior and the Questionnaire Survey

Within this part of the case study chapter, the researcher will conduct a questionnaire survey targeting local communities in the study area. As discussed in the methodology chapter; this step is crucial for developing an overall understanding of the individual's environmental perception. based on pro-environmental behavior models, which assess people's behavior toward the environment in an interpretive approach.

5.1.1 Basis and Limitations

For this study, the preferable model for pro-environmental behavior is kept simple due to the previously discussed limitations within the population within the study area, being very multi-cultural under privileged.

The survey is based upon the most popular models of pro-environmental behavior are known to be the quickest and simplest in analyzing and measuring environmental knowledge, awareness, and concern towards positive environmental behavior, where the gaps and barriers between the value possessed and taking action are interpreted.

A simple illustration of this is shown below in figure 59, as adapted previously from literature and developed by the researcher. This model is essential, as it combines forces towards advancing an individual's environmental values towards action, which further help develop environmental awareness in communities.

Figure 59: Pro-environmental behavior progression simple model.

The research survey will take place in the city center of Amman. The questionnaire for the local communities will be conducted traditionally on-site due to the urban poor nature of the subjects of the survey which makes more modern approaches uneasy. More limitations have been considered due to the educational background of the inhabitants, where it was highly expected that due to poor education levels due to the poor urban conditions, a significant number of the respondents may face difficulty conducting the questions for two reasons; language barriers and lack of sufficient scientific background to comprehend the data within. For those reasons, the researcher purposely approached samples onsite for assistance, if needed. Also, the questionnaire is translated into the local language "Arabic" with a simple "less" scientific terminologies for respondents; ordinary people- to be able to comprehend the questions easily.

5.1.2 Data Collection and Description Methods

The data collected through the questionnaire survey will be conducted over a number of samples representing the whole population. An initial number of subjects for the questionnaire survey was calculated using the Raosoft online sample size calculator – as shown next, where a 5% margin of error was accepted and a 95%

confidence level was needed. Given the 52,475 population size within the city center, and a 50% response distribution, the survey will be conducted with 382 subjects. The significance level here is the margin of error and is usually set to 5%. It represents the risk of getting the true null hypothesis of the survey.

Sampling methods include probability sampling and non-probability sampling. Non-probability sampling is traditionally used within qualitative research and indicates a non-random selection of the sample representing the population which is usually based on the researcher's criteria of choice, thus allowing a more accessible collection of specific data. Within each sampling method lies several sampling types. For this survey, this research will be conducted as a non-probability sampling method applying a purposive sampling selection which allows the researcher, based on the purpose of the survey and their judgment, to select the sample out of the population and address the study towards them based on the criteria intended. Figure 60.

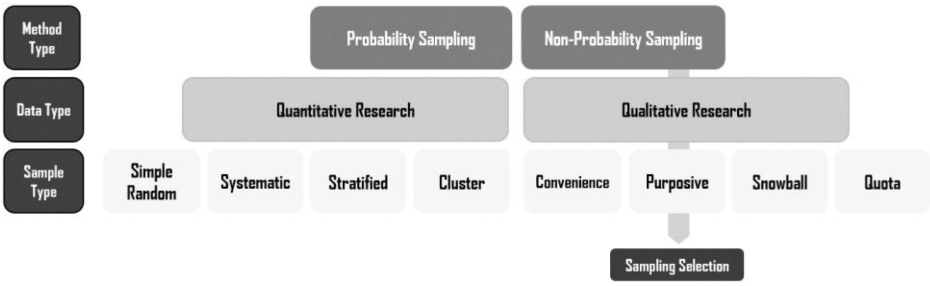


Figure 60: Sample selection methodology.

Data collected from each questionnaire must be described to conduct a statistical analysis to test their significance. In addition, the data collected must be summarized by the researcher to review and collect descriptive statistics upon translating them. In this study, descriptive data analysis organizes data in tables and graph charts based on frequencies and percentages as a helpful way to assess results. Microsoft Excel and IBM® SPSS will help organize, interpret and visualize the data.

5.1.3 Statistical Data Analysis Method

The data analysis will take some specific criteria that address the study's central issue: GI-oriented resiliency. As defined within the case “Amman city center” profile, the area consists of a mix of communities from several cultural backgrounds, which makes the society somehow scattered. The fact that there are mixed uses within the urban structure requires a careful distribution of the survey across all types for the sample to truly represent the whole population in the area. From this perspective, the survey firstly questions respondents for their cultural background. This is done for the purposes of categorizing the samples, Figure. 61

2. What is your cultural back ground, ethnic representation?

☐ Local citizen

☐ Immigrant

☐ Other; please state: ……………………………………………

Figure 61: Sample question addressing the main criteria for the statistical data analysis methodology grouping the variables.

When one of the responses is open-ended like we see in this question: “other; please state……….”. The statistical analysis methods usually add a specific category to the answers. From the perspective of this case, the “others” are expected to be from those waves of immigrants who came in recent decades to the city due to political conflicts at their countries as mentioned previously. This raises the question; if the others are predicted and known to be more likely immigrants, why did not the researcher stop at just the two variables “local citizen or immigrant?”. As such, the researcher is set by another limitation, which was explained earlier, the immigrants who came to the city came in waves, some of whom are those who settled since the development of the town and even before it was known as “Amman the capital city of Jordan in 1921”. And subsequently were part of the city development and were given local citizenship, such as the Caucasian communities from the early 1900s and Palestinian communities from the late 1940s and late 1960s. Therefore, they are predicted to have a sense of belonging and responsibility towards their permanent living place. However, here it is worth mentioning that some of the early Palestinian immigrants who fled to refugee camps within the city center of Amman refused to be granted local citizenship due to their beliefs that it would deny them the right to one day go back home, which highly implies how they have no sense of belonging or attachment to their place of living.

Moreover, the "others" in the question refer to the more recent immigrant communities who were not granted nationality and are still living a temporary life, such as the Iraqi communities who fled the war in the late 1990s and the Syrian communities who fled war the late 2000s. Another crucial part of the expected "other category" is the individuals who come and settle in big groups as workers with temporary permits, such as the Egyptian workers who are a big known part of individuals dwelling within the city center, making them present community as a whole. Some minimal expected categories might include workers other than those from Egyptian communities, such as individuals who seek better living conditions and work atmosphere and some business owners. Figure 62.

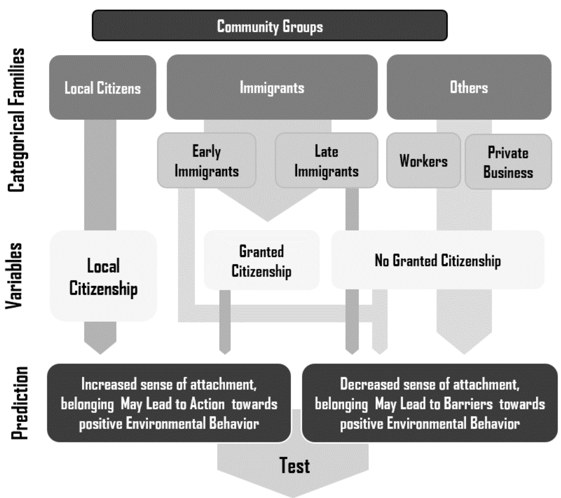


Figure 62: Illustration showing development of the statistical analysis methodology.

To this end, advanced statistical analysis usually needs a specific null hypothesis as a prediction – as a value of comparison to test the results and conclude from them. Therefore, the statistical analysis methodology will follow a descriptive research design and will set this limitation to how the samples will be divided into groups for comparison in a way that supports and addresses the study's main research question.

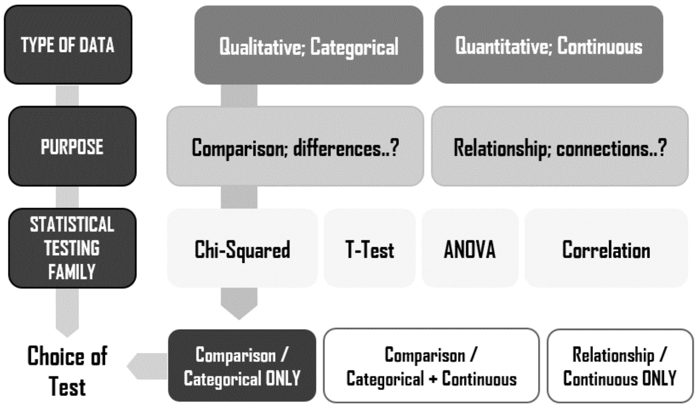


Figure 63: Illustration showing the choice of the statistical analysis test.

The variables of data analysis referred to in statistical data methods as categorical variables here are qualitative. Therefore, the study will conduct a Chi-Squared test between the groups' "variables" of comparison "Local VS Immigrant". This sets the ground for the null hypothesis that will help the researcher test the significance of the data acquired from the questionnaire, which is the claim or the prediction of the survey. Also, it allows comparison between several groups of categorical data, as in this study. Statistical testing will be conducted through IBM® SPSS platform. The overall statistical analysis research methodology is as follow in figure 64;

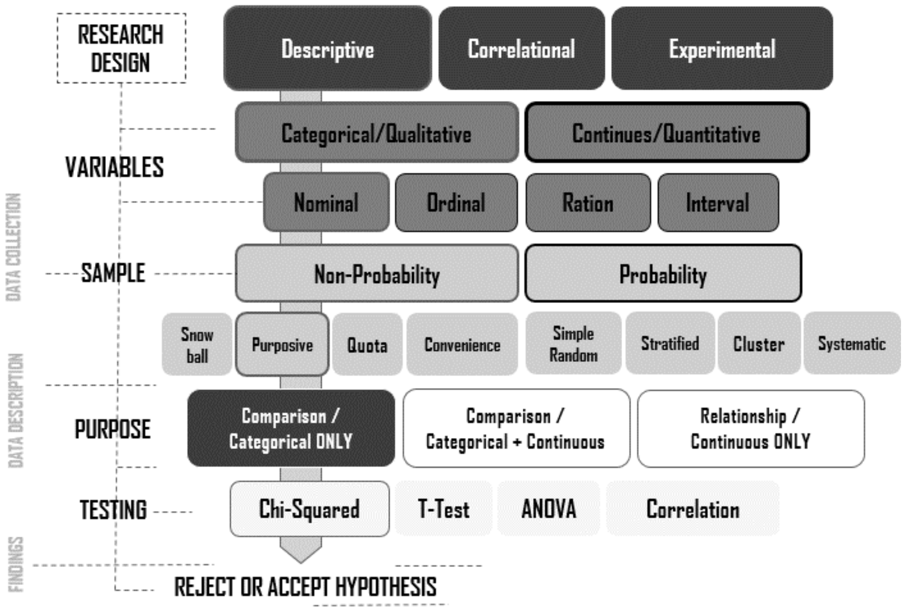


Figure 64: Illustration showing the statistical analysis research methodology.

5.1.4 Results; Statistical Analysis

The results of the questionnaire survey will be obtained following set of processes and procedures shown below in figure 65;

Figure 65: Illustration showing the statistical analysis research process.

<u>Setting Hypothesis</u>; For a formal way of writing the prediction about the population being surveyed, the research sets its main claim as a statistical hypothesis and rephrased it into null and alternative hypotheses for further testing. The central hypothesis discussed earlier is concerned about two main variables "local citizens and immigrants with or without citizenship, citizen =value/action, or non-citizen =barriers towards positive environmental behavior". Here the Null hypothesis, which is identified to show no relationship or effect between variables, would be;

Being a local citizen or an immigrant with granted citizenship will have no effect on showing positive environmental behavior values or barriers towards its action.

Whereas the Alternative hypothesis would be;

Being a local citizen or an immigrant with granted citizenship will increase positive environmental behavior values and decrease the barriers towards its action.

Data Description; Descriptive Statistics; Within this part of the study, the researcher, after collecting the 386 questionnaire survey responds conducts Data Description. The descriptive statistics stage aims at summarizing and organizing the massive amount of data collected for all its characteristics. But mainly, as the research design was set, and due to the general categorical nature of the variables, the overall results will be in a comparative approach between relevant sets of the data described for frequencies, percentages, and cross-tabulation.

The first question within the questionnaire focused on measuring the educational background within the sample representing the population within the study area. The majority of the sample were within educational levels ranging between diploma and bachelor degree with holders, were as those ranging between no-education to middle school were a smaller share, and those with higher education are at minimum range. The descriptive analysis frequencies and percentages procedures were conducted; the results are presented as follows. Table 10, figure 66.

Table 10: Frequencies and Percentages of educational levels within the survey sample are presented in number and percentage, conducted through the SPSS platform.

level of education

	Count	%
Non-Educated	67	17.4%
Middle-High School	54	14.0%
Diploma	96	24.9%
Bachelor	130	33.7%
Masters	24	6.2%
PhD	15	3.9%

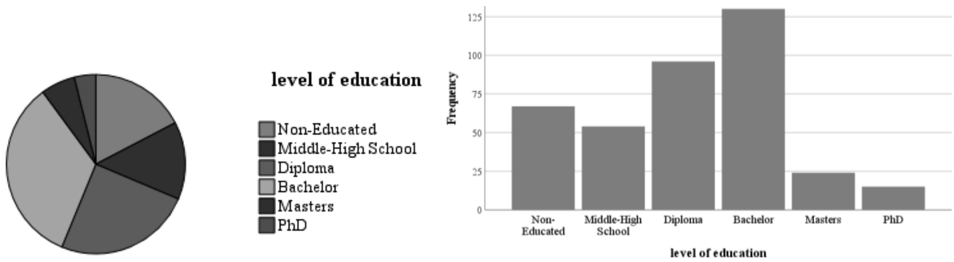


Figure 66: Charts showing educational level percentages and frequencies. Conducted through the SPSS platform.

The second question focused on measuring the cultural representation – background of the population. Due to the diverse nature of the people, the study categorized all residents with granted citizenship or locals as citizens, while those without citizenship, immigrants, and workers as non-citizens. The results showed that even though closely distributed, the number of citizens is more minor than non-citizens, which was initially expected after the historical to current background analysis on the study area before the survey and is now further confirmed by the results. Once more, the descriptive analysis frequencies and percentage procedures were conducted; the results are displayed as follows. Table 11, figure 67.

Table 11: Frequencies of cultural representation within the survey sample presented both in number and percentage, conducted through the SPSS platform.

Citizen or non-Citizen

	Count	%
Citizen-Granted Citizenship	177	45.9%
Non-Citizen	209	54.1%

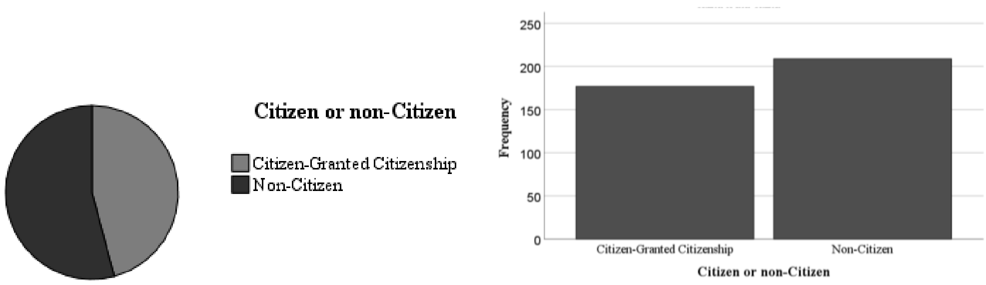


Figure 67: Charts showing cultural representation percentages and frequencies. Conducted through the SPSS platform.

The descriptive analysis procedure cross-tabulation was conducted to compare the two categorical variables from questions 1 “education level” and 2 “background”. The results show that most citizens have a bachelor's degree education level. While those non-citizens have two central majorities, one is non-educated, and the second is withholding only a few educational diploma degrees, typical for workers seeking low-income work opportunities. The results are shown as follows. Table 12, figure 68.

Table 12: Comparison between educational level vs. citizenship frequencies and percentages within the survey sample presented both in number and percentage, conducted through the SPSS platform.

level of education * Citizen or non-Citizen Cross tabulation

			Citizen or non-Citizen: Citizen-Granted Citizenship	Citizen or non-Citizen: Non-Citizen	Total
level of education	Non-Educated	Count	3	64	67
		%	1.7%	30.6%	17.4%
	Middle-High School	Count	26	28	54
		%	14.7%	13.4%	14.0%
	Diploma	Count	15	81	96
		%	8.5%	38.8%	24.9%
	Bachelor	Count	103	27	130
		%	58.2%	12.9%	33.7%
	Masters	Count	22	2	24
		%	12.4%	1.0%	6.2%
	PhD	Count	8	7	15
		%	4.5%	3.3%	3.9%
Total		Count	177	209	386
		%	100.0%	100.0%	100.0%

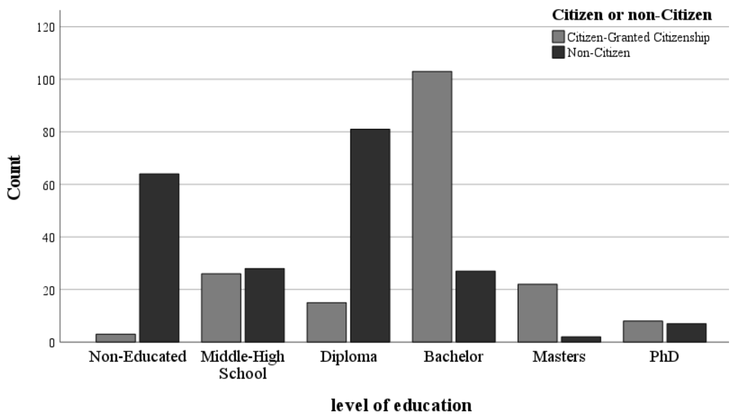


Figure 68: Bar chart showing Comparison between educational level vs. citizenship frequencies. Conducted through the SPSS platform.

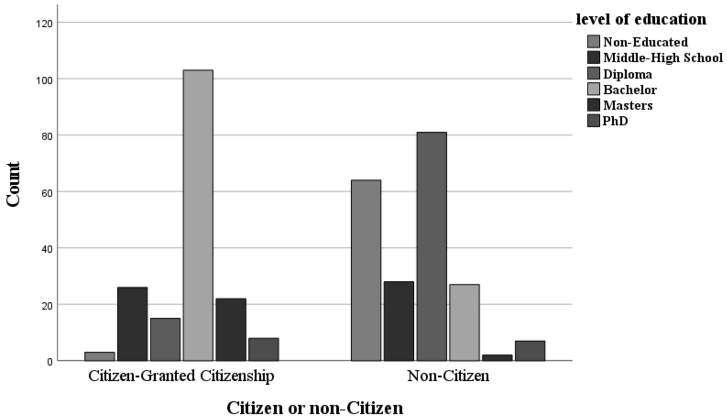


Figure 69: Bar chart showing Comparison between educational level vs. citizenship frequencies as separate groups. Conducted through the SPSS platform.

The third question focused on measuring the awareness of GI strategies/features and their associated benefits to the population. The results showed that even though closely distributed, the number of people aware of GI and its related benefits was less than those who were aware. Again the descriptive analysis frequencies and percentage procedures were conducted; the results are shown as follows. Table 13, figure 70.

Table 13: Frequencies of GI awareness within the survey sample presented both in number and percentage, conducted through the SPSS platform.

Awareness on GI	N	%
Yes	180	46.6%
No	206	53.4%

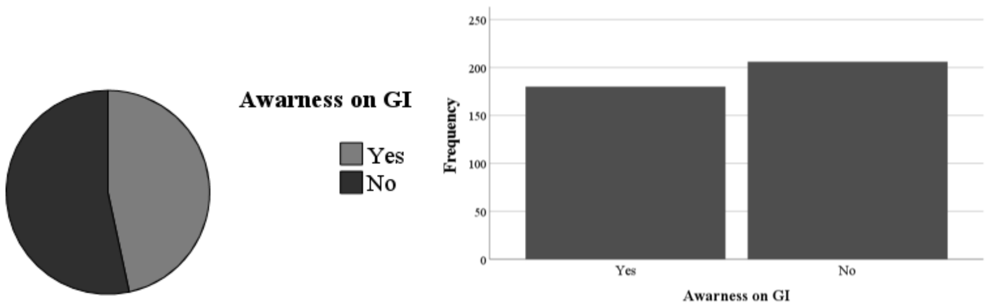


Figure 70: Chart showing GI awareness percentages and frequencies. Conducted through the SPSS platform.

Next, a comparison between the level of education and GI awareness will be conducted to draw a comparison between both. Results show that the awareness of GI in each category of the educational class does not imply a significant relationship between both. All categories show a high count of non-awareness, except the master's and Ph.D. higher education categories, indicating better knowledge. The descriptive analysis procedure cross-tabulation was conducted; the results are given as follows.

Table 14: Comparison between educational level vs. citizenship frequencies and percentages within the survey sample presented both in number and percentage, conducted through the SPSS platform.

level of education * Citizen or non-Citizen Cross tabulation

			Citizen or non-Citizen		
			Citizen-Granted Citizenship	Non-Citizen	Total
level of education	Non-Educated	Count	3	64	67
		% within Citizen or non-Citizen	1.7%	30.6%	17.4%
	Middle-High School	Count	26	28	54
		% within Citizen or non-Citizen	14.7%	13.4%	14.0%
	Diploma	Count	15	81	96
		% within Citizen or non-Citizen	8.5%	38.8%	24.9%
	Bachelor	Count	103	27	130
		% within Citizen or non-Citizen	58.2%	12.9%	33.7%
	Masters	Count	22	2	24
		% within Citizen or non-Citizen	12.4%	1.0%	6.2%
	PhD	Count	8	7	15
		% within Citizen or non-Citizen	4.5%	3.3%	3.9%
Total		Count	177	209	386
		% within Citizen or non-Citizen	100.0%	100.0%	100.0%

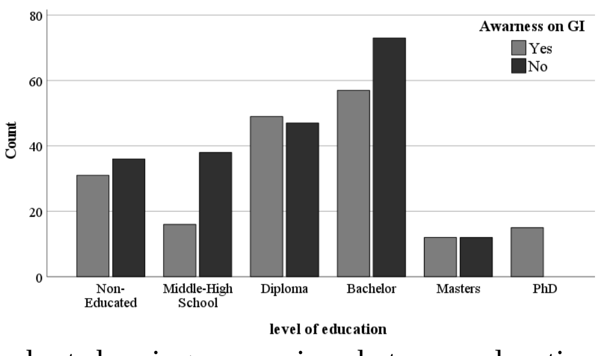


Figure 71: Bar chart showing comparison between educational level vs. GI awareness frequencies. Conducted through the SPSS platform.

Next, a comparison between citizenship and GI awareness will be conducted to draw a comparison between both. Results show that a more significant portion of the population is unaware of GI and its related benefits. This percentage is higher among non-citizens, which further implies that non-citizens who had lower educational levels are the ones most unaware of GI. The descriptive analysis procedure cross-tabulation was conducted, and the results are shown as follows. Table 15, figure 72.

Table 15: Comparison between GI awareness vs. citizenship frequencies and percentages within the survey sample presented both in number and percentage, conducted through the SPSS platform.

Citizen or non-Citizen * Awareness of GI Cross tabulation

			Awareness on GI		Total
			Yes	No	
Citizen or non-Citizen	Citizen-Granted Citizenship	Count	71	106	177
		% within Awareness on GI	39.4%	51.5%	45.9%
	Non-Citizen	Count	109	100	209
		% within Awareness on GI	60.6%	48.5%	54.1%
Total		Count	180	206	386
		% within Awareness on GI	100.0%	100.0%	100.0%

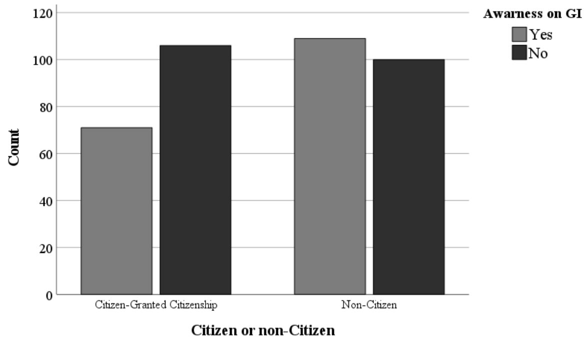


Figure 72: Bar chart showing comparison between GI awareness vs. citizenship frequencies. Conducted through the SPSS platform.

Then, comparison was done between the first three questions and their variables; the results will be described as bar charts for the awareness of GI within ***citizens*** and for the awareness of GI within ***non-citizens*** along with their educational levels separately showing how the three variables relate to each other. Figure 73, 74.

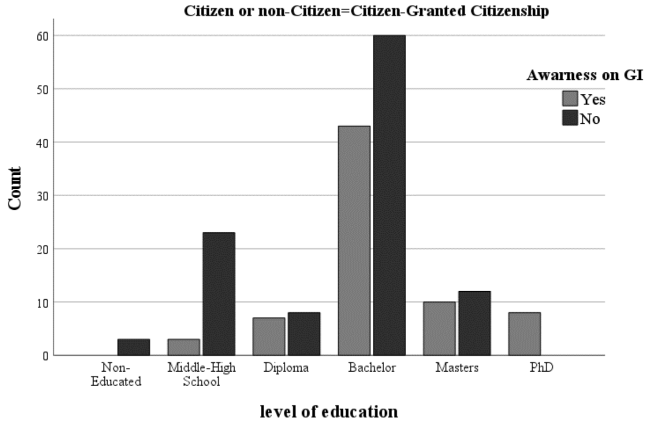


Figure 73: Bar chart showing comparison between GI awareness vs. citizenship "citizen /granted" vs. educational level count, conducted through the SPSS platform.

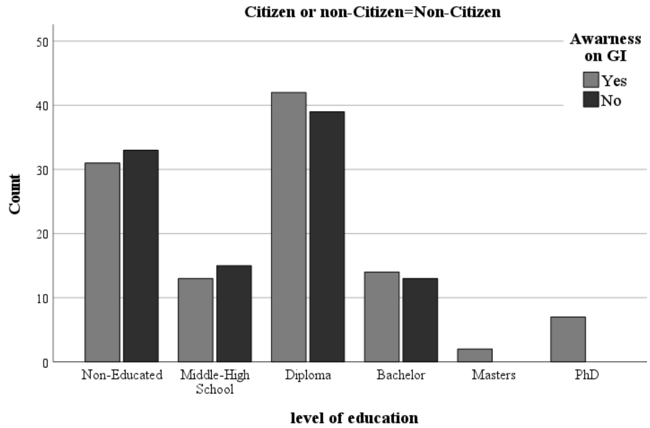


Figure 74: Bar chart showing Comparison between GI awareness vs. citizenship "Non-citizen" vs. educational level count. Conducted through the SPSS platform.

The in following question 4, the researcher set 10 main variables resembling GI elements suitable within an inner city context, as a multiple response question. The purpose of this question is to draw some preference to which GI are chosen within the population being tested as a whole and to gain insight into their general knowledge of the strategies given. Descriptive analysis frequencies and percentage procedures were conducted; the results were produced separately for each variable and then merged as a whole within this following table are for the whole 386 respondents sample. Table 16, figure 75.

Table 16: Summary table showing GI choice and preferences frequencies and percentages. As conducted through SPSS platform and adapted by researcher.

Preferences - GI Choice			
		Count	%
Street Trees	Yes	125	32.4%
	No	261	67.6%
	Total	386	100%
Green Walls/Roofs	Yes	120	31.1%
	No	266	68.9%
	Total	386	100%
Community Gardens	Yes	97	25.1%
	No	289	74.9%
	Total	386	100%
Urban Farming	Yes	68	17.6%
	No	318	82.4%
	Total	386	100%
Rainwater Harvesting Systems	Yes	47	12.2%
	No	339	87.8%
	Total	386	100%
Neighborhood Parks	Yes	146	37.8%
	No	240	62.2%
	Total	386	100%
Private Gardens	Yes	119	30.8%
	No	267	69.2%
	Total	386	100%
Green Spaces	Yes	116	30.1%
	No	270	69.9%
	Total	386	100%
Public Parks /Recreational Areas	Yes	162	42.0%
	No	224	58.0%
	Total	386	100%
Preamble Pavements	Yes	50	13.0%
	No	336	87.0%
	Total	386	100%

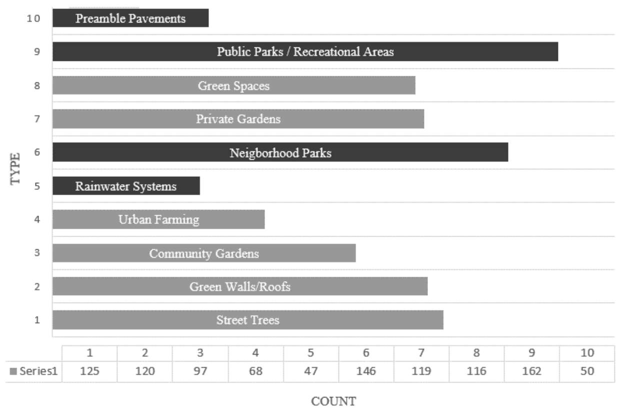


Figure 75:Horizontal bar chart showing GI choice/preference within the sample. Data retrieved through SPSS, chart adapted by the researcher through Excel sheets.

Results show that the sample generally had little knowledge and preference towards the more advanced GI types such as preamble pavements and rainwater harvesting systems. And showed more preference towards the very traditional types, especially at the neighborhood and public scale.

Previously, the analysis results showed that local citizens withhold better educational background. To investigate whether this affects the preference of GI typologies, the researcher will conduct a cross-tabulation procedure to describe the frequencies of the two categories. This will help define proper GI strategies in the following section of the study because the survey results showed that most of the sample resembling the population are non-citizens. However, only the YES values for each GI type for both citizen categories will be conducted for a more straightforward representation of data. Table 17, figure 76.

Table 17: Summary table showing GI choice, preferences frequencies, and percentages between the two sample categories cross-tabulation. As conducted through the SPSS platform and adapted by the researcher.

Preferences -GI Choice * Citizen or non-Citizen Cross tabulation

	Citizen		Non-Citizen		Total	
GI Preference - Choice	Count	%	Count	%	Count	%
1, Street Trees	55	44%	70	56%	125	100%
2, Green Walls/Roofs	68	57%	52	43%	120	100%
3, Community Gardens	62	64%	35	36%	97	100%
4, Urban Farming	37	55%	32	45%	68	100%
5, Rainwater Harvesting System	31	66%	16	34%	47	100%
6, Neighborhood Parks	76	52%	70	58%	146	100%
7, Private Gardens	59	50%	60	50%	119	100%
8, Green Spaces	70	60%	46	40%	116	100%
9, Public Parks /Recreational Areas	89	53%	73	47%	162	100%
10, Preamble Pavements	28	56%	22	44%	50	100%

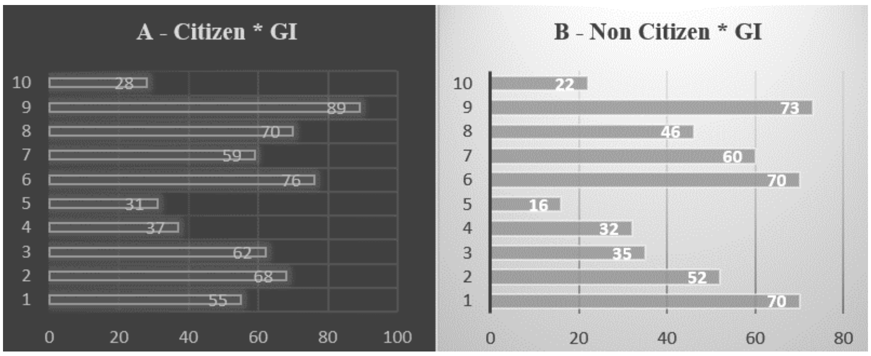


Figure 76: A- showing bar chart for citizen*GI choice, while B- shows bar chart for non-citizen*GI choice. Data produced within the SPSS platform, tables adapted by the researcher via excel sheets.

The comparison shows that types 6 and 9 still prevail within both categories. However, non - citizens' choice of selecting one was prevailing as well, while the rest of the data show similarities between both categories for the whole sample.

Question 5 focuses on investigating whether the respondents use or have any of the GI strategies mentioned to them previously in question 4, measuring the availability of urban greening. Results showed that more than half of the respondents have UGI available at their residence or neighborhood level. Again the descriptive analysis frequencies and percentage procedures were conducted; the results are as follows.

Table 18: Availability of GI frequencies and percentages within the sample. Conducted by SPSS platform.

UGI availability at the residence or neighborhood level	Count	%
Yes	222	57.5%
No	164	42.5%

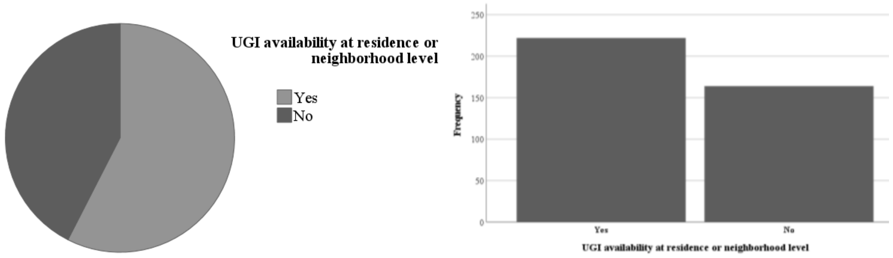


Figure 77: Charts showing percentage and frequencies of UGI availability for the whole sample. Conducted by SPSS.

A comparison between whether the two categories of respondents, "citizens and non-citizens," answered differently to the question is also conducted to determine whether being a citizen gives more privilege to owning or living close to GI. The results showed that most respondents with available UGI within their residence or neighborhood are those from the citizen's category. Finally, the descriptive analysis procedure cross-tabulation was conducted; the results are shown as follows. Table 19, figure 78.

Table 19: Cross-tabulation between Citizen – Noncitizen * UGI Availability. Produced by the SPSS platform.

UGI availability at residence or neighborhood level * Citizen or non-Citizen Cross tabulation

		Citizen or non-Citizen					
		Citizen-Granted Citizenship		Non-Citizen		Total	
		Count	%	Count	%	Count	%
UGI availability at residence or neighborhood level	Yes	143	80.8%	79	37.8%	222	57.5%
	No	34	19.2%	130	62.2%	164	42.5%
Total		177	100%	209	100%	386	100%

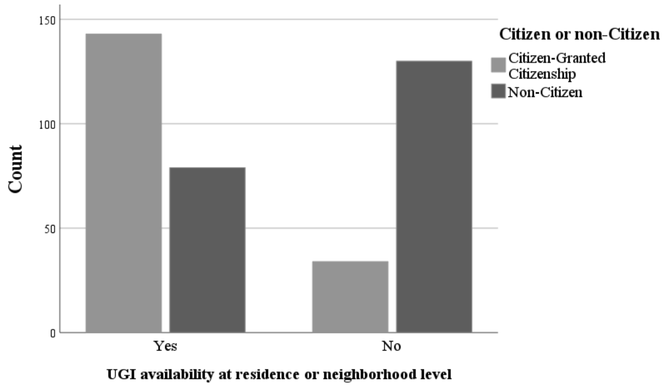


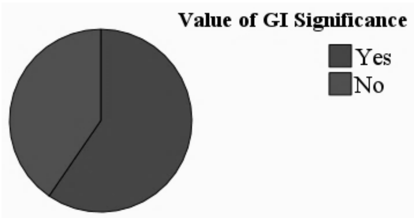
Figure 78: Bar chart showing comparative frequencies between Citizen – Noncitizen * UGI Availability. Produced by the SPSS platform.

Question 6 was intended to explore why the respondents did not use GI from a personal perspective. However, the majority did not respond. Thus it was excluded. The following question, 7, focuses on assessing the population's willingness to participate through GI strategies if found significant. The results showed that the level of respondents who valued GI and were willing to participate was more extensive than those who did not. Again the descriptive analysis frequencies and percentage procedures were conducted; the results are shown in as follows. Table 20, figure 79.

Table 20: Value of GI Significance frequencies and percentages within the sample. Conducted by SPSS platform.

Value of GI Significance

	Count	%
Yes	230	59.6%
No	156	40.4%



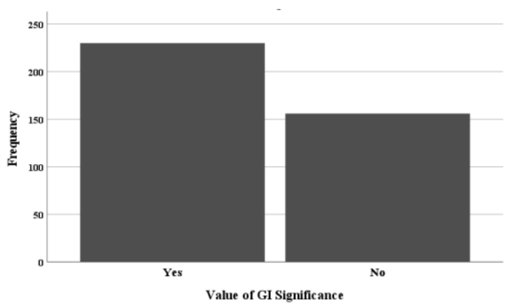


Figure 79: Charts showing percentages and frequencies of Value of GI Significance for the whole sample. Conducted by SPSS.

Comparison between whether the two categories of respondents, "citizens and non-citizens," answered differently to the question is also conducted to draw attention to whether being a local citizen or not gives more value to GI significance to participating and engaging with GI. The results showed that the respondents responded almost evenly to YES, welling to, and NOT from both categories. Finally, the descriptive analysis procedure cross-tabulation was conducted; the results are as follows. Table 12, figure 80.

Table 21: Cross-tabulation between Citizen – Non-citizen * GI value of significance. Produced by the SPSS platform.

Citizen or non-Citizen * Value of GI Significance Crosstabulation

		Value of GI Significance					
		Yes		No		Total	
		N	%	N	%	N	%
Citizen or non-Citizen	Citizen-Granted Citizenship	108	47.0%	69	44.2%	177	45.9%
	Non-Citizen	122	53.0%	87	55.8%	209	54.1%
Total		230	100.0%	156	100.0%	386	100.0%

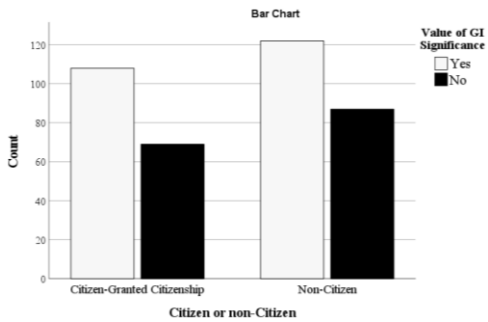


Figure 80: Bar chart showing comparative frequencies between Citizen – Non-citizen * GI value of significance. Produced by the SPSS platform.

Proceeding to question 7, question 8 intends to measure if the population is still willing to corporate if the government subjected an extra cost such as mandatory governmental bills on infrastructure. The results showed the immense majority of respondents refused the idea of paying the cost of GI. Again the descriptive analysis frequencies and percentage procedures were conducted; the results are as follows. Table 22, figure 81.

Table 22: Willingness to Pay extra GI Cost frequencies and percentages within the sample. Conducted by SPSS platform.

	Willingness to Pay extra GI Cost	
	Count	%
Yes	92	23.8%
No	294	76.2%

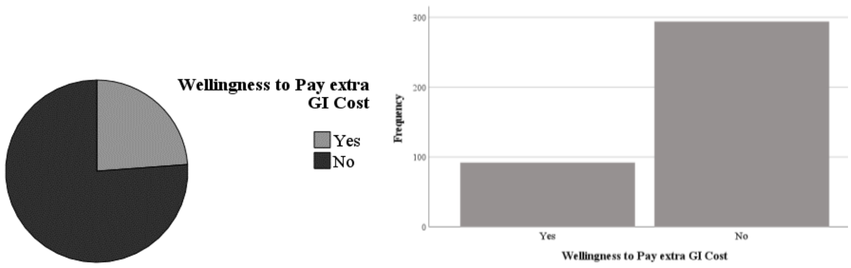


Figure 81: Charts showing percentages and frequencies of Willingness to Pay extra GI Costs for the whole sample. Conducted by SPSS.

The following is a comparison between those who showed a willingness to participate due to the value of significance but refused when suggested needing to pay mandatory costs for GI amongst the sample as a whole. Results showed that from all the people who found GI significant and agreed to participate, more than half of them changed their mind when the extra cost was subjected as a means of participation for GI implementation. In contrast, some of those who did not believe in its significance agreed on paying the additional fees. Thus, the two variables are not dependent on each other as having value did not necessarily imply a willingness to pay. The procedure cross-tabulation was conducted; the results are shown next;

Table 23: Cross-tabulation between willingness to pay * GI value of significance. Produced by the SPSS platform.

Value of GI Significance * Wellingness to Pay extra GI Cost Crosstabulation

		Wellingness to Pay extra GI Cost					
		Yes		No		Total	
		N	%	N	%	N	%
Value of GI Significance	Yes	71a	77.2%	159b	54.1%	230	59.6%
	No	21a	22.8%	135b	45.9%	156	40.4%
Total		92	100.0%	294	100.0%	386	100.0%

Each subscript letter denotes a subset of Wellingness to Pay extra GI Cost categories whose column proportions do not differ significantly from each other at the .05 level.

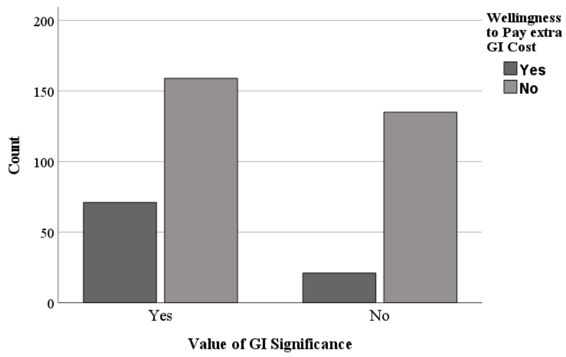


Figure 82: Bar chart showing results of cross-tabulation between willingness to pay * GI value of significance. Produced by the SPSS platform

The researcher then compared the two main population categories, citizens and non-citizens separately, for their willingness to pay. The results showed that in the two categories, most of the respondents were not willing to pay for GI costs. The number of those not willing, however in the non-citizen category was higher. Finally, the descriptive analysis procedure cross-tabulation was conducted; the results are shown as follows. Table 24, figure 83.

Table 24: Cross-tabulation between willingness to pay * Citizen – Non-citizen. Produced by the SPSS platform

Citizen or non-Citizen * Wellingness to Pay extra GI Cost Crosstabulation

		Wellingness to Pay extra GI Cost					
		Yes		No		Total	
		N	%	N	%	N	%
Citizen or non-Citizen	Citizen-Granted Citizenship	50a	54.3%	127a	43.2%	177	45.9%
	Non-Citizen	42a	45.7%	167a	56.8%	209	54.1%
Total		92	100.0%	294	100.0%	386	100.0%

Each subscript letter denotes a subset of Wellingness to Pay extra GI Cost categories whose column proportions do not differ significantly from each other at the .05 level.

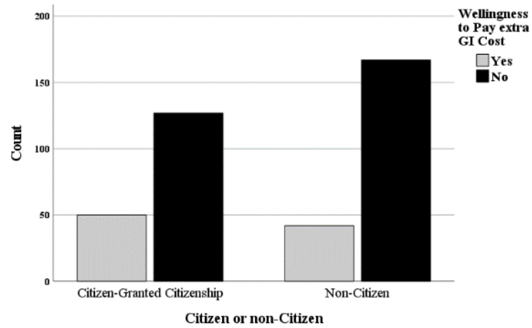


Figure 83: Bar chart showing cross-tabulation results between willingness to pay * Citizen – Non-citizen. Produced by the SPSS platform

Proceeding to questions 7 and 8, a further cross-tabulation procedure will be done for a deeper descriptive analysis of the two main population categories: citizens and non-citizens, which will be used for testing the hypothesis in the following section of this part of the study. The results are shown as follows. Table 25, figure 84.

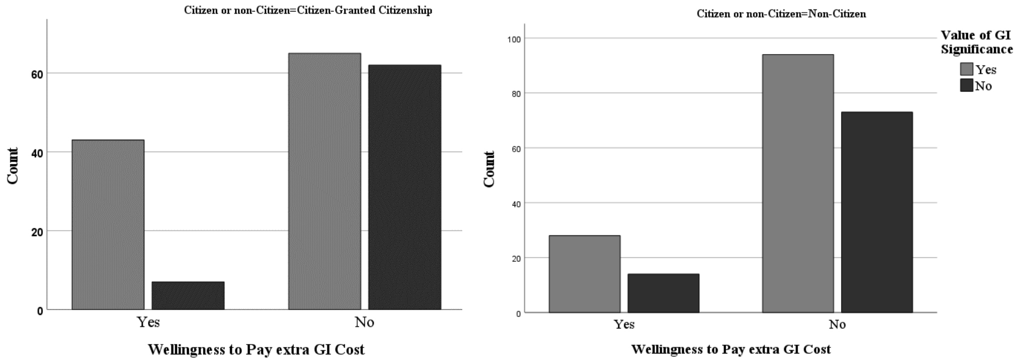
Table 25: Comparison between Value of GI vs. citizenship vs. willingness to pay frequencies and percentages. Conducted through the SPSS platform.

Wellingness to Pay extra GI Cost * Value of GI Significance * Citizen or non-Citizen Crosstabulation

Citizen or non-Citizen				Value of GI Significance Yes	No	Total
Citizen-Granted Citizenship	Wellingness to Pay extra GI Cost	Yes	Count	43_a	7_b	50
			% within Wellingness to Pay extra GI Cost	86.0%	14.0%	100.0%
		No	Count	65_a	62_b	127
			% within Wellingness to Pay extra GI Cost	51.2%	48.8%	100.0%
	Total		Count	108	69	177
			% within Wellingness to Pay extra GI Cost	61.0%	39.0%	100.0%
Non-Citizen	Wellingness to Pay extra GI Cost	Yes	Count	28_a	14_a	42
			% within Wellingness to Pay extra GI Cost	66.7%	33.3%	100.0%
		No	Count	94_a	73_a	167
			% within Wellingness to Pay extra GI Cost	56.3%	43.7%	100.0%
	Total		Count	122	87	209
			% within Wellingness to Pay extra GI Cost	58.4%	41.6%	100.0%
Total	Wellingness to Pay extra GI Cost	Yes	Count	71_a	21_b	92
			% within Wellingness to Pay extra GI Cost	77.2%	22.8%	100.0%
		No	Count	159_a	135_b	294
			% within Wellingness to Pay extra GI Cost	54.1%	45.9%	100.0%
	Total		Count	230	156	386
			% within Wellingness to Pay extra GI Cost	59.6%	40.4%	100.0%

Each subscript letter denotes a subset of Value of GI Significance categories whose column proportions do not differ significantly from each other at the .05 level.

The following bar graphs show separately the willingness to pay for GI vs the Value of GI significance for the two respondent categories; citizens and non-citizens.



a b

Figure 84: (a) Comparison between Value of GI vs. willingness to pay count within Citizens. (b) Comparison between Value of GI vs willingness to pay count within Non-Citizens. Conducted through SPSS platform.

The final question, 8 explores the barriers facing GI application within the population. In this multi-response question, the respondents were freely given the choice to choose as many of the five answers as they saw fit. While almost all the results were chosen closely, choices number 1 "high cost" and 4 "Insufficient efforts by authorities" were among the top choices amongst all respondents. Again the descriptive analysis frequencies and percentage procedures were conducted; the results were produced separately for each variable and then merged as a whole. Table 26, figure 85.

Table 26: Summary table showing Gaps and Barriers towards GI Application frequencies and percentages. Conducted by SPSS platform, adapted by the researcher.

Gaps and Barriers to GI Application

		Count	%
High cost	Yes	181	46.9%
	No	205	53.1%
	Total	386	100%
Lack of Community awareness	Yes	114	29.5%
	No	272	70.5%
	Total	386	100%
Insufficient policies	Yes	136	35.2%
	No	250	64.8%
	Total	386	100%
Insufficient efforts by authorities	Yes	155	40.2%
	No	121	59.8%
	Total	386	100%
Insufficient resources	Yes	121	31.3%
	No	265	68.7%
	Total	386	100%

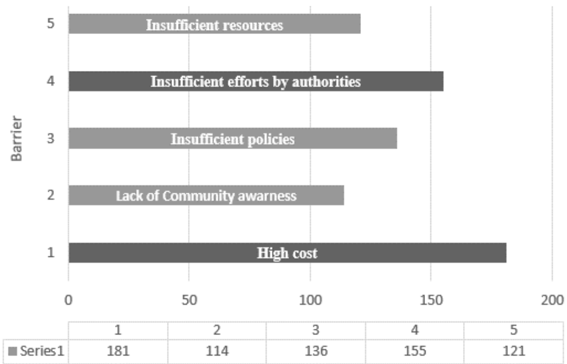


Figure 85: Bar chart showing Gaps and Barriers toward GI Application frequencies. Data Conducted by the SPSS platform, adapted by the researcher on excel sheets.

The researcher will then analyze the data further by separating results from a citizen from those non-citizens to bring a closer look at which barriers are more prevailing for each category. Here, results for citizens are very much similar to the population as a whole, while non-citizens' main concern was the first barrier; cost. The cross-tabulation procedure is used again; the results are shown in as follows.

Table 27: Summary table showing Gaps and Barriers towards GI Application frequencies and percentages between the two sample categories cross-tabulation. As Conducted through the SPSS platform and adapted by the researcher.

GI Barrier * Citizen or non-Citizen Cross tabulation

	Citizen		Non-Citizen		Total	
GI Barrier	Count	%	Count	%	Count	%
1, High cost	98	54.1%	83	45.9%	181	100%
2, Lack of Community awareness	60	52.6%	54	47.4%	114	100%
3, Insufficient policies	66	48.5%	70	51.5%	136	100%
4, Insufficient efforts by authorities	90	58.1%	65	41.9%	155	100%
5, Insufficient resources	60	49.6%	61	54.1%	121	100%
Total count for each category	**333**		**373**			

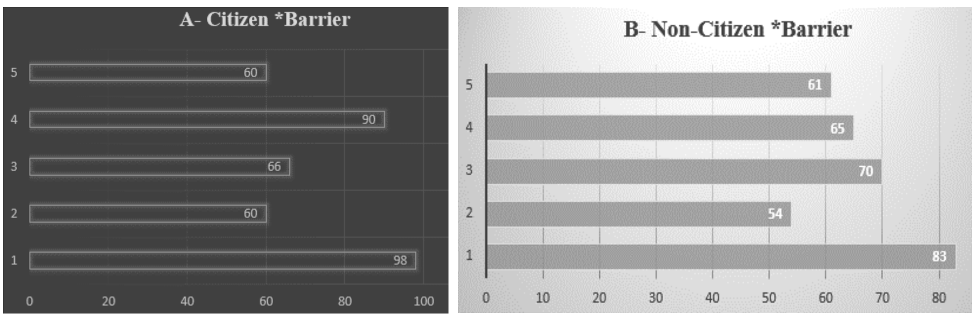


Figure 86: A- shows bar chart for citizen*GI Barrier, while B- shows bar chart for Non-citizen*GI Barrier. Data produced within the SPSS platform, tables adapted by the researcher via excel sheets.

<u>Test Hypothesis; Inferential Statistics</u>; In the process of testing the hypothesis, inferential statistics for formal testing of the set hypothesis enables the research to estimate the population. Moreover, this can help draw conclusions and predictions from the sample.

Testing for significance is essential to prove that the results obtained from the survey and described within the descriptive analysis are accurate and did not just happen by chance. For that, and as the research design was set, a chi-squared analysis will be done along with cross-tabulation for the questions testing knowledge, value, and willingness to pay against the two main categories within our population; citizen or non-citizen. As while the questionnaire survey had multiple questions, each focused on drawing and investigating specific information, only 4 of those are essential for testing the main hypothesis, which is questions 3 “knowledge”, 7 “value of significance,” and 8 “willingness to participate by paying cost”. After that, the researcher drew three main estimates about the population that will help prove whether the previous set hypothesis was true or false and whether the data retrieved by respondents were statistically significant. Finally, we need to test whether the variables are dependent on or independent from each other.

The hypothesis was as follows; the Null hypothesis, which is identified to show no relationship or effect between variables; *Being a local citizen or an immigrant with granted citizenship will have no effect on showing positive environmental behavior values or barriers towards its action.* Whereas the alternative hypothesis is; *Being a local citizen or an immigrant with granted citizenship will increase positive environmental behavior values and decrease the barriers towards its action.*

The aim here is to prove whether the results obtained from the survey are sufficient enough to accept the null hypothesis or reject it. Testing a hypothesis uses a conventional 5% significance level. Any data showing less than 5% means that the null hypothesis is rejected. Cross tabulation and Pearson chi-squared procedures are done as shown in table below as follows.

Table 28: Cross tabulation for Willingness to Pay extra GI Cost * Citizen or non-Citizen * Value of GI Significance * Awareness on GI, conducted through SPSS.

Willingness to Pay extra GI Cost * Citizen or non-Citizen * Value of GI Significance * Awareness of GI Cross tabulation

					Citizen or non-Citizen		Total
Awareness on GI	Value of GI Significance				Citizen	Non-Citizen	
Yes	Yes	Willingness to Pay extra GI Cost	Yes	Count	23_a	17_b	40
				% within Willingness to Pay extra GI Cost	57.5%	42.5%	100.0%
			No	Count	31_a	56_b	87
				% within Willingness to Pay extra GI Cost	35.6%	64.4%	100.0%
		Total		Count	54	73	127
				% within Willingness to Pay extra GI Cost	42.5%	57.5%	100.0%
	No	Willingness to Pay extra GI Cost	Yes	Count	3_a	8_a	11
				% within Willingness to Pay extra GI Cost	27.3%	72.7%	100.0%
			No	Count	14_a	28_a	42
				% within Willingness to Pay extra GI Cost	33.3%	66.7%	100.0%
		Total		Count	17	36	53
				% within Willingness to Pay extra GI Cost	32.1%	67.9%	100.0%
	Total	Willingness to Pay extra GI Cost	Yes	Count	26_a	25_b	51
				% within Willingness to Pay extra GI Cost	51.0%	49.0%	100.0%
			No	Count	45_a	84_b	129
				% within Willingness to Pay extra GI Cost	34.9%	65.1%	100.0%
		Total		Count	71	109	180
				% within Willingness to Pay extra GI Cost	39.4%	60.6%	100.0%
No	Yes	Willingness to Pay extra GI Cost	Yes	Count	20_a	11_a	31
				% within Willingness to Pay extra GI Cost	64.5%	35.5%	100.0%
			No	Count	34_a	38_a	72
				% within Willingness to Pay extra GI Cost	47.2%	52.8%	100.0%
		Total		Count	54	49	103
				% within Willingness to Pay extra GI Cost	52.4%	47.6%	100.0%
	No	Willingness to Pay extra GI Cost	Yes	Count	4_a	6_a	10
				% within Willingness to Pay extra GI Cost	40.0%	60.0%	100.0%
			No	Count	48_a	45_a	93
				% within Willingness to Pay extra GI Cost	51.6%	48.4%	100.0%
		Total		Count	52	51	103
				% within Willingness to Pay extra GI Cost	50.5%	49.5%	100.0%
	Total	Willingness to Pay extra GI Cost	Yes	Count	24_a	17_a	41
				% within Willingness to Pay extra GI Cost	58.5%	41.5%	100.0%
			No	Count	82_a	83_a	165
				% within Willingness to Pay extra GI Cost	49.7%	50.3%	100.0%
		Total		Count	106	100	206

				% within Willingness to Pay extra GI Cost	51.5%	48.5%	100.0%
Total	Yes	Willingness to Pay extra GI Cost	Yes	Count	43_{a}	28_{b}	71
				% within Willingness to Pay extra GI Cost	60.6%	39.4%	100.0%
			No	Count	65_{a}	94_{b}	159
				% within Willingness to Pay extra GI Cost	40.9%	59.1%	100.0%
		Total		Count	108	122	230
				% within Willingness to Pay extra GI Cost	47.0%	53.0%	100.0%
	No	Willingness to Pay extra GI Cost	Yes	Count	7_{a}	14_{a}	21
				% within Willingness to Pay extra GI Cost	33.3%	66.7%	100.0%
			No	Count	62_{a}	73_{a}	135
				% within Willingness to Pay extra GI Cost	45.9%	54.1%	100.0%
		Total		Count	69	87	156
				% within Willingness to Pay extra GI Cost	44.2%	55.8%	100.0%
	Total	Willingness to Pay extra GI Cost	Yes	Count	50_{a}	42_{a}	92
				% within Willingness to Pay extra GI Cost	54.3%	45.7%	100.0%
			No	Count	127_{a}	167_{a}	294
				% within Willingness to Pay extra GI Cost	43.2%	56.8%	100.0%
		Total		Count	177	209	386
				% within Willingness to Pay extra GI Cost	45.9%	54.1%	100.0%

Each subscript letter denotes a subset of Citizen or non-Citizen categories whose column proportions do not differ significantly from each other at the .05 level

In the previous table, the cross-tabulation was set to test all three variables against the population's citizens/non-citizens' category, shown in the column cells compared to the row cells. The rows simultaneously resemble the percentages of those aware of GI, value its significance, and are willing to pay for it. Within the table, each subscript letter donates a subset of citizen or non-citizen categories column proportions that do not differ significantly from each other at the 0.05 set significance level. Those values are highlighted within the table, indicating differences in the non-citizens' willingness to pay, valuing GI, and being aware of it. To prove whether these results are significant enough to deny or accept the hypothesis, subsequent chi-square testing is conducted, but to do the chi-square test to specifically test the cross-tabulation independency of the variable to test the hypothesis, a smaller table of the total count is tested that further categorize all data retrieved from questions 7 "significance of GI = value" and 8 "willingness to pay GI cost". In comparison to citizen and non-citizen categories, as shown as follows.

Table 29: Cross tabulation for Willingness to Pay extra GI Cost * Value of GI Significance * Citizen or non-Citizen. Conducted through SPSS.

Willingness to Pay extra GI Cost * Citizen or non-Citizen * Value of GI Significance Cross tabulation

Value of GI Significance				Citizen or non-Citizen: Citizen-Granted Citizenship	Citizen or non-Citizen: Non-Citizen	Total
Yes	Willingness to Pay extra GI Cost	Yes	Count	43_a	28_b	71
			% within Willingness to Pay extra GI Cost	60.6%	39.4%	100.0%
		No	Count	65_a	94_b	159
			% within Willingness to Pay extra GI Cost	40.9%	59.1%	100.0%
	Total		Count	108	122	230
			% within Willingness to Pay extra GI Cost	47.0%	53.0%	100.0%
No	Willingness to Pay extra GI Cost	Yes	Count	7_a	14_a	21
			% within Willingness to Pay extra GI Cost	33.3%	66.7%	100.0%
		No	Count	62_a	73_a	135
			% within Willingness to Pay extra GI Cost	45.9%	54.1%	100.0%
	Total		Count	69	87	156
			% within Willingness to Pay extra GI Cost	44.2%	55.8%	100.0%
Total	Willingness to Pay extra GI Cost	Yes	Count	50_a	42_a	92
			% within Willingness to Pay extra GI Cost	54.3%	45.7%	100.0%
		No	Count	127_a	167_a	294
			% within Willingness to Pay extra GI Cost	43.2%	56.8%	100.0%
	Total		Count	177	209	386
			% within Willingness to Pay extra GI Cost	45.9%	54.1%	100.0%

Each subscript letter denotes a subset of Citizen or non-Citizen categories whose column proportions do not differ significantly from each other at the .05 level.

The highlighted results indicate how the statistical analysis for the non-citizens shows a significant difference at the 0.05 level. They are interpreted as follows; from the Non-citizen category, we can see that 39.4% showed positive value GI significance and are willing to pay for it, in contrast to 60.6% of those from the citizen category. In another interpretation, only 39.4% of non-citizens who value GI are willing to pay for it compared to 60.6% of citizens who value GI and are willing to pay for it. Moreover, from the non-citizen category, 59.1% of those who showed positive value for GI were NOT willing to pay for it. In comparison, that number is lower within the citizen category, which is 40.9%, which means that citizens who value GI and are willing to pay for it are significantly more prominent in count than non-citizens, which supports the central hypothesis of how being a non-citizen such as an immigrant or a worker can result in decreased environmental behavior and increased barriers towards positive action. To provide evidence that these results are statistically significant chi-squared testing was conducted, and the results are shown in Table 30 as follows.

Table 30: Chi-square testing. Conducted through the SPSS platform.

Chi-Square Tests

Citizen or non-Citizen		Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Citizen-Granted Citizenship	Pearson Chi-Square	18.285[c]	1	<.001		
	Continuity Correction[b]	16.851	1	<.001		
	Likelihood Ratio	20.225	1	<.001		
	Fisher's Exact Test				<.001	<.001
	N of Valid Cases	177				
Non-Citizen	Pearson Chi-Square	1.488[d]	1	.223		
	Continuity Correction[b]	1.091	1	.296		
	Likelihood Ratio	1.516	1	.218		
	Fisher's Exact Test				.293	.148
	N of Valid Cases	209				
Total	Pearson Chi-Square	15.517[a]	1	<.001		
	Continuity Correction[b]	14.573	1	<.001		
	Likelihood Ratio	16.387	1	<.001		
	Fisher's Exact Test				<.001	<.001
	N of Valid Cases	386				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 37.18.

b. Computed only for a 2x2 table

c. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 19.49.

d. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.48.

So mainly, the chi-squared testing aims to answer the main question that will help accept or deny our hypothesis; Is there a relationship between being a citizen or having been granted citizenship with showing value for GI and willingness to participate in it by paying the cost? The chi-square testing was used to help understand the association between our categorical variables; the relationship between value and willingness to pay for GI and citizenship. The results from the chi-squared statistical testing showed that amongst the citizen category, the value is 18.285, with one degree of freedom and a p-value "asymptotic significance set by SPSS" of <0.001, providing very strong evidence against the null hypothesis that amongst the citizens' category there are two variables; value for GI and willingness to participate in paying are independent or not associated in the population which from our data was drawn, meaning that we can accept the alternative hypothesis that being a citizen does imply having more value and fewer barriers for GI. On the other hand, the chi-square testing for the non-citizen's category showed a value of 1.488, with one degree of freedom and a p-value "asymptotic significance set by SPSS" of 0.223, which provides insufficient evidence against our null hypothesis, which means we can reject it; reject that there is no relationship between citizenship and value of GI/willingness to pay for GI.

In other words, to the above interpretations, the chi-testing provides statistical evidence-based proof that from our population tested; There is a strong relationship between being a citizen and having a positive value for GI/willingness to participate in it. To this end, we can statistically conclude that non-citizens are likely to show less value for GI, and more barriers to its application, in contrast to those citizens.

Findings; Interpretation and Generalization; Results showed that from the 386 samples tested for cultural background, 209; 54.1% were non-citizens "no granted citizenship, immigrants, workers", while the citizens "locals or immigrants with granted citizenship" were insignificantly lower in the count at 177, which resembles 45.9% of the population being tested. While there is no significant increase in the number of non-citizens, this and according to the previously statistically proven hypothesis, means that the large number of the population who are not citizens will impose barriers on GI application.

Results show that from the 386 samples tested, the most general category of education was Bachelor's at 33.7%, followed by Diploma at 24.9%, Not-educated at 17.4%, Middle to high school at 14%, Masters at 6.2%, and Ph.D. at 3.9%. This indicates that most of the population are well educated at the diploma and Bachelor's degree levels. However, those from the citizen category showed higher educational levels with a Bachelor's degree at 58.2% against those non-citizens whose main level of education almost closely shifted between non-educated at 30.6% and withholding a Diploma degree at 24.9%. Here, the lower education levels in the non-citizen category impose gaps towards positive environmental behavior and action, such as the lack of value and willingness to participate. As for the educational level affecting awareness and knowledge, the results were as follows;

- Non-citizens are MORE aware of GI at 60.6% of the total sample resembling the whole population “109 out of 209 tested”, in contrast to citizens who were 39.4% aware of GI and its associated benefits “71 out of 177 tested”. To explain this contradicting result, the respondents were asked to provide a reason for how they are aware of GI, or at best, what they think urban greening was. Most of those immigrants answered with “from their background in farming”, and workers who studied diploma in agriculture to pursue a career in it. As it turns out, many of them were associated with urban farming in their place of origin. Moreover, many older immigrants who are not workers came from agricultural communities, such as Palestinians who forcefully left their villages and Circassia’s communities descended from the green Caucasian mountains.
- Furthermore, statistical analysis verified the responses as from the non-citizen’s category, most of those who showed awareness of GI were the non-educated at 28.4% of the whole sample, and the diploma with holders at 38.5% of their entire sample. In contrast to citizens whose background in GI was explained due to their high educational level, a bachelor's degree was 60.6% of their total sample count.
- To this end, the researcher may conclude that lower education levels might affect GI value or willingness to participate within the population tested. Yet, it does not affect the background knowledge and awareness.

Results show that from the 386 samples tested, 222 resembling a percentage of 57.5% of the total sample for the population tested, have urban greening available within their residence or neighborhood level. While 164; 42.5% do not. Of which 177 were citizens, with 143; 80.8% with GI available. In contrast to those 209 citizens, from which only 79, 37.8% have GI available. This shows that citizens with available GI at their residence level or neighborhood levels are significantly higher than those non-citizens; only 19.2% of the citizens do not have GI compared to 62.2% of non-citizens. This is likely because the living conditions for the immigrants and workers, who are usually shallow-income urban dwellers, are very underprivileged.

Results show that from the 386 samples tested, 230 respondents resembling 59.6% of the total sample value GI significance, in contrast to the 156; 40.4% don't. Of those who value GI significance, 47% were citizens, and 44.2% were non-citizens. The results here do not show a significant difference, drawing attention to how citizenship does not affect value. However, this was further investigated against willingness to participate in drawing more profound conclusions.

The results were as follows;

- Out of the whole sample "386 respondents" being tested, 92; 23% of the total showed a willingness to participate in GI costs. In contrast to 294, 76.2% showed unwillingness.
- Out of the total 230 resembling, 59.6% of the respondents valued the significance of GI, while 40.4% did not.
- Only 92 out of 386 respondents were willing to pay for GI cost, from which 71 showed value towards it; 77.2%.
- 294 respondents were not willing to pay GI, of which 159; 54.1% responded with a positive value towards it.

- 45.9% of the sample do not value GI nor are willing to pay for it. At the same time, 54.1% valued GI but were not willing to pay for it.
- This indicates that having a positive value for GI does not necessarily result in positive activities such as willingness to participate in GI costs.

Furthermore, 92 out of 386 respondents showed a willingness to pay for GI. 50 were citizens; 54.3%, while non-citizens were 42; 45.7%. On the other hand, 294 out of 386 respondents were NOT willing to pay for GI, out of which 127; 43.2% were citizens and 167; 56.8% were non-citizens. This indicated that even though not significantly different, non-citizens are less willing to participate by paying for GI than citizens. This can resemble another gap/barrier to its application because more than half of the population are non-citizens.

However, further analysis of how citizens and non-citizens affect both willingness to pay and the value of GI shows that 86% of those citizens who value GI are willing to pay for it, "resembling only 43 respondents". In comparison, 66.7% of non-citizens who value GI are willing to pay for it, "resembling only 28 respondents". While those percentages may seem high, they resemble a very small proportion of the population compared to the count, which puts the willingness to participate given having value as a main gap/barrier towards GI application.

The survey explored more gaps and barriers toward GI application in a multi-response question. The results were as follows;

- High cost was the number one barrier with 181; 46.9% total count of responses.
- Followed by insufficient efforts by authorities as the second most prevailing barrier as chosen 155 times; 40.2% of reactions count.
- Insufficient policies with 136; 35.2% of all responses.

- Scarce resources with 121; 31.3% of all responses. And finally, the lack of community awareness with most minor responses; 114; 29.5%.

Even though they are not significantly different from each other, more barrier was seen prevailing than the other. However, all barriers should be tackled within the population for a successful GI application. The analysis for the barriers further analyzed the chosen ones for the citizenship category. Results showed that the prevailing barrier for both types was still high cost at 54.1% for the citizens and 45.9% for the non-citizens. However, the citizens were more concerned with the lack of efforts by authorities at 58.1% in contrast to non-citizens at 41.9%. This implies that local citizens are more concerned with their local municipalities being a driver for GI applications.

The overall result from the statistical cross-tabulation and chi-square procedure for the significance test of the hypothesis provided sufficient evidence to accept the set hypothesis; *Being a local citizen or an immigrant with granted citizenship will increase positive environmental behavior values and decrease the barriers towards its action*. And there is a clear relationship between citizenship and showing positive environmental value and action.

5.1.5 Inner City GI Strategies Based on Survey

GI *strategies, typologies, features, or elements* – however they are referenced within the literature- were investigated throughout the relevant studies. The researcher concluded with several most commonly mentioned types, summarized previously in the chapter 2. However, the summary included various kinds of traditions such as street trees and untraditional practices such as preamble pavements. It also had GI types at all scales and contexts, ranging from outer city scale to smaller inner city scale. For this study, the researcher filtered and limited the scope of GI types to that internal city

GI and are as follows; Urban gardens, Green corridors/belts, Urban parks, Green walls/roofs, Green spaces, and street trees. However, there had been some other less popular features of urban GI which withhold great potential for inner-city context implementation that engages community members with GI, which are; community gardens and residential gardens. Preamble pavements, artificial and natural surfaces are some features that are highly cost-effective, efficient, and relevant.

However, as GI features were set as a context-sensitive element within the theoretical framework of the study as it is highly dependent on human preferences, it was included within the questionnaire survey conducted as a multi-response question that aims at exploring what the communities within the study area are genuinely lacking, or what they truly understand GI to be and chose to be implemented. To this end, question 4 from the survey summarized and simplified ten main GI types presented to the sample as a multi-response question. The results were as follows;

- The most prevailing GI type chosen by the respondents were the neighborhood parks at 42% and the public parks/ recreational areas at 37.8% of the total responses. This shows interest in the population for having public green places within their area of living and closely by within their neighborhoods,
- Secondly, the respondents chose street trees at 32.4%, green walls/roofs at 31.1%, private gardens at 30.1%, and green spaces at 30.1%. Those results imply further that the population is interested in having GI seen more within the cityscapes, on and between their buildings.
- Lower values were shown for community gardens at 25.1% and urban farming at 17.6%. The fact that these GI types were less chosen can be interpreted by how it is unfamiliar for those inner city dwellers to be engaged with such activities and are not usually found within the inner city context of the city center of Amman.

- Finally, the least chosen responses were towards the untraditional GI types, which to many respondents did not resemble "green" in its traditional manner, which are the preamble pavements at 13% and rainwater harvesting systems at 12.2%. Those types of GI, while highly important for environmental enhancements such as decreasing surface floods that are very common within the study area, are very unfamiliar to the public being approached for the survey, which implies that such strategies must be coordinated within GI planning by specific authorities responsible for infrastructure advancement.

The study further explored if the two categories of the population being tested, citizens and non-citizens, showed different choice and GI preferences because the study area's population count of non-citizens was identified to be higher. The results were as follows;

- Public parks/ recreational areas and neighborhood parks were still the main GI types mostly chosen within both categories, yet the non-citizens preferred them more than citizens.
- Citizens who chose green walls/roofs and green spaces were higher in count than those non-citizens. While for street trees, the category that showed more interest was the non-citizen category. Private gardens were chosen equally through the two categories.
- Citizens chose community gardens more while non-citizens chose urban farming more. This can be explained because being interested in a community garden implies having someplace attachment and responsibility towards the place of residence, which is naturally higher among citizens. While urban farming was more familiar to non-citizens for reasons discussed before; immigrants from

agricultural communities and workers familiar with agriculture within their field of work or living.

- As for the non-traditional GI types, preamble pavements, and rainwater harvesting systems, these types were chosen more often by citizens than non-citizens, which can be due to their educational background.

However, GI is not only sensitive to community preferences. It is susceptible to the context. Land use significantly affects the choice of GI. As for the study area composed of several land uses, GI typologies must be carefully chosen to best fit and adapt to the land use. Table 37 summarizes the general land use within the study as a matrix, matching the best GI approaches that can fit into it for proper application and implementation. The types are set according to preferences retrieved from the survey concludes this part of the study.

Table 31: Matrix of land use within Amman city center * proper GI type. Developed by the researcher.

Land use / **GI Type**	Residential	Commercial office	Traditional commercial	Light industrial	Civic – cultural heritage	Institutional, Public
Neighborhood parks	*					
Public parks/ Recreational areas	*				*	
Street trees	*	*	*	*	*	*
Green walls/roofs		*				*
Private gardens	*					
Green spaces				*Replace industries	*	*
Community gardens	*					
Urban farming				*Replace industries		
Preamble pavements	- *Replace traditional paved surfaces for all uses.*					
Rainwater harvesting systems	- *Tailored according to infrastructure planning.*					

*Noting, While GI here can be introduced into several land use, in every left over space and spaces between buildings. It is important, for the purposes of this study to focus to integrating GI with publicly accessible spaces that withhold high potential of human impact to ensure both systems interact and benefit from each other’s resources. Discussed in the following part of the methodological approach.

5.2 Space Syntax / Graph Theory Mapping Analysis

Within this part chapter, the methods of choice derived from the space syntax theory and graph theory to visualize human and ecosystem spatial patterns are applied. At the same time, the process requires both methods to be executed separately as each tool is driven by different parameters and results in different. Yet, the study will overlay and merge both patterns for an integrated human ecosystem analysis. Results will be then utilized to discuss how GI can be approached in the study area from the perspective of its socio-ecological system's components; urban communities. Applying methods to the case will take several steps, summarized in figure 87;

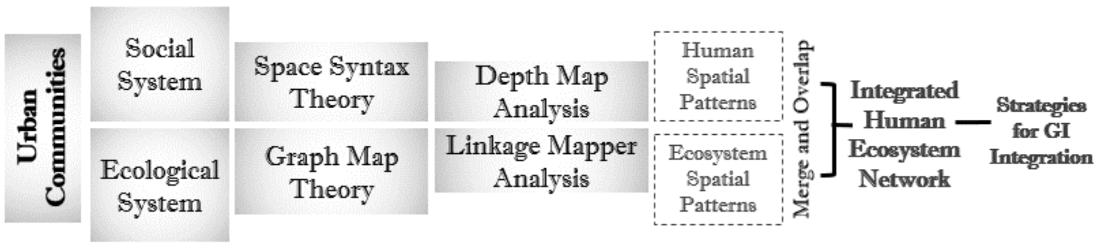


Figure 87: Summary of the process of applying methods to the case.

5.1.1 Space Syntax Methodology; Mapping Analysis

Space syntax methods will be applied to visually assess the spatial patterns as introduced in the methodology chapter. The approach included several steps and are applied to the case as follows;

The first step; **CAD Files Preparation and Integration**. Files were initially prepared, geo-referenced and coordinated. The final Output files are produced as a set of several layers, shown below.

a. General roads network (Major, Minor, Paths, and Parks), figure 88. The following parameters and settings have been applied to this layer: all roads are divided into (20 Meters for Major Roads, 20 Meters for Highways, and 10 Meters for Paths and Minor roads)

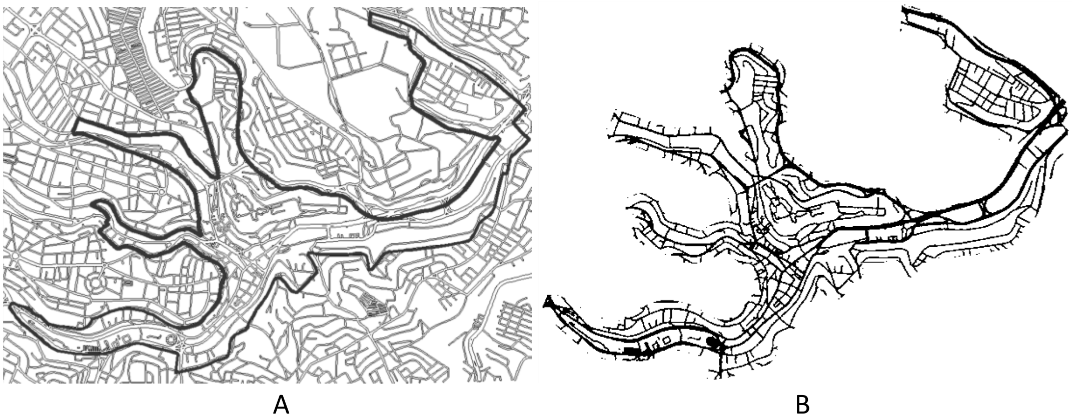


Figure 88: A: Map of the study area showing the boundaries and roads within the surrounding area. B: Map showing roads within the boundaries of the study area.

b. 2D buildings, figure 89

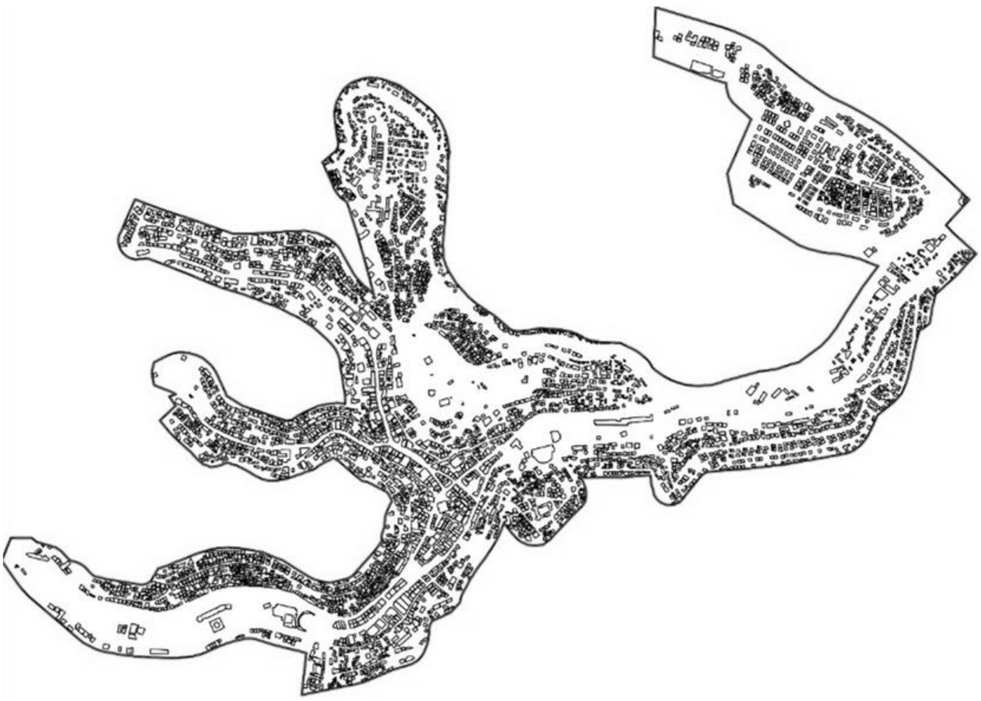


Figure 89: Map showing existing buildings within the boundaries of the study area.

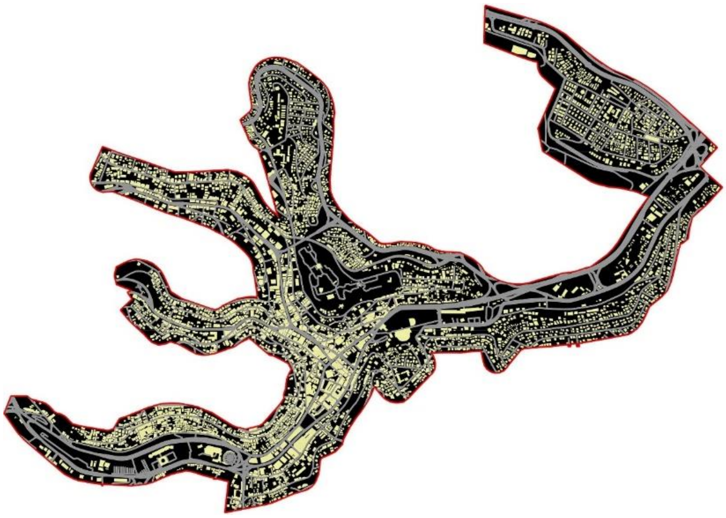


Figure 90: Map showing a rendered visualization of both buildings and roads layers.

c. Topography and contour lines; values for each line were given every 5 meters.

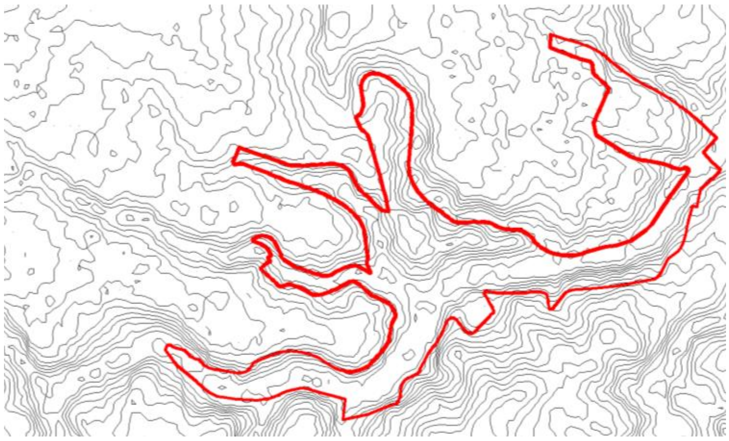


Figure 91: Topography map of the study area and its boundaries. DEM Value Range between 729 – 970 m.

In the next step; **Space Syntax Depth Map Analysis**; the previously prepared layer was integrated into depth map software and were run based on the chosen techniques as stated in the methodological approach for this study. The selected maps for further analysis are; From the Axial map analysis- "Axial connectivity, Axial integration, and Axial mean depth maps", From the Segment map analysis- "Metric road network analysis/ n=100 map", and the VGA map. And are as discussed and explained as follows;

1) Axial Maps Analysis;

They are considered a way of analyzing space. Here, the urban spatial layout is presented as an axial map of the main road network. While the axial map analysis withholds many techniques, the study only focus on the connectivity, integration, and depth analysis techniques, as they hold more considerable potential in visually assessing human/space relationships given road networks of this study area.

- <u>Axial Connectivity analysis;</u>

The axial connectivity map measures and visualizes the value of one line to others from the perspective of how many intersections the line has with other lines. In our case, the road network is presented as two main parts; major and minor roads, the connectivity map here visualizes their relationship to each other in terms of intersections. The roads with higher color values, as graphically presented on depth map software, indicate increased connectivity. In contrast, the colder/blue colors indicate low connectivity within the road network, as shown in the map in figure 92. The values shown give the researcher a clear idea of the roads with high connectivity, indicating that those roads "and adjacent areas" are within human flow preferences. Roads with high connectivity imply high pedestrian flow.

Figure 92: Axial connectivity map of the study area as produced by depth map.

- <u>Axial Integration analysis;</u>

The axial integration analysis measures the overall integration of axial lines, where high colored values represent the indication for higher integration degrees on the map. Here, the intersection between roads within a network is not considered. However, the whole length of the streets is considered, despite nature, "major or minor" and despite the existence of an intersection. The axial integration map for the study area is shown in the map in Figure 93, where higher degrees of integration are presented as the higher/warmer color values.

Figure 93: Axial integration map of the study area as produced by depth map.

Explaining integration in terms of human–space relationships, the human spatial patterns are expected to show higher values given high integration degrees as it indicates ease of access, where accessible lines within a road network imply more pedestrian flow.

- <u>Axial mean depth analysis;</u>

Within the axial mean depth analysis, a definition of the mean of the total depths from each line to all other lines on the road network is measured. The map shows the relationship between each road line "major or minor" to one another within the urban road network, keeping in mind that it measures the relationship between the minor roads to each other, and the major roads to each other "minor to minor/major to major".

The following map in figure 94 shows the resulting axial mean depth analysis for the study area, where higher color values again indicate strong relationships and wise versa. It is noticed within the map that the stronger relationships are increasing when the lines move away from the major roads, which implies that it is more likely to have a human relationship to the minor roads.

Figure 94: Axial mean depth map of the study area as produced by depth map.

2) Segment Map Analysis;

Segment maps are typically constructed based on an axial map, where the axial lines get broken at the point of intersection. Values can be the radius for each road (angle between two roads). Alternatively, and as used in this study's analysis, metric radius is a syntactic measure where the radius is given in meters.

- <u>Segment metric radius roads network analysis;</u>

Within this analysis, the measures given are in meters and are understood as; Walk 400 meters or 5 min; 800 meters or 10min (the same as cycling for 5 min.); 1200 meters imply 15 min walking' 7.5 min cycling, or 5 min. driving. (n, 200,400,800,1200). Here the "n" is the distance from a certain point covering a full radius around it. The resulting maps indicate how much people are expected to show spatial flow whenever the "n" value is decreased in high to low color values. In other words, the less the metric distance is, the more likely there is pedestrian movement. For this, part of the analysis will show the least "n=100 meters" radius, as follows;

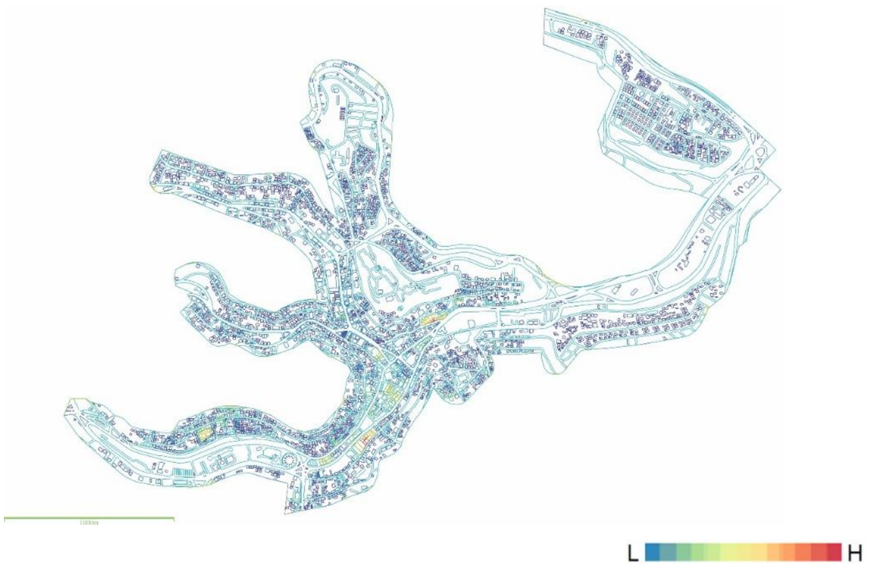


Figure 95: Metric roads network analysis map - radius type: Metric (n,100), produced by depth map.

3) Visibility Graph Analysis VGA;

VGA is a method used to investigate the characteristics of a visibility graph that is typically derived from a spatial layout such as an urban environment as an urban grid. VGA is usually applied in one of the following two levels; either an eye level (what people can see) or a knee level (how people can move). Indicating points and nodes of human activities and intersections. Also known as VGA Connectivity map, indicating in high to low color values "warm to cold" the presence of nodes. The nodes here mean that the areas with high values of "high node count" are the areas with the most intersections and movement intersections. The resulting map implies that people tend to "flow" more towards the center of the study area, as shown next in figure 96.

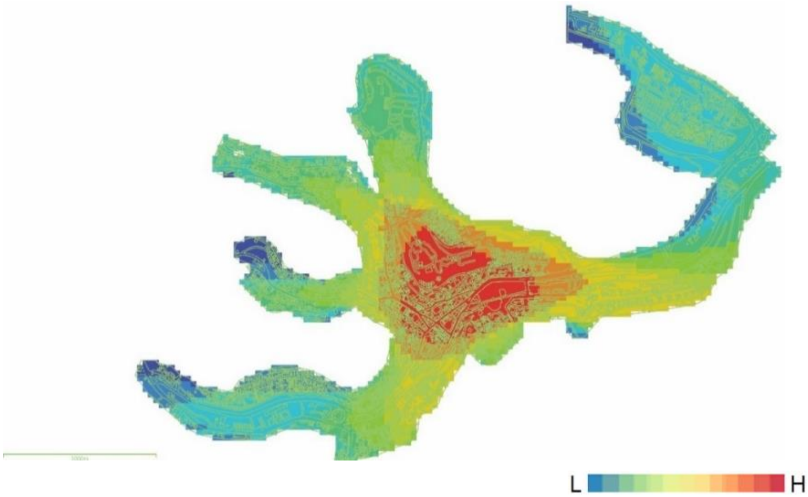


Figure 96: VGA connectivity map of the study area, produced through depth map.

The third and final step in space syntax analysis; **Human Spatial Network Map.** Within this part of the methodological approach, a general map showing the overall human spatial network. Each of the previous space syntax maps will be limited to its medium to high human spatial patterns. The process in summarized as following;

- The low values "medium-low to low" shown in green, blue colors will be eliminated/ excluded on each space syntax map, figure 97.

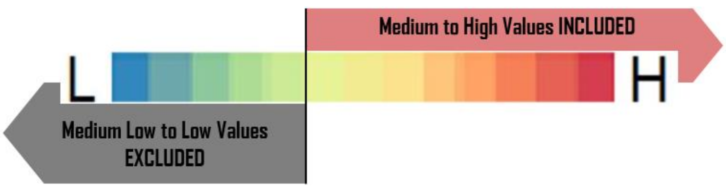


Figure 97: Values of Inclusion and Exclusion.

- The total of all positive values "medium to high" shown in yellow, orange, and red will be separately included, overlapped, and merged into one layer. This will provide an overall understanding and visualization of the sum of all human activities; movement, flow, integration, and centralization within the study area and the spaces with public access and public preferences. Space syntax analyzed maps with medium to high values are as follows;

- Axial Connectivity Analysis; Medium to high values only.

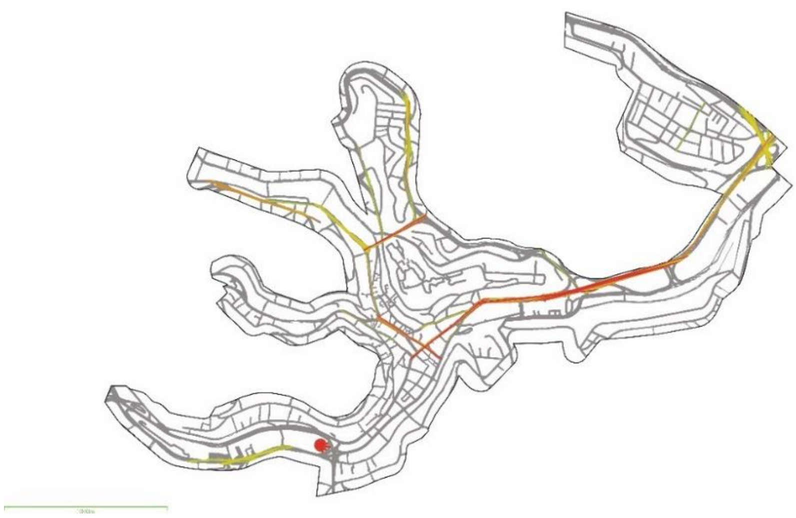


Figure 98: Axial Connectivity Map; Medium to high values only.

- Axial Integration analysis; Medium to high values only.

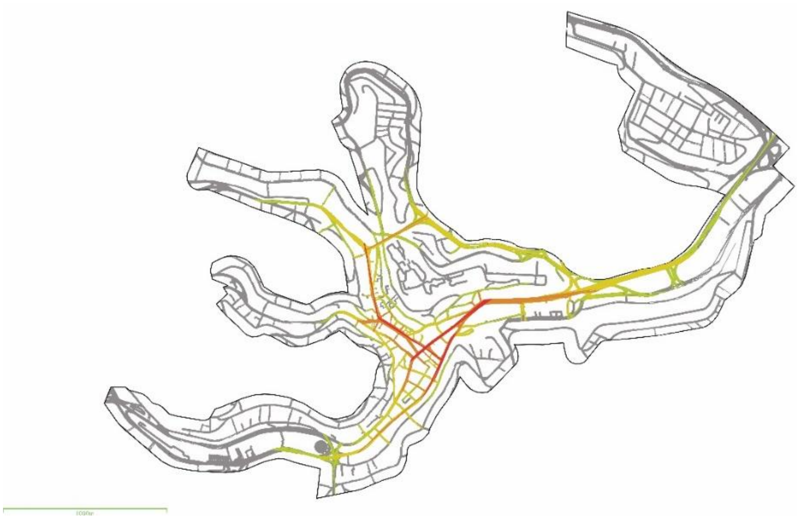


Figure 99: Axial Integration Map; Medium to high values only.

- <u>Axial mean depth analysis;</u> Medium to high values only.

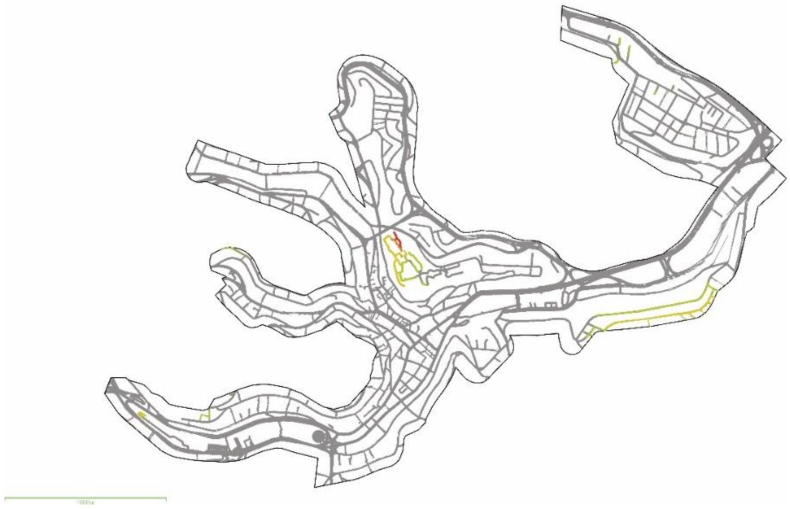


Figure 100: Axial Mean Depth Map; Medium to high values only.

- <u>Metric radius roads network analysis: Metric n=100</u>; Medium to high values only.

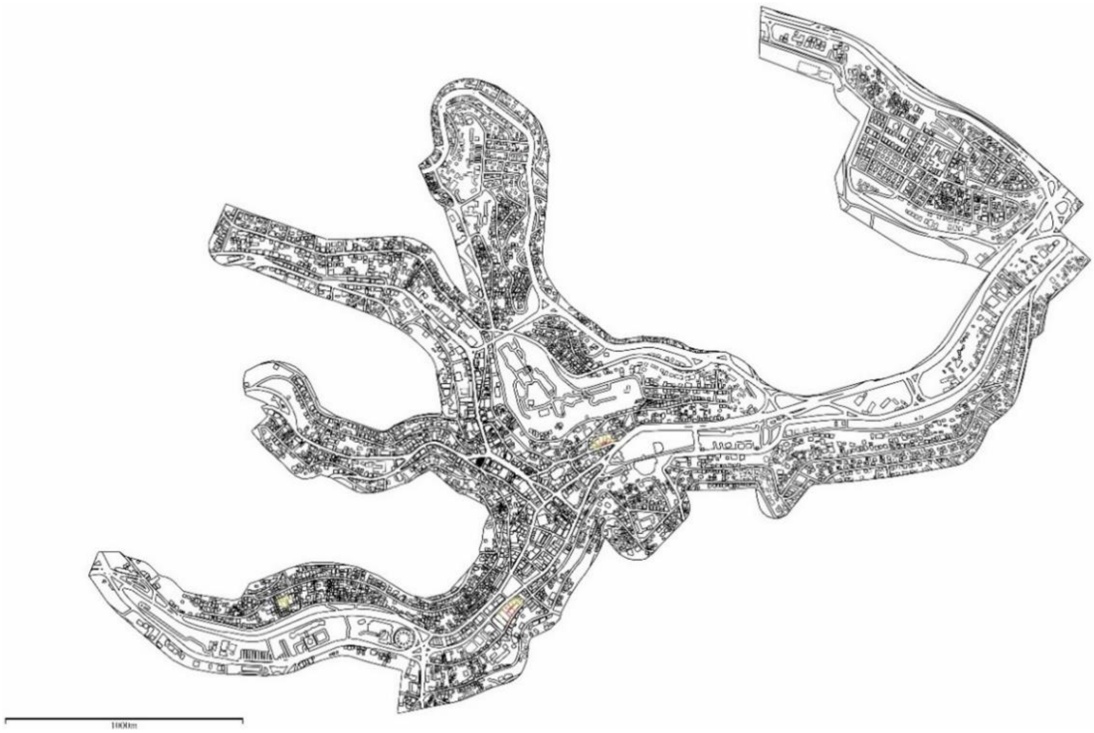


Figure 101: Segment Metric radius type n=100 Map; Medium to high values only.

- <u>VGA connectivity analysis</u>; Medium to high values only.

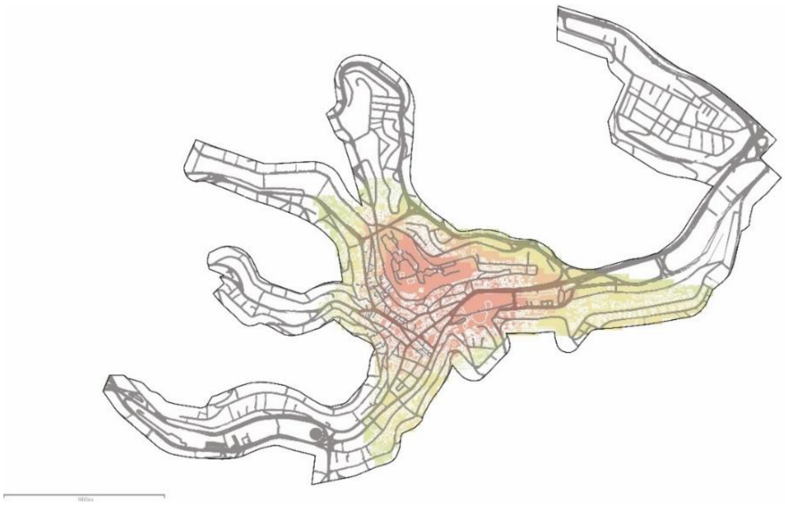


Figure 102: VGA Connectivity Map; Medium to high values only.

To conclude, an overall human spatial network map that overlaps all the above values of medium to high human spatial patterns is attained as following in figure 103;

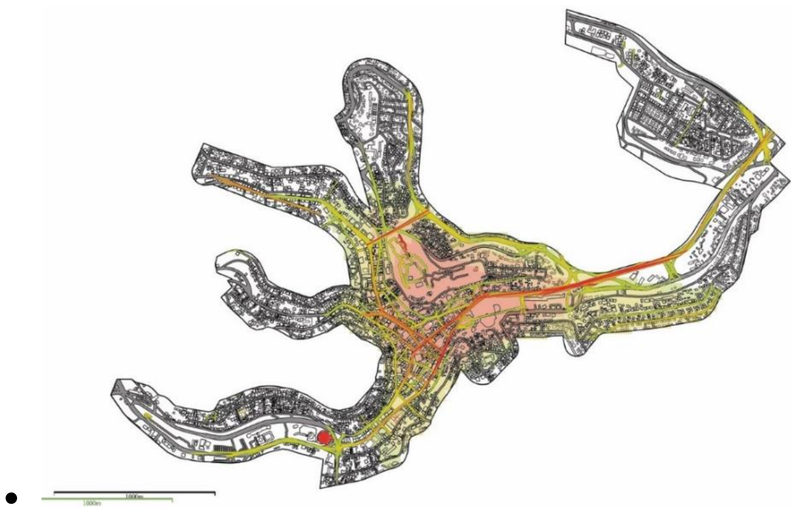


Figure 103: Sum of all; Human spatial network map; Medium to high values only.

Moreover, within the human spatial network map, an indication of land use as discussed in chapter 4 is given towards understanding the preferable human activity locations within the urban layout of the study area. The land use is organized from points of high value and descending to medium as follows;

a. The main terminal of new public transportation, cultural and civic site.

b. Historical heritage sites – touristic attractions.

c. Socio-economic hub, traditional commercial areas, shopping streets - touristic attraction.

d. Traditional public transportation emphasizes "Raghadan Terminal".

e. Mix of use areas; residential, public - commercial – offices, and light industrial.

The following map shows indications of land use within the human spatial network map, shown in figure 104.

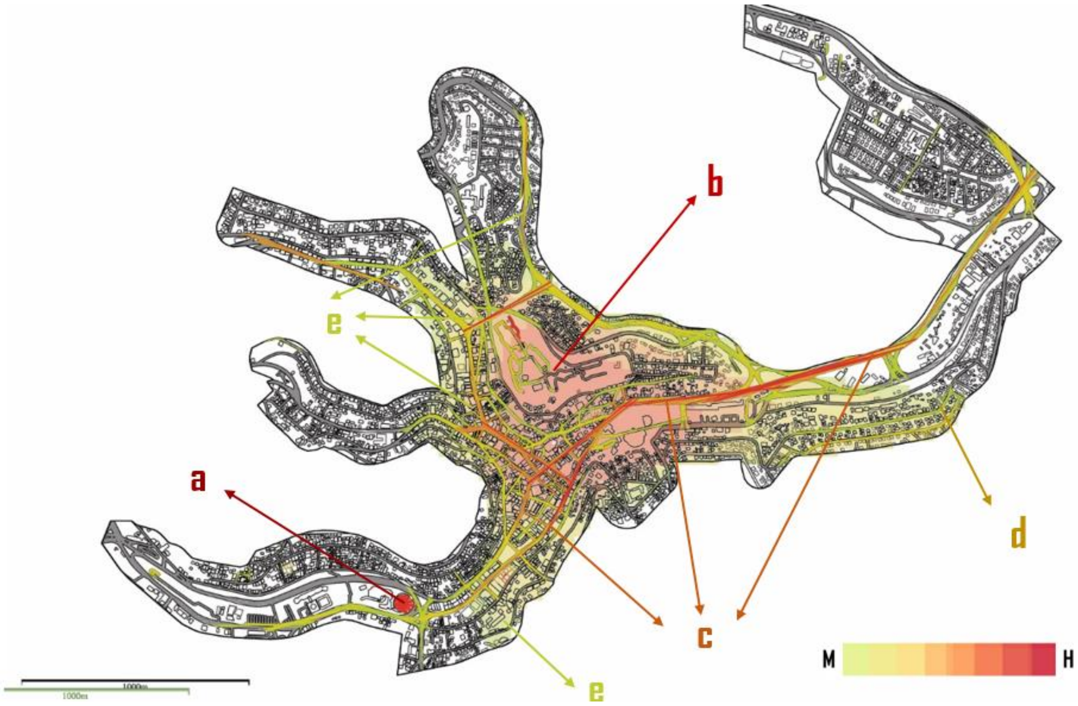


Figure 104: Human spatial network Map of Amman city center; Given Land use.

Finally Noting; Land uses of no given value or indication is either inaccessible open spaces such as private lands, unplanned or left areas like old industrial sites, or sites with no current use. Similarly, dense residential neighborhoods showed shallow values and are understood within space syntax theories as they are the foreground of public movement and include much-segregated usage. They are mostly found further towards the edges of the study area, far from major roads and nodes of activities.

5.2.2 Graph Map Methodology; Mapping Landscape Connectivity

Within this part of the study, the research will apply the graph theory methods and tools towards visually measuring the quantitative values of landscape connectivity within the study area. The reality of the area is much more complex and is shown in the following sattelite image in figure 105.

Figure 105: Map of the study zone and surrounding areas. As retrieved from Google earth pro satellite images in 2022.

The study focuses on the ecological system as a whole set of patches (no matter how fragmented or small) as a potential space for integration. According to the logic of graph theory, every patch of nature within an urban area, even as small as some flower pots on residential balconies can enhance the overall connectivity, thus landscape functionality and health. For this purpose, the research will primarily focus on analyzing the study area and surroundings for its landscape structure.

The researcher analyzes the study area for three main attributes; the urban fabric for street networks /buildings, and the natural environment for the ecological habitat areas; patches - however fragmented. Never the less, the map for landscape connectivity analysis was seen to be extended for areas surrounding the boundary of the city center for several reasons, most notably to give a comprehensive look at how the ecological system is found in the areas adjacent to the center as sometimes those patches get more intensive and extend in a more integrated way which overall will affect the values of landscape connectivity.

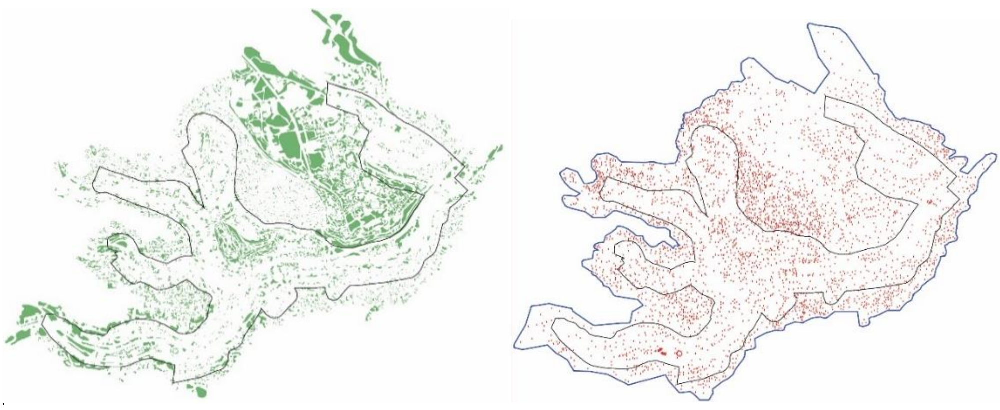
The boundary of the study area, Amman's city center, is shown along with a more extensive boundary representing the edges chosen to extend the mapping of the ecological area, as shown in the following map in figure 106.

Figure 106: Map of the study area showing ecological habitat areas, street network and building layout. Developed by Author.

It is observed from the ecological habitat areas in the map that the landscape structure is more integrated into the areas outside the boundary of the downtown, especially in those areas with a more private use towards the northeast of the center, where the remaining patches of the natural ecosystem are more extensive and more integrated, as opposed to what is noticed within the study area overall, where the patches are very fragmented due to overpopulation and urban sprawl, small in areas as nodes, and poorly connected in distance.

Moreover, the only areas with noticeable patches in the study area are the previously discussed cultural heritage site of the citadel mountain area, and the cultural civic site around the complex of Amman Municipality at Ras Al-Ain.

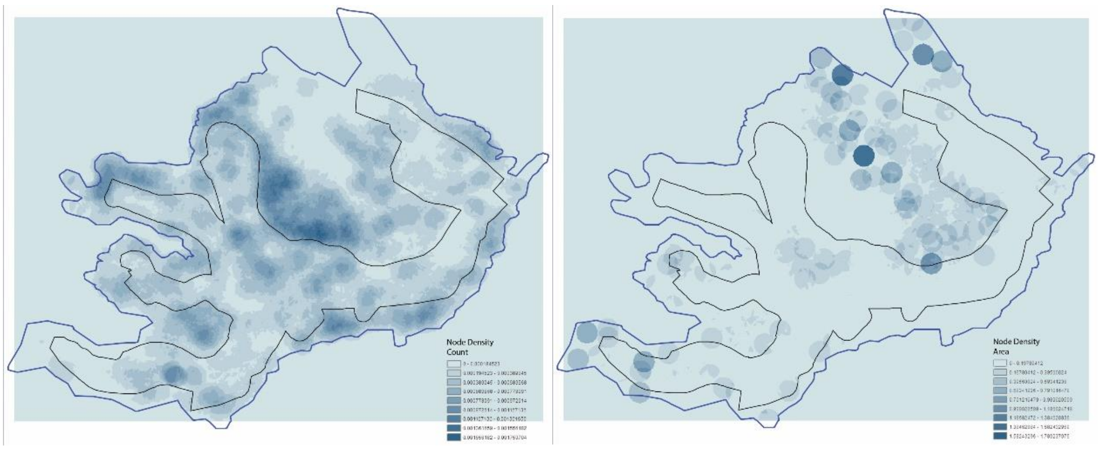
The linkage mapper tool that operates through ArcGIS is used to conduct the landscape connectivity analysis. However, firstly, the study area will be analyzed through ArcGIS to generate a general spatial analysis, which will initially transform each patch into a node at its center utilizing the feature to point manager tool with GIS spatial analysis, then show patch density by count/area values using the feature to density manager tool, which is more of graphical visualization of the ecological habitat areas, with no graph theory metrics taken into count shown in figure 107.



a b

Figure 107: a- showing green patches, b- showing same patches after turned into nodes using Arc-GIS spatial analysis feature to point manager tool.

Here, it is clear how the nodes are concentrated within areas that in reality are low in ecological patches, as the GIS spatial analysis transforms every patch into a node despite the area of it in such a way that a node can represent a vast area as well as a single detached tree, which can result in misleading visualization, which is why it is not preferable to attempt to read landscape connectivity through such tools. However, the following generated node density shows two different values; The node density by count that withhold the same limitation of being misleading, and the Node density by area given as a specific radius "calculated to the 100m default value", which resembles some more realistic analysis of where the ecological habitat areas is prevailing by the size of the patches at each node. However, the node density by area still lacks some essential measurement that actually resemble landscape connectivity such as where and how the nodes are connected. Figure 108



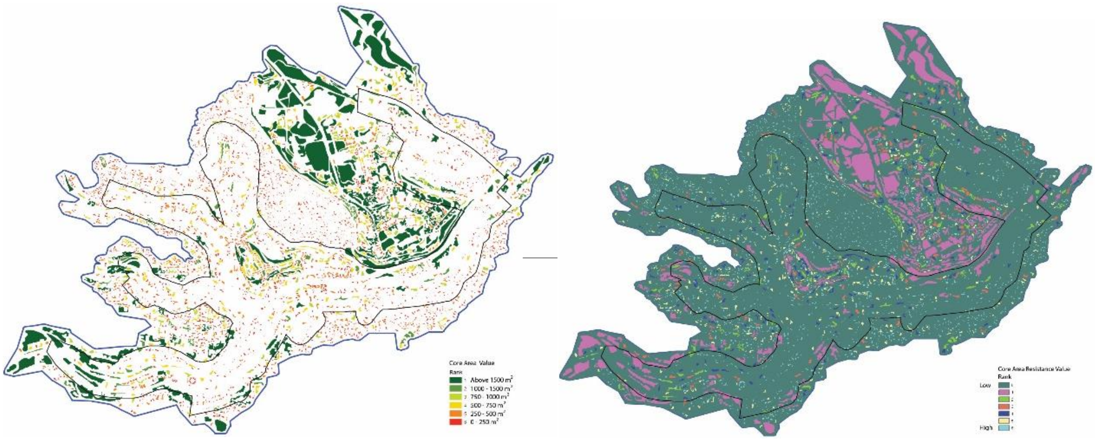
a b

Figure 108: a- Node density by count value, b- Node density by area value. Maps generated using Arc-GIS software spatial analysis tools.

To this end, the ecological system will be analyzed through the Linkage Mapper toolkit. Firstly, the researcher prepared the initial files by choosing the data layers needed to calculate the resistance surface. This step is essential as the linkage mapper requires resistance data from a raster surface map to run the analysis. The layer of green patches is chosen and divided into six foremost ranks depending on their area and land use. The data was given resistance value ranks and transformed into raster maps, then used to calculate the resistance surface map. Criteria for choosing the resistance value were based on built-up area values and ecological availability at the site.

To generate raster resistance map for the patches, the initial map was merged so that the close-up patches connected into single polygons when exploded within Arc-GIS, hence decreasing the overall patch count. The patches were then divided into six main categories based on several intervals; where 0-250 m^2 indicating a high resistance rank value of 6, and the lowest resistance rank value of 1 is given to areas above 1500 m^2, then transferred into a raster map given resistance value by the ranking areas. In the identification of core habitat areas, the linkage mapper analysis was given only to the patches with areas above 1500 m^2, representing 185 cores; 5% of the total patches.

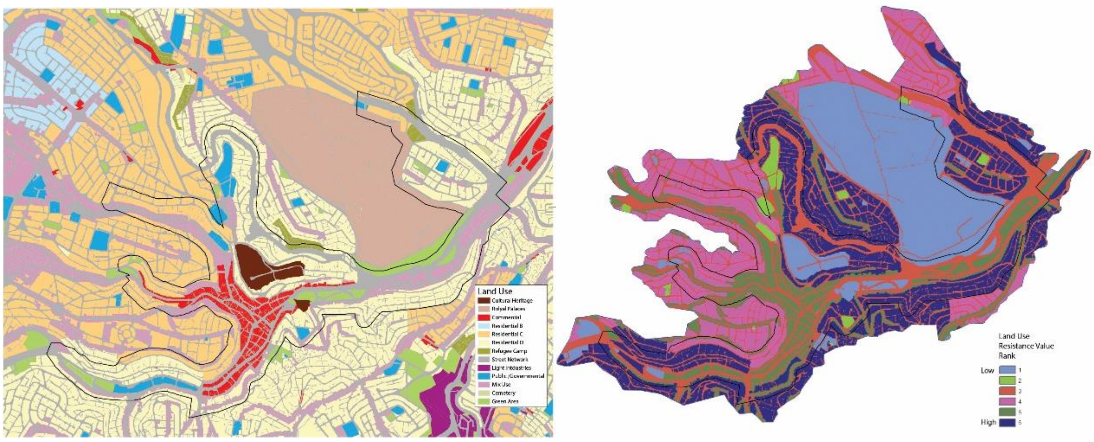
The most minor patch found was 1.5 m^2 compared to the biggest patch of around 44200 m^2 area, while the smallest value does not indicate any vital measurement towards ecosystem, yet it was important to identify it so that the raster grid applied reads patches at all scales, and for that it was set to be a 1 by 1 m cell grid.



a b

Figure 109: a- showing green patches values by rank, b- showing raster resistance map of green patches. Maps generated using Arc-GIS platform.

The resistance values for land use were decided upon by expert opinions after evaluating the site in an unofficial interview at greater Amman municipality GAM. Values are set between 1 and 6, 1 being the highest, such as high-density residential areas. The resistance value here is meant to be a numerical indication of whether the data given facilitates or prevents ecological linkages. Figure 110.



a b

Figure 110: a- Land use (GAM), b- Raster resistance map of land use given resistance value. Maps generated using Arc-GIS platform.

However, the street network was given a zero value as it represents the land use background. Here, it was essential to give it a zero value so that it does not get excluded from analysis by the linkage mapper tool, as streets have a high potential for urban greening and forming links and bridges between fragmented patches of nature within an urban context by implementing preamble pavements and street trees for example.

The data types and resistance values are used to obtain both raster resistance maps for core areas, green patches, and land use, the linkage mapper ran helped calculate the resistance surface map, merging both resistance values resulting in values between 1 "indicating raster cells with low resistance" and 12 "indicating resistance cells with high resistance", as shown in the map in figure 111, and values in table 32.

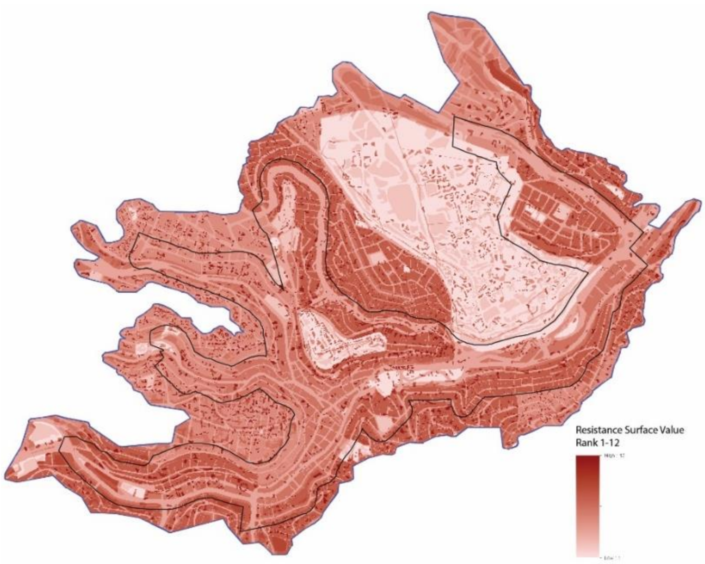


Figure 111: Resistance surface map. Generated through linkage mapper tool, operated within ArcGIS platform.

Table 32: Resistance values by data type rank.

Data type (Rank)	Resistance Value (High=1 - Low=6)
Land Use (Cultural Heritage)	6
Land Use (Royal Palaces)	6
Land Use (Commercial)	4
Land Use (Residential Type B; low density)	5
Land Use (Residential Type C; medium density)	3
Land Use (Residential Type D; high density)	1
Land Use (Refugee Camps; very high density)	1
Land Use (Light Industries)	1
Land Use (Public/Governmental)	5
Land Use (Mix Use)	2
Land Use (Green Spaces)	6
Land Use (Cemetery)	6
Land Use (Street network)	0
Green Patch Area (Above 1500 m^2)	6
Green Patch Area (1000 - 1500 m^2)	5
Green Patch Area (750 - 1000 m^2)	4
Green Patch Area (500 - 750 m^2)	3
Green Patch Area (250 - 500 m^2)	2
Green Patch Area (1 - 250 m^2)	1

Secondly, the researcher ran the resistance surface map through the linkage pathways mapper tool, resulting in several readings mapping the linkages between the core areas given "patches of the area above 1500 m^2" that are presented as corridors of possible spatial connection between those patches and is read through LCP least cost path value. Also, presented as CWD cost weight distance that visualizes the value of landscape connectivity by distance from core areas and is visualized in two different values. The result allowed the researcher to identify where landscape connectivity is high and which corridors facilitate spatial ecosystem patterns efficiently, figure 112.

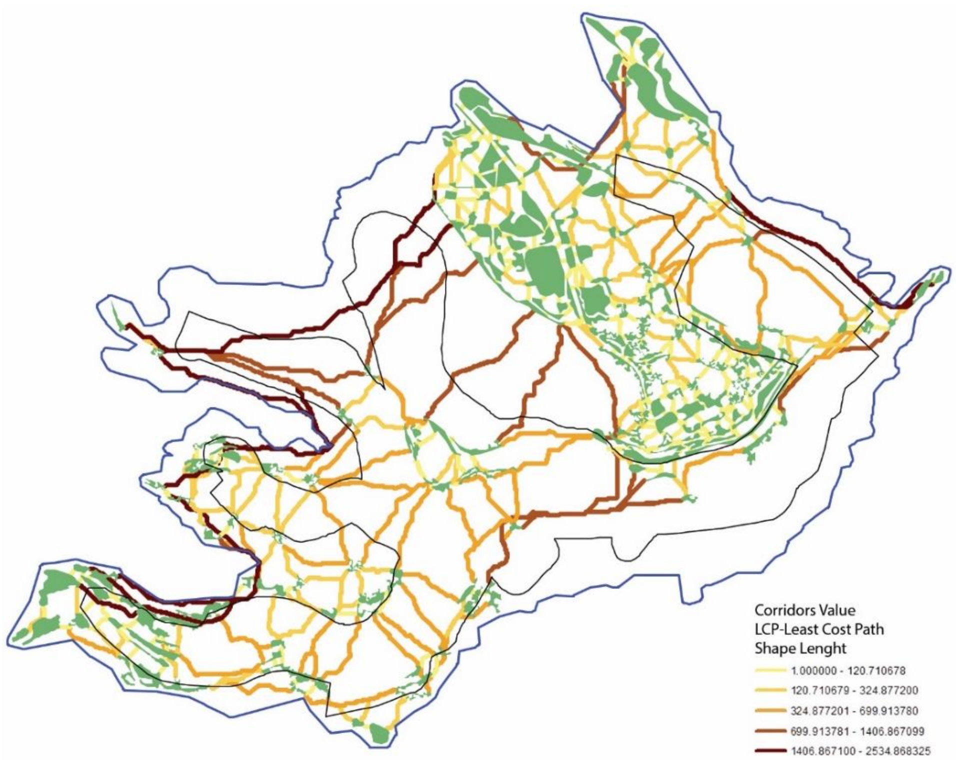


Figure 112: Corridors between habitat core areas, LCP map. Generated through linkage mapper tool, ArcGIS.

The corridors are measured by shape length and are referred to as the LCP. Corridors connect habitat core areas visualizing all possible spatial flow between cores. Therefore, longer corridors imply weak landscape connectivity. The network produced 538 possible linkages between the previously defined 185 core habitat areas, with a minimum value of 1 and a maximum of 2535 meters. The corridors with a high connectivity value range between 1 and 120 meters are visualized by light color value, presenting almost 320 links, which account for almost 60% of all corridors, implying a fair connectivity value as compared to the mean value of 199 m. However, the mean length and standard deviation difference are considered high and statistically indicate a big spread in linkages lengths throughout the habitat core areas.

LCP is given color value where dark values indicate weak pathways; compromised spatial flow. This is represented further in the following map in figure 113, which indicates where the landscapes are mostly integrated shown as a color value, where the warmer colors mean more integration, and vise-versa.

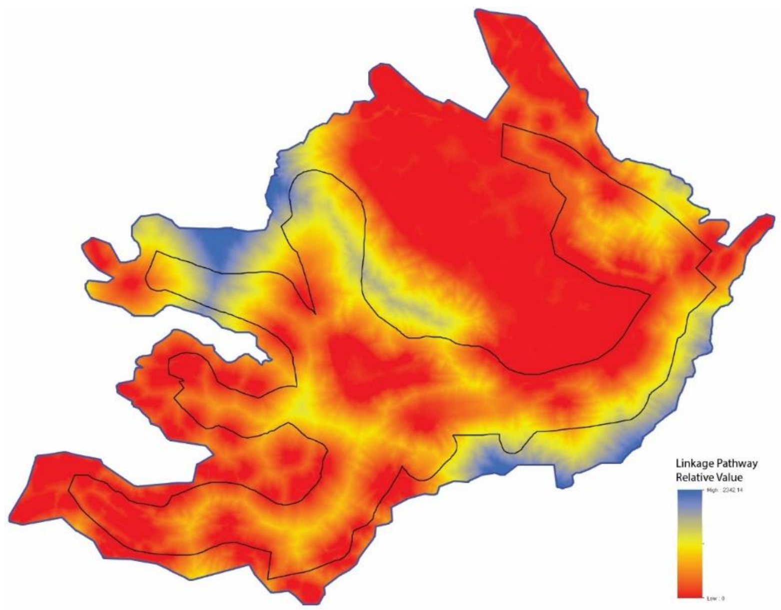


Figure 113: Linkage pathways "connectivity" relative value map CRV. Generated through linkage mapper tool, ArcGIS.

We notice how the landscapes within the study area boundary are somehow interrupted, which is explained by the fragmentation of the habitat core areas due to overpopulation and rapid urbanization. Land use here plays a significant role as it was one of the main attributes represented by this calculation. The areas with lower connectivity values are those with higher densities, such as the high population residential types, and refugee camps. On the contrary, the areas with high connectivity values are the cultural heritage sites and the cultural civic sites where the most core areas exist. The relative value here indicates habitat suitability for facilitating environmental spatial functions or, as this study refers to, connectivity relative value; CRV.

In another representation, the linage mapper produced a CWD cost weigh distance value of linkage pathway "connectivity" shown in the map in figure 114. Here, we notice how the values decrease when shifting further in the distance from the core areas, which are added for more precise visualization. Decreased values - indicated in lighter colors - is loss of connectivity and weaker corridor connections.

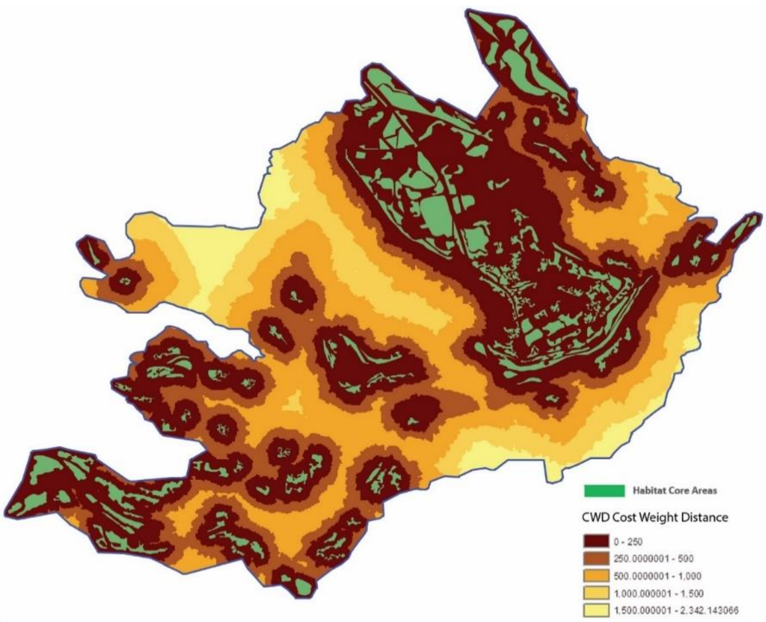
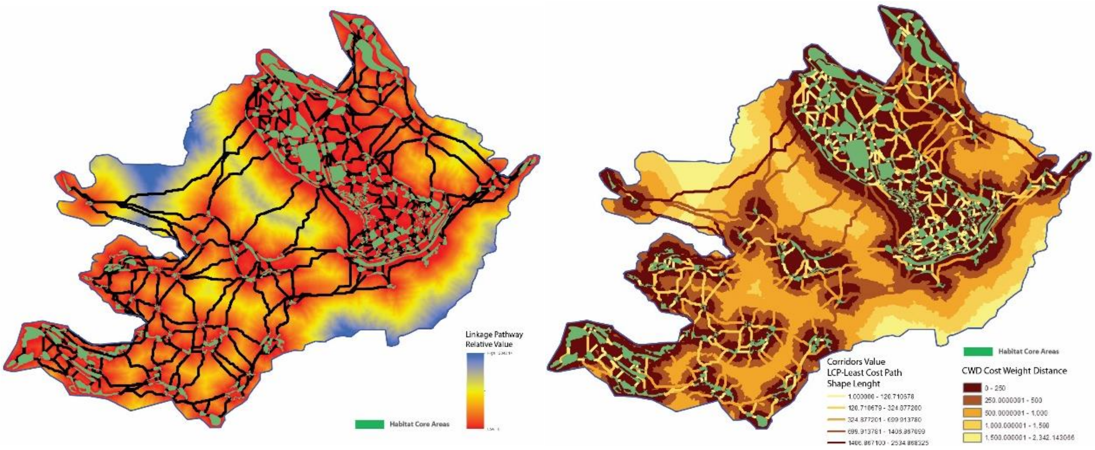


Figure 114: Linkage pathways "connectivity", CWD map. Generated through linkage mapper tool, ArcGIS.



a b

Figure 115: a- Connectivity relative value showing core habitat areas and corridors, b- Connectivity value CWD showing LCP of corridors and habitat core areas. Maps generated using linkage mapper toolbox operated within Arc-GIS platform.

Note: LCP and CWD values are the leading indicators of landscape connectivity value and are given the same color values but in reverse to highlight how shorter LCP implies higher connectivity between habitat core areas and vice-versa.

In the next step, the researcher uses a linkage pathway mapper to run the centrality mapper. The centrality mapper analyzes centrality values between cores and corridors as a whole network. Once corridors have been mapped using Linkage Mapper, Centrality Mapper analyzes the resulting linkage networks, calculating current flow centrality across the networks, which measures how important a link or core area is for keeping the overall network connected. Figure 116

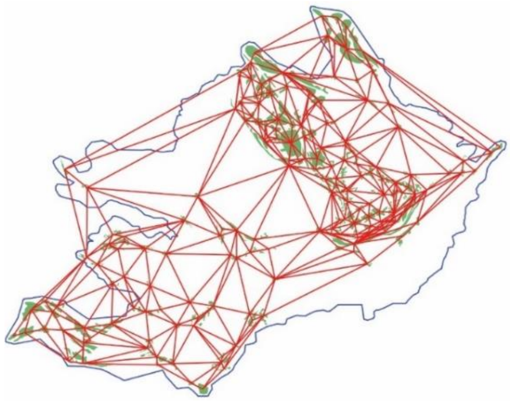


Figure 116: Centrality map, showing the core network to corridor connections. Generated through linkage mapper centrality mapper tool, ArcGIS.

The centrality mapper tool then renders a visual value of the network produced depending on the Euclidian distance of the lines within the network, as shown in the map in figure 117. Warmer color values here imply the critical connections that facilitate functional connectivity, implying strong spatial patterns and helping visually recognize the most critical corridors within the ecosystem patches. On the other hand, it helps identify the most compromised linkages within the network and weak habitat corridors that need enhancement, and at the same time, it assists in preventing more deterioration when taken into consideration by decision-makers.

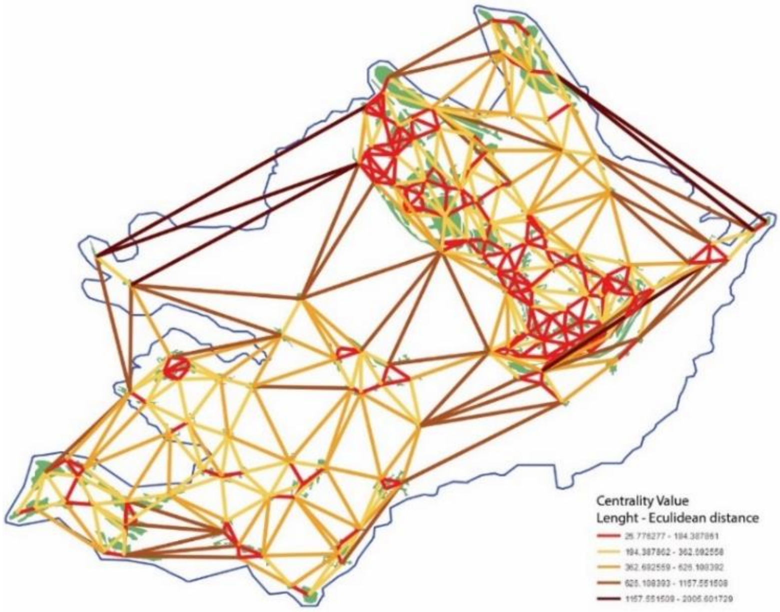


Figure 117: Centrality map, showing centrality values within the network. Generated through linkage mapper centrality mapper tool, ArcGIS.

While corridor shape length resembles the LCP, giving value to linkage connectivity between core habitat areas from edge to edge, the centrality is measured with Euclidian distance, which is the shortest link between core centers. Nevertheless, they are measured differently, which explains the difference between the outcomes. Here the highest value, shortest network path, is almost 27 meters, while the lowest, longer length value is 2005 meters. The mean length is 280 meters, which lies between the best two values, implying the best network connections. High connectivity value links are shown in light color values, while those with high priority functional connections towards landscape connectivity and ecosystem spatial flow are in red.

The following map in figure 118 merges connectivity CWD value, habitat core areas, and centrality network with functional connection values. This visualizes how the centrality functional network lies within CWD connectivity value, highlighting priority links within the network.

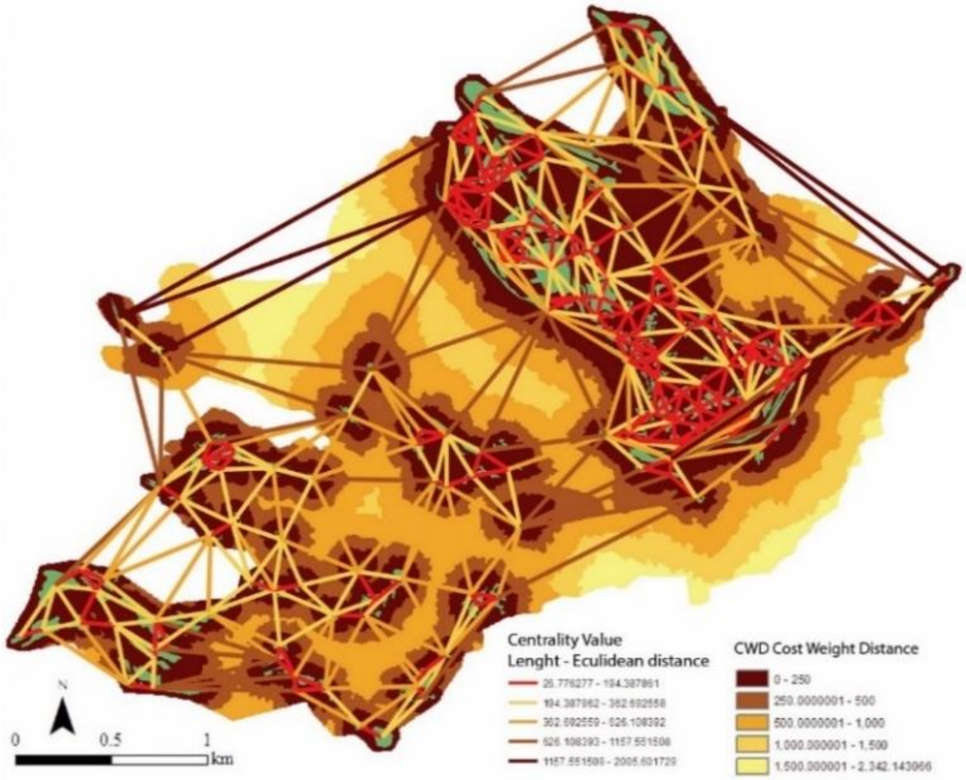


Figure 118: Centrality map showing core habitat areas, functional connections network values, and connectivity value CWD. Maps generated using linkage mapper toolbox operated within Arc-GIS platform.

After visually measuring connectivity and functional centrality between habitat core areas within the study zone, the researcher will run a barrier mapper that uses the results obtained from the linkage pathways mapper to measure ecological barrier locations visually. Once corridors have been mapped using Linkage Mapper, Barrier Mapper detects significant barriers that affect the corridors' quality and/or location. This step is essential for identifying the ecological gaps within the landscape connectivity and ecological restoration areas to strengthen landscape connectivity to be further integrated within the social-spatial pattern network for further analysis in the next part of this study. The barrier map shown in the following figure 119 indicates the areas with the most barriers to ecosystem connectivity with low to high values. Low barrier values are indicated in yellow and light blue color values that concentrate into dark blue when reaching the highest barrier points.

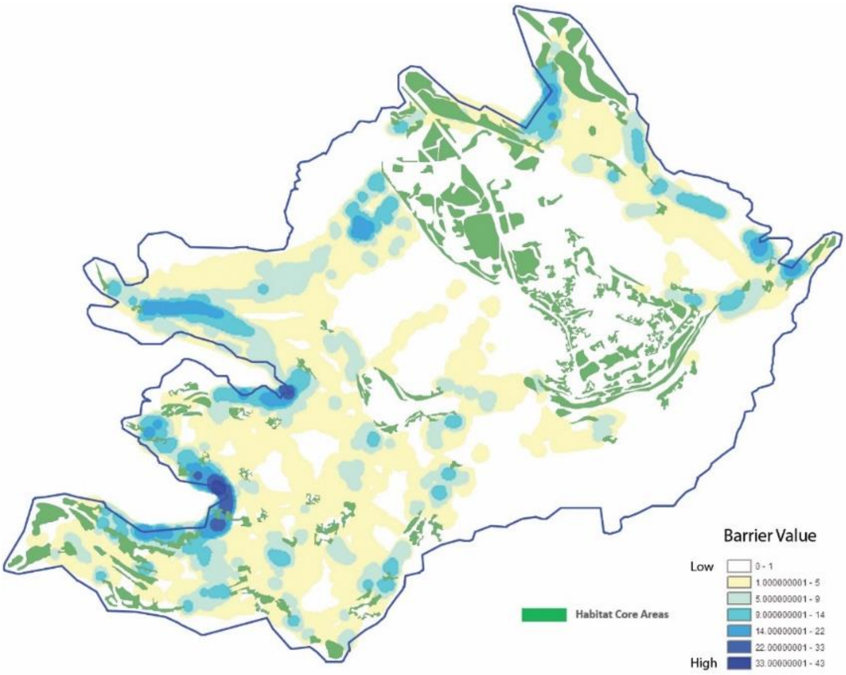
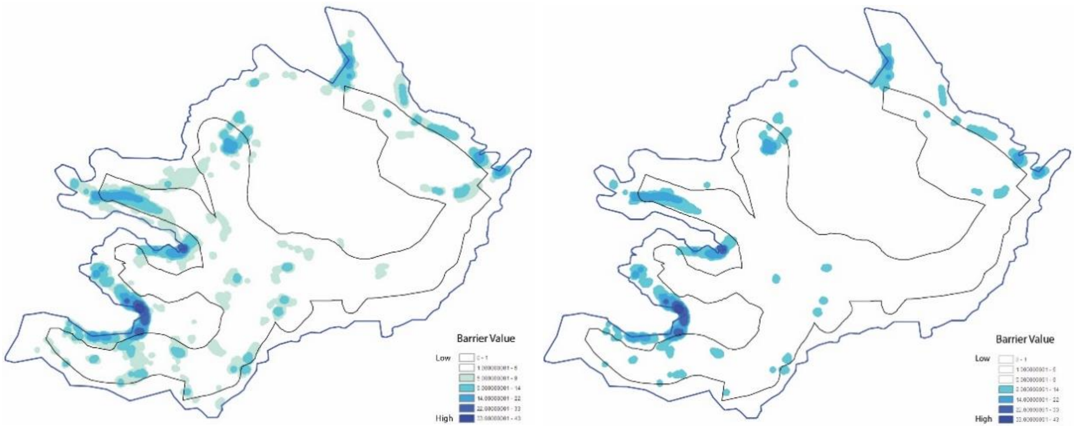


Figure 119: Barrier map, all values. Map generated using linkage mapper – barrier mapper tool operated within Arc-GIS platform.

Barriers are noticed to be mainly concentrating in areas with few habitat cores. However, they also exist around some of them where land use resistance value and ecosystem patch size resistance value identified and rendered previously play an essential role in identifying points of high resistance to ecosystem spatial movements; barriers.



a b

Figure 120: a- Barrier map, medium to high barrier values. b- Barrier map, high barrier values only. Maps generated using linkage mapper – barrier mapper tool operated within Arc-GIS platform.

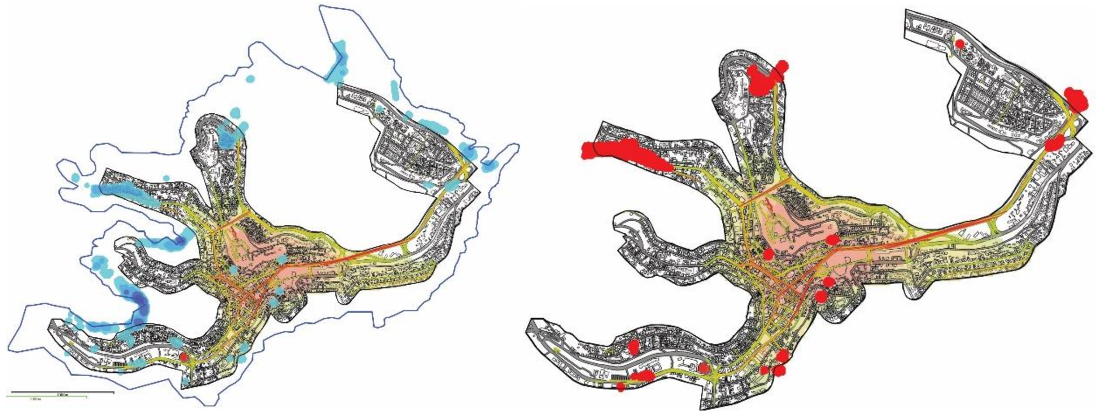
As shown in the previous maps in figures 120 a and b, the researcher excluded low to medium barrier values, reaching for high ones. This was done to identify the most critical barrier points for further analysis in section 5.3 of this chapter.

5.3 Human/Ecosystem Integration; Mapping Human Spatial and Ecosystem Analysis

Within this part of the methodological approach, the researcher integrates human spatial and ecosystem analysis maps. This is done to identify the ecological barriers within human activity areas, so that ecosystem restoration is tackled in those specific areas by implementing GI as the study focuses on enhancing social-ecological resiliency through UGI strategies in the study area. Literature review on the topic had proven the value of UGI in that. However, this part of the study aims to provide practical tools for questioning how decreasing ecological barriers by considering new ecological habitat areas can increase landscape connectivity, which implies enhancing ecological resiliency. Furthermore, doing this within human spatial patterns focal areas ensures the delivery of GI benefits to inhabitants, which will also imply increasing their resiliency, resulting in an enhanced social-ecological resiliency in the study area.

The study conducts steps in this part of the methodological approach. The barrier areas are identified for the whole ecological habitat area boundary in the previous section and excluded medium-low to low barrier areas. The researcher then overlaps medium-high to high barrier areas with summed maps of medium-high to high human spatial pattern maps previously analyzed, shown in figure 121 a and b.

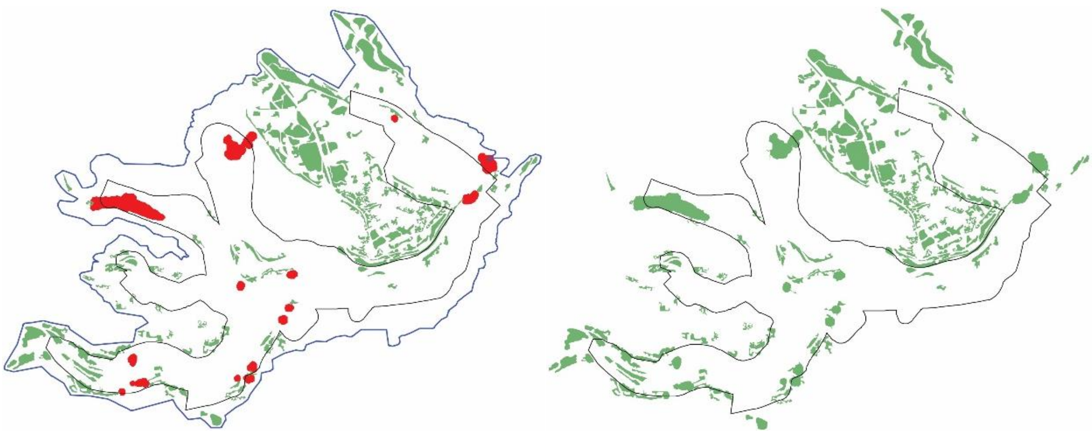
Moreover, it is also pointed out where barriers and human activity areas overlap focusing on the original study area, boundary of downtown Amman, defining those areas as new habitat cores where ecological restoration projects will be recommended by implementing proper GI in the final section of this chapter. Figure 122



a b

Figure 121: a- High barrier values overlapped with high human spatial pattern map. b- High barrier values overlapped with a high human spatial pattern map, Excluding barriers outside the main study area boundary. Maps generated using linkage mapper – barrier mapper tool.

*Note: The high barrier areas, on some occasions, lapped with old core habitat areas, for which the researcher utilized ArcGIS to merge the new cores into the old ones to transform them into polygons to enable re-calculating the resistance surface map for new linkage mapper and centrality mapper analysis.

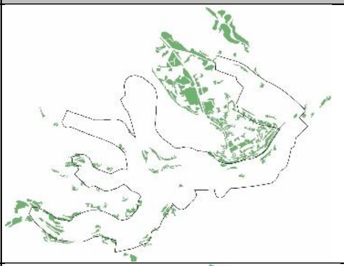
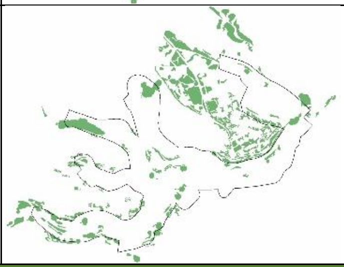


a b

Figure 122: New HCA map, showing suggested new ecological core areas map.

Habitat core areas, due to the criteria chosen – "Only high barrier values and only taking into account those which overlap with high human activity areas"; did not significantly increase in number. However, they increased in the area, as per patch and as a total area count, which implies higher enhanced ecological impact, as a higher value of patch area increased functional connectivity and ecological stability. Summary comparisons between old/new HCA statistics are given as following;

Table 33: Summery comparison between old/new HCA statistics.

HCA >1500m^2	**Map**	**Count**	**Min Area m^2**	**Max Area m^2**	**Sum m^2**
Old HCA		**185**	**1,513**	**44,205**	**93,1197**
New HCA		**187**	**1,513**	**87,803**	**117,7936**
% of change		***1.1 %**	**-**	**+49.65%**	**+20.95%**

While this initial comparison shows an increased ecological habitat area, implying enhanced ecosystem, the researcher re-calculates landscape connectivity to prove this enhancement visually. To do so, the researcher calculates the new resistance surface map, using the same resistance value ranks as before. Next, the result is used to run the linkage mapper toolbox to visualize new landscape connectivity values by LCP, and CWD, as well as for new habitat corridors utilizing the linkage pathways mapper tool and functional connectivity utilizing the centrality mapper tool. Finally, the results of each will be compared and analyzed to calculate approximate landscape connectivity enhancement values.

*Note: Landscape connectivity is a quantitative measure of how landscape interacts and facilitates ecological spatial movement. Linkage mapper tools provide both visual and quantitative values for this. However, studies use different methods to estimate those quantitative numbers, which are usually based on the area/length values conducted through the linkage mapping analysis. For this study, the data produced are used to evaluate the change within landscape connectivity at the values analyzed; by relative connectivity value, CWD, LCP, and centrality.

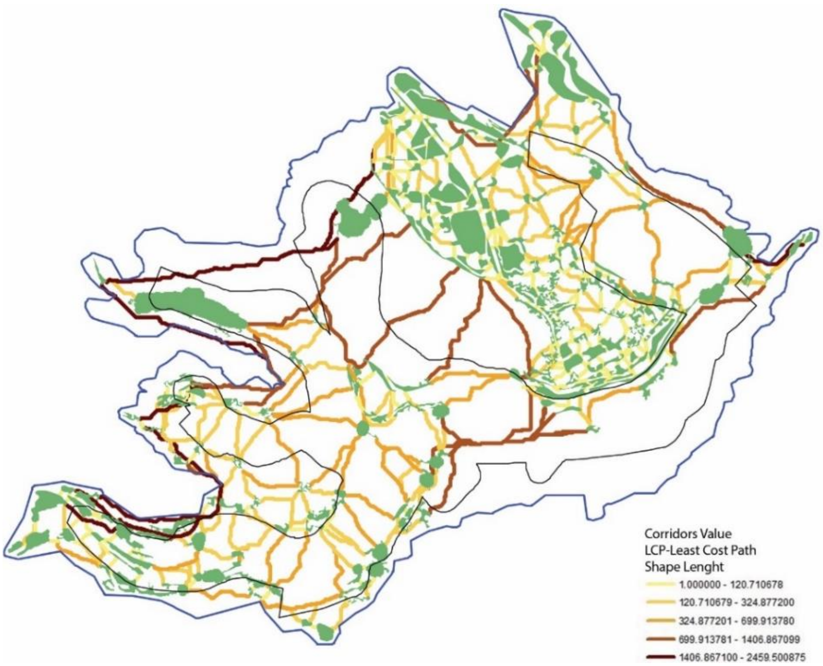
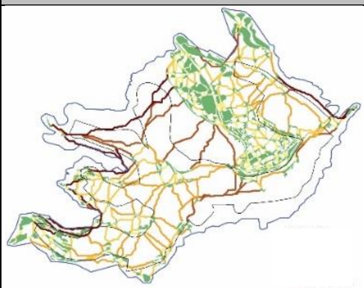
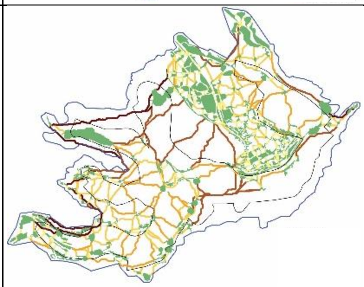


Figure 123: New Corridors map between habitat core areas, LCP map. Generated through linkage mapper tool, ArcGIS.

The previous map shows the new corridors map, measuring all possible linkages between habitat core areas by LCP; shape length values are noticeably enhanced than the initial corridors map with much more linkages with low length values indicated in light colors, and fewer long corridors indicated in darker colors; "the longer the length value of LCP the lower the ability of the corridor to facilitate spatial ecosystem patterns; implying low connectivity levels". In addition, many of the medium to high-valued LCP corridors, which suggest weakness in the linkages, are noticed to decrease in value; this is due to the presence of new HCA that reduced the number and length of high value LCP corridors and better landscape connectivity amongst them. A statistical comparison of this enhancement is summarized as following:

Table 34: Summary comparison between old/new LCP "linkage corridors" statistics.

LCP	Map	Count	Max length m	Count at low LCP	Sum m
Old LCP		**538**	**2535**	**325**	**107,459**
New LCP		**547**	**2459**	**410**	**99,400**
% of change		**+1.7%**	**-3%**	**+26.2%**	**-7.5%**

*Note: Here, the decreased percentage in values such as corridor length indicates an enhancement as connectivity is more assertive at shorter LCP corridor length; fewer are low LCP values. The 7.5% decrease in the total sum of all corridor lengths implies an overall enhancement as the network became shorter in length and more robust connectivity linkages. Also, the count of LCP at the low-value interval "stronger paths" is significantly enhanced by approximately 26.2 %.

The overall connectivity by relative value CRV result showed significant retrieve in the low connectivity areas, visualized in blue- to calculate the value of enhanced connectivity, the researcher uses a pixel measure within GIS, as the images rendered by linkage mapper tools are considered raster data and are set by the researcher as 1 by 1-pixel cell size grid "1 m^2" to meet to patches at all scales as mentioned previously.

This allowed an easy pixel count of values indicated initially with color value by eliminating all values implying good to high connectivity – warm colors, and measuring those indicating low connectivity – cold color/blue value.

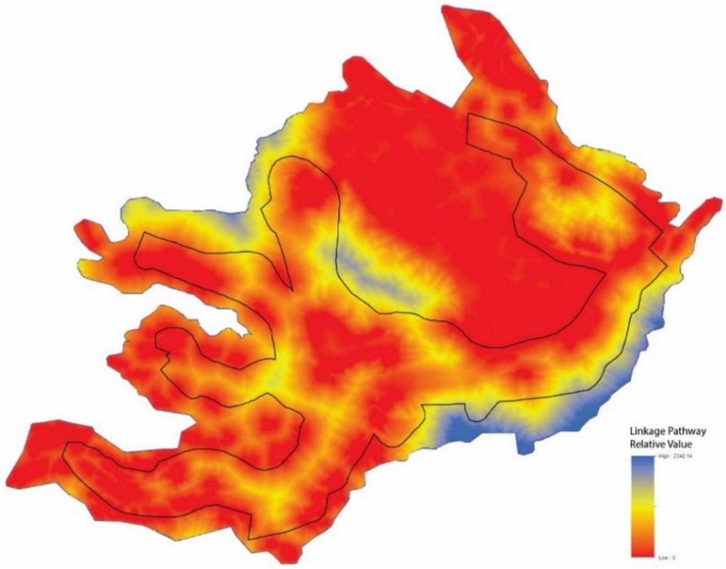
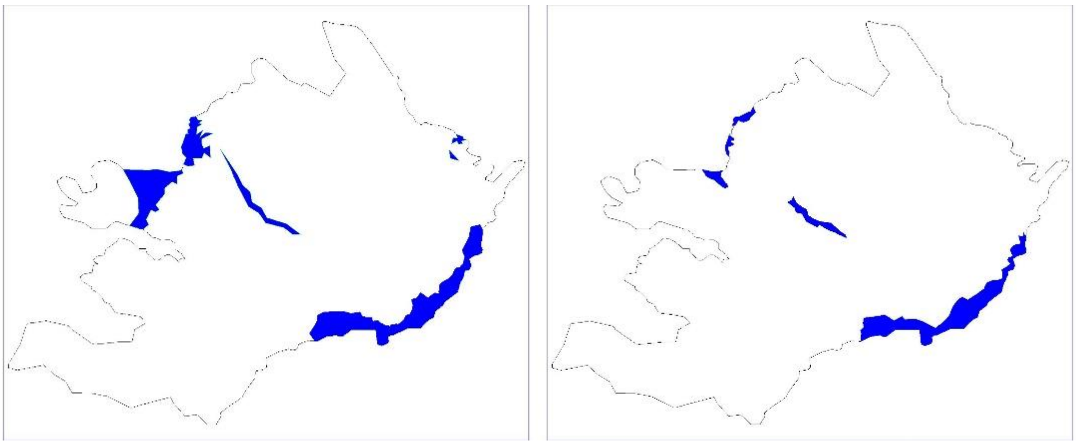


Figure 124: New linkage pathways "connectivity" relative value map - CRV. Generated through linkage mapper tool, ArcGIS.

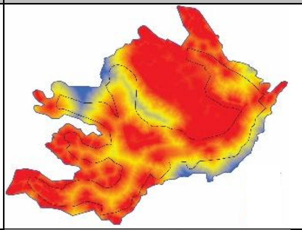
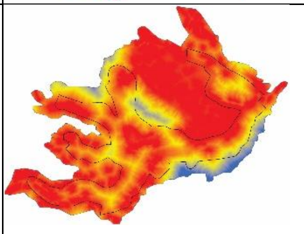


a b

Figure 125: a- Low connectivity value areas map. b- New low connectivity value areas map, showing significant retrieve in low value areas.

The previous maps in Figures 126 a and b show that after eliminating all medium to high connectivity values from the background of the study area, there was a noticeable retrieve in the areas with low CRV. The statistics of the enhancement of landscape connectivity by relative value measure are shown as follows.

Table 35: Summary comparison between old/new CRV "Connectivity relative value" statistics; Approximate area by pixel count.

CRV	Map; Boundary total Area = 9,420,000 m^2	Pixel Count = Area m^2 ; M to H Values	Pixel Count = Area m^2 ; Low Values	Total Area	% of Low CRV to total
Old		**8,813,000**	**607,000**	**9,420,000 m2**	**6.4%**
New		**9,085,000**	**335,000**		**3.6%**
% of change		**+3.1%**	**-44.8%**	**-**	**-43.8%**

It is observed that the connectivity relative value CRV showed significant improvement. The analysis resulted in a decrease of 44.8% of all low connectivity value areas, where the addition of different ecological habitat areas within high barrier points improved the overall medium to high CRV by 3.1% and resulted in a 43.8% decrease in the low-value areas; where ecological spatial movements are weak- as compared to the whole study area.

As for connectivity value by cost weigh distance CWD, the mapping analysis shows a noticeable retrieve of the high-value CWD far towards the edges of the study area, indicating an overall enhancement in values within. The statistical summary of CWD before and after suggesting new ecological restoration areas where the pixel count was utilized again to measure the overall change in CWD value based on the 1 by 1-pixel cell grid in GIS, values measured are those with lowest CWD- shown in figure 128 a and b, against all other "medium to high" CWD values.

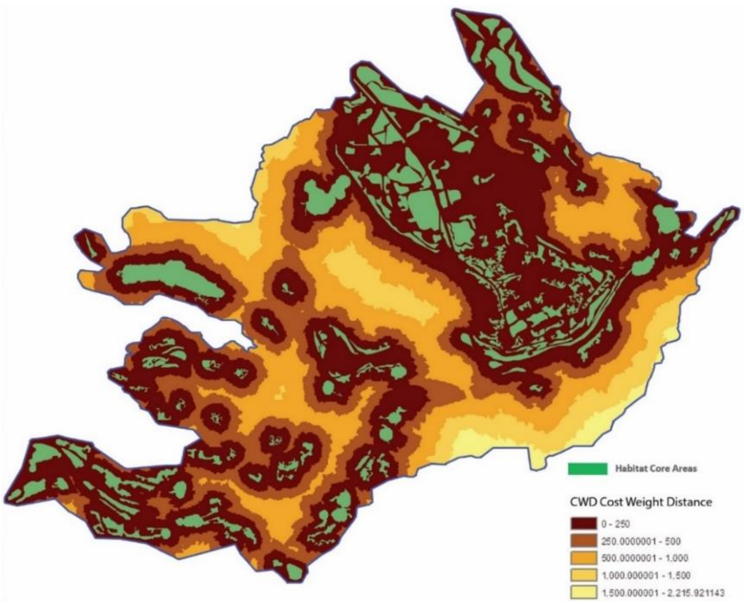
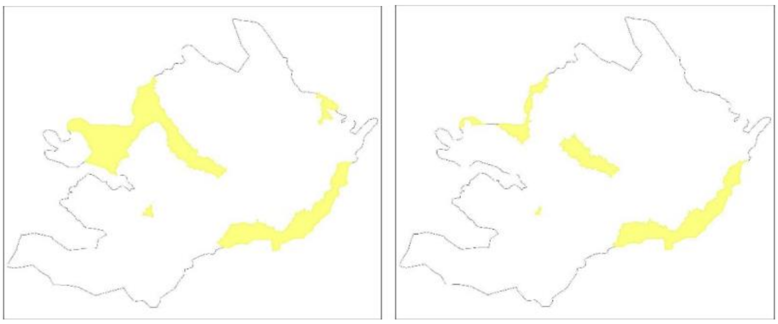


Figure 126: New Linkage pathways "connectivity", CWD map. Generated through linkage mapper tool, ArcGIS.

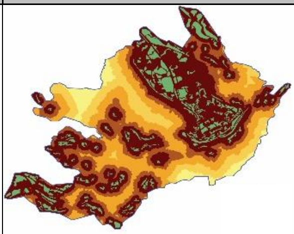
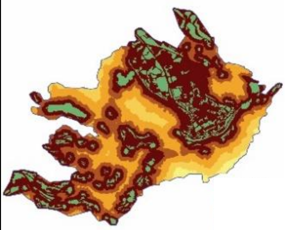


a b

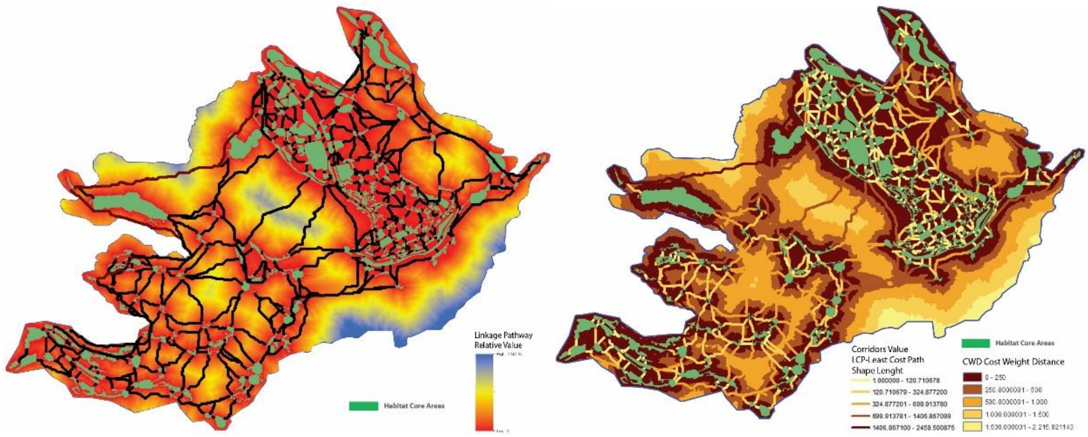
Figure 127: a- Low-Value Linkage pathways "connectivity", CWD map. b- Low-Value Linkage pathways "connectivity", CWD map, showing significant retrieve in low values areas.

Results indicate that the total linkage connectivity value measured by CWD was enhanced by 6.7% after adding the new HCA. This also led to a decrease of about 42.5% both in the area with low CWD and the percentage of the total low-value CWD within the whole study area which indicates an overall enhancement in landscape connectivity.

Table 36: Summary of comparison between old/new CWD "Linkage pathways connectivity by cost weight distance" statistics.

CWD	Map; Boundary total Area = 9,420,000 m^2	Pixel Count = Area m^2 ; M to H Values	Pixel Count = Area m^2 ; Low Values	Total Area	% of Low CRV to total
Old		8,137,000	1,283,000	9,420,000 m2	13.62%
New		8,682,000	738,000		7.83%
% of change		+6.7%	-42.48%	-	-42.52%

The following maps in figure 129 visualize the overall change after suggesting new HCA for the previous values analyzed and discussed.



a b

Figure 128: a- New CRV showing core habitat areas and corridors, b- New Connectivity value CWD showing LCP of corridors and habitat core areas. Maps generated using linkage mapper toolbox operated within Arc-GIS platform.

Lastly, the researcher runs the centrality mapper tool to re-calculate new centrality values between cores and corridors after the addition of the suggested new HCA in place of high barrier areas that overlap with high human activity areas. The new network as a whole is visualized as follows in figures 129.

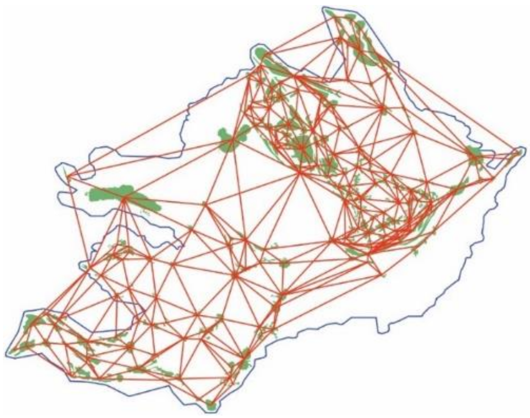


Figure 129: New Centrality map, showing the new network of the core to corridor connections. Generated through linkage mapper centrality mapper tool, ArcGIS.

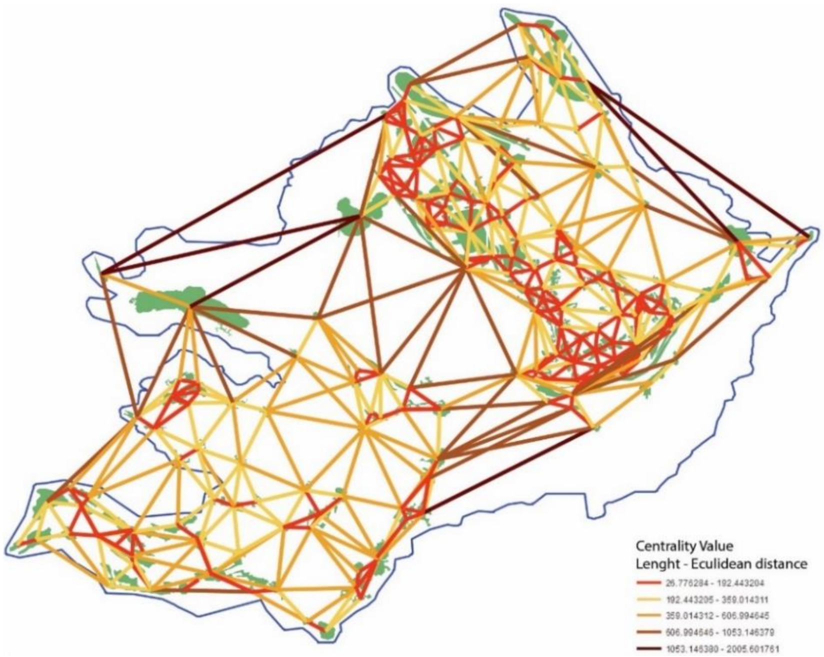
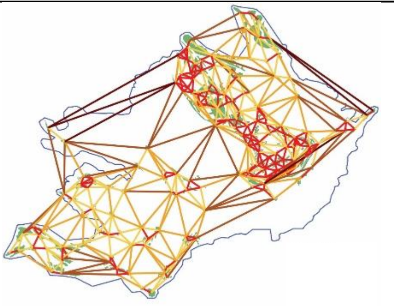
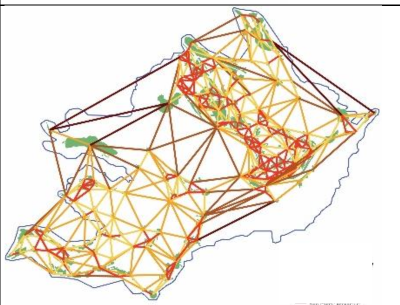


Figure 130: New Centrality map, showing new centrality values within the network. Generated through linkage mapper centrality mapper tool, ArcGIS.

Centrality values depending on Euclidean distance ECD which are shown in figure 130 indicate a visually increased value in both high value functionally connections and priority ones. A statistical summary of the results is shown in table that follows;

Table 37: Summary comparison between old/new Euclidean distance ECD "centrality" statistics.

ECD	Map	Count	Mean length m	Standard deviation	Sum m
Old ECD		**538**	**280**	**249**	**150310.3**
New ECD		**547**	**275**	**227**	**150477.6**
% of change		**+1.7%**	**-1.8%**	**-8.84%**	**+0.11%**

Results provide some evidence of an overall enhancement of centrality; functional connectivity as there are not any significant changes through them statistically. However, it is noticeable how the quantity of high-value connections has increased as well as for the noticeable spread of the network within areas that showed weak connections prior to the additions of the new HCA. While the means are about the same, the standard deviation decreased in the new centrality network. This indicates that the connection values in the new network are more consistent.

In conclusion, the analysis results indicate how the new HCA's presence enhanced the overall landscape connectivity values measured. This implies enhanced ecosystem resilience, while at the same time, choosing potential locations that overlap with human activity help focus on ecological restoration with an added opportunity to increase human ecosystem interactions. This research will propose appropriate GI strategies within these areas to potentially engage GI with inhabitants, which promises enhanced social resilience. This is discussed in the final section of this chapter 5.4.

5.4 Results; Strategies for a GI-oriented Human/Ecosystem Advancement

As discussed, this study aims to implement GI toward building social-ecological resiliency. For that, the researcher proposed a framework where both graph theory and space syntax theory were used as a mixed method to analyze ecosystem and human spatial patterns to apply GI within those specific areas. The case study was used as a testbed for the method. The analysis of the landscape connectivity is based on the graph theory linkage mapper tool and resulted in specific locations for priority ecological enhancement areas that were further filtered to those that met human activity areas as analyzed by depth map software based on space syntax theory. To this end, the researcher will present the final results as a set of GI strategies to promote human and ecosystem health. Chosen GI strategies are defined according to three main factors;

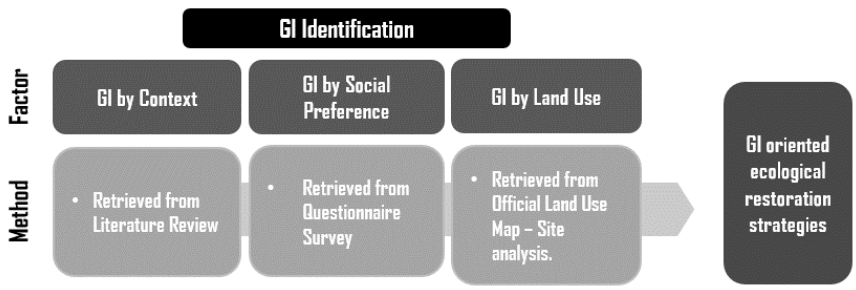


Figure 131: Illustration showing process for choosing appropriate UGI.

a- *GI is defined by context/scale. Most relevant inner city urban GI strategies were Identified from the literature review in chapter 2 and summarized in table 8.*

The most relevant are urban gardens, green corridors/belts, urban parks, green walls/roofs, green spaces, and street trees. However, there had been some other less mentioned features of urban GI which withhold great potential for inner-city context implementation that engages community members with GI, which are; community gardens and residential gardens. In addition, less relevant features are seen essential for their value in decreased natural disasters such as surface floods and are considered a replacement for traditional infrastructure: Preamble pavements, artificial and natural surfaces, and storm water management systems.

b- *GI is defined by social preferences. Preferences for GI were surveyed across the population in the study area by the researcher, where respondents were given few choices based on general inner city GI typologies. Presented in Chapter 4- section 4.7: Inner city GI strategies "by surveyed social preferences".*

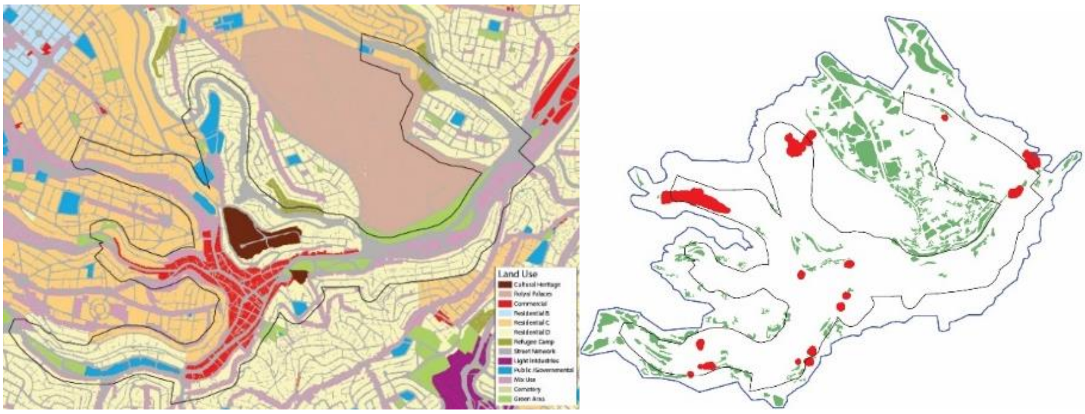
The researcher, within the questionnaire survey, conducted a multi-response question to investigate preferred GI types. The results reflected what the community member indeed lacked and what they mostly understood. Results indicated that the general population had little knowledge and various preferences, especially regarding nontraditional green infrastructures such as preamble pavements and rainwater harvesting systems. Moreover, they preferred the traditional types, especially that neighborhood and public scale. A summary of this is shown in the following table in a descending choice manner;

Table 38: Summary of table showing GI choice and preferences within the surveyed population at study area; sample size 385 respondents.

GI Preference - Choice	Preference value	Count	%
1 Neighborhood Parks	**High**	**146**	**56.2%**
2 Public Parks /Recreational Areas		**162**	**42.1%**
3 Street Trees	**Medium**	**125**	**32.5%**
4 Green Walls/Roofs		**120**	**31.2%**
5 Private Gardens		**119**	**30.9%**
6 Green Spaces		**116**	**30.1%**
7 Community Gardens	**Low**	**97**	**25.2%**
8 Urban Farming		**68**	**17.7%**
9 Preamble Pavements	**Very Low**	**50**	**13%**
10 Rainwater Harvesting System		**47**	**12.2%**
Total		**385**	**100%**

c- GI is defined by land use. The researcher will limit chosen GI in each ecological restoration area according to suitability with current land use retrieved formally from the city's municipality.

After the questionnaire survey analysis, the researcher concluded a set of GI strategies that are both appropriate to the context, initial land use analyzed, and local community preferences. This was further developed to include specific land use, as a closed analysis of the land use per each ecological restoration potential area was conducted to show that the prior land use analysis was too general, as many plots within one land use shown were seen to have several lands uses; this is due to the lack of commitment to regulations at times, and the ability of landlords and owners to manipulate or change official land use. . The following maps in figures 132 and 133 show the process of overlapping the suggested areas for ecological restoration with the land use map for a closer identification of specific land use in each area.



a b

Figure 132: a- Official land use map, Identifying study area (GAM, 2021). b- HCA map, highlighting new suggested HCA based on barrier mapper analysis.

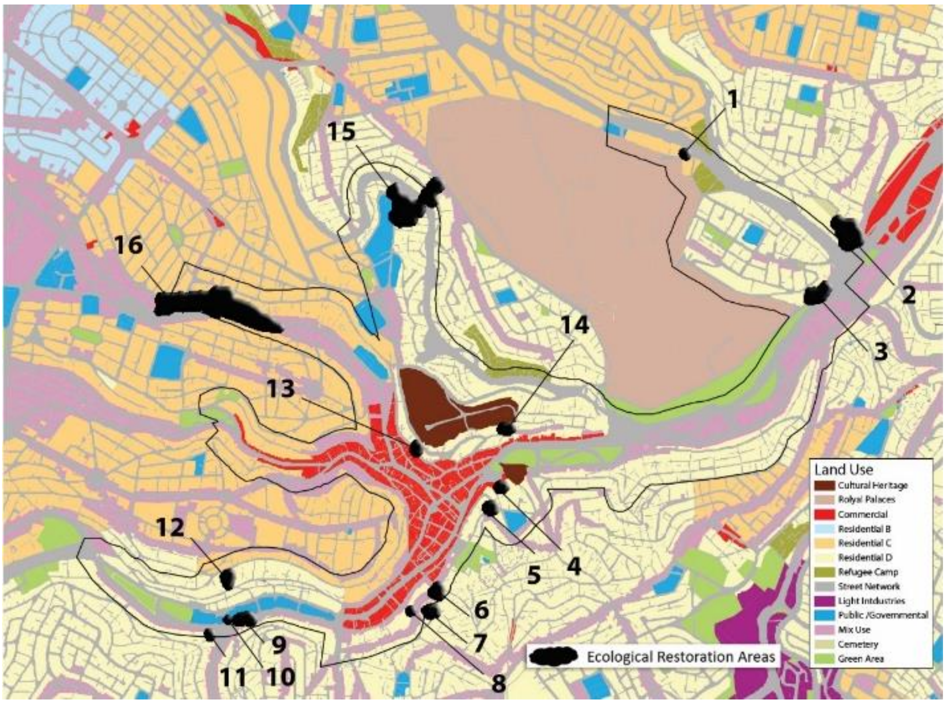


Figure 133: Official Land Use map as retrieved from GAM, indicating new ecological restoration areas; indexed 1 to 16. Adapted by Author.

Moreover, the analysis from chapter 4 concluded what communities indeed preferred when they were given a choice. However, the final incorporation will include more GI elements for reasons such as; some land use is non-residential, which means landlords, municipalities, or government make the decision. Also, some GI strategies are a part of the urban infrastructure that contribute to NDRR, i.e., surface floods, such as the rainwater systems, and high authorities and not community members decide upon such strategies. The list of GI strategies that were both retrieved from literature and survey for social preferences and at the same time meet specific land use in the study area are as follows; Neighborhood parks, Community gardens, Residential/Private gardens, Green walls/roofs, Green spaces, and street trees, However, some specific GI can be applicable at all uses as a part of the urban infrastructure, as seen fit by the decision makers and urban planners at the municipality, which is; permeable pavements, natural surfaces, and Storm water management systems.

Table 39 identifies ecological restoration areas shown in the previous map in figure 133 by land use, then suggests proper GI for each as a conclusion to the discussion of this chapter.

Table 39: Ecological restoration areas ER-Area defined by "land use/regulation (Retrieved from GAM, 2022)" VS appropriate UGI suggestions (adopted by Author).

ER-Area Index	Land Use Type/Types	Allowable built area	UGI	Responsible Party
1	Residential C "Medium density"	51%	Neighborhood parks, Residential/Private gardens, Community gardens, street trees	Municipality, community members
2, 3, 6, 8, 11	Residential D "High density"	55%	Neighborhood parks, Residential/Private gardens, Green spaces, street trees	Municipality, community members
2, 3, 6, 8, 11	Mixed Use	%45	Green walls/roofs, street trees	Municipality, Landlords, owners
4, 13	Commercial	50%	Green walls/roofs, street trees	Municipality
4, 13	Residential D "High density."			
5	Residential D "High density."			
7, 12, 14	Residential D "High density."			
9, 15	Residential D "High density."			
9, 15	Mixed Use			
9, 15	Public/Governmental /Institutional	*Regulations based upon surrounding land use*	Green walls/roofs, Green spaces, street trees	High authorities, Municipality
10	Public/Governmental /Institutional			
16	Residential C "Medium density."			
16	Mixed Use			

*Note; New HCA; was suggested ecological restoration by implementing proper GI are being analyzed lies within Amman's city center boundary. However, more areas "Indexed; 2, 7, 11, 15, and 16" are included, which are those areas exist at the edge of the boundary extending to its close outer periphery. Also, noting; that some areas overlap with several land use types within one patch and are categorized in the table 39 accordingly for a more focused choice of GI strategies. Moreover, the color index of land use matches the legend on the map for easier interpretation and avoids repetition as many areas share the same use.

This chapter enquired how the tools of the methodological framework suggested by the researcher can be applied. The discussion and the analysis were done in a specific urban context; Amman city center- but the framework can be further applied within different urban contexts. The urban context of the case study is an example of a highly complex, overbuilt environment, which proves that GI can be implemented towards socio-ecological resiliency in all urban environments.

The researcher initially stated that GI could contribute to building resiliency based on scientific and pragmatic evidence. The new methods that contributed to this, space syntax methods/graph theory methods, shed light on bridging the theories behind human space relationships and landscape connectivity relationships effectively when merged to analyze crucial areas that can enhance social and ecological resilience. Moreover, this method is time effective and efficient in identifying areas for enhancing the resiliency of a city's social-ecological system, especially when the context is of a large complex scale, such as the case study was chosen.

To this end, specific UGI strategies within ecological restoration projects of any scale and kind can be approached where they are most needed, ensuring an overall benefit is bringing more robust connected human/ecological spatial integration with all its associated benefits.

Chapter 6

CONCLUSION

This chapter will summarize the key research findings as a set of concluding remarks whilst responding to the research hypothesis, research question, aims, and questions and discussing the study's primary values and contributions. It will also review the limitations of the study and propose opportunities for future research.

6.1 Concluding Remarks

The theoretical framework critically explored literature utilizing a broad number of theoretical and practical studies. Within the theoretical discussions this study concluded into main key findings that further helped address aims, questions, as well as facilitate discussions. The main key findings are highlighted as follows;

- The literature review identified a gap regarding the effect of engaging GI within challenging urban contexts to advance resiliency and DRR within scientific research and theory as well as within practical frameworks and publications.
- Moreover, urban practices acknowledge the same gap from the sense of bridging existing theories into the practice of actual implementation of GI, especially in a multi-functional way. Large city scale GI, especially within an inner city scale - is acknowledged to be challenging for cities and therefore GI is mostly being integrated into a single functional approach.
- While numerous studies discuss the significance of GI in building environmentally resilient cities, discussion on its role in building social resilience is limited, while its impact on building socio-ecological resilience is relatively weak in theoretical

discussions. Also, existing practical resilience frameworks offer limited tools for specific assessment of the contributory role of GI towards urban resilience.

- The relationship between the concepts of GI, human health/wellbeing, and socio-ecological resiliency is still vague between studies from different disciplines.
- There is a lack of assessment frameworks or proper practical tools that focus on the ability of complex urban contexts to build resiliency as an integrated social-ecological system approach in urban communities. Existing tools do not approach the urban system from their urban communities' perspective. As such, research that overlooks a city from its spatial human ecosystem networks is non-existing.
- While there are studies that discuss human/environmental psychology from the perspective of drivers/barriers of positive behavior within pro-environmental behavior models, studies on this topic are linked to assessing and developing successful management of human ecosystem relationships with urban GI through understanding those drivers are still on the sidelines. Even though barriers to GI exceed human behavior, investigating existing frameworks showed that their inclusion is still limited.
- Most importantly, even though limited, existing frameworks are very general, very case sensitive, and cannot be generalized in different urban contexts because they lack contextual sensitivity and comprehensive factors within their assessment tools. The development of a context-sensitive tool that can also have the flexibility of easy adaptation is still considered a significant gap.

6.2 Explicit Answer to the Research Question, Addressing Aims

In the introduction chapter, the main research hypothesis was presented. The sub-questions, aims, and objectives helped the researcher bring an extensive theoretical, evidence-based, and practically tested answer. Accordingly, the study's main question, sub-questions, aims, and objectives have been answered and addressed.

The results are presented as a set of statements withdrawn from the overall theoretical background investigation, practical explorations, critical literature review of several disciplines, case study analysis, testing, and interpretations included within the methodological approach processed by the researcher in an attempt to find all relevant links toward building an understanding towards all possible aspects of the main research question; *How can GI be implemented into the human ecosystem spatial networks of challenging inner city urban contexts to reach socio-ecological resiliency, versus developing tactical solutions during emergency situations?*

- Socio-ecological resilience; the human ecosystem approach that enables to assess resiliency within urban contexts- should involve the partcipation of urban communities. Both systems rely upon and benefit from each other, raising each other's adaptive capacities to withstand stress and remain functioning through change as they raise each other's health and well-being by positively transforming into a better functioning structure.
- Green infrastructure is defined as a set of naturally inspired strategies that promises advancing resilience when properly integrated within urban contexts in a multi-functional approach. GI's relationship with advancing urban resilience is that it withholds many contributions to enhancing human/ecosystem health and wellbeing, thus, enhancing social and ecological capacities and decreasing their vulnerabilities. From this perspective, it can be considered a new theoretically based approach to actual resiliency planning and DRR practices, as suggested by the study.

- Moreover, GI strategies differ in scale and context. Proper development of GI within the challanging inner city urban areas must consider that. However, targeting specific areas for GI integration withholding high human impact increases its foreseen multi-benefits as GI promises the delivery of ecosystem services of nature to humans, which implies a mutual enhancement of resilience capacities and a decrease in vulnerabilities in both systems. According to this study, this can be applied when GI is integrated into urban areas through investigating human ecosystem spatial networks.
- Carefully planning for GI, taking into consideration several factors such as appropriate scale to context, preferenced choice, available resources, regulations, and land use, amongst others, can help in properly integrating GI to meet all proper aspects, even at the scale of a highly urbanized urban system where planning for GI can be very challenging. Approaching GI through specific locations based on human ecosystem networks can provide a practically applicable solution with minimum invasive measurements which can be further generalized.
- This study's primary aim was; *to develop a theoretically based framework that approaches a GI-oriented resilient inner city structure through the spatial networks of its urban communities that can be further applied to real practice to provide the tactical solutions to tackle DRR.* In this perspective, the study investigated the -however limited- existing frameworks and studies towards building resiliency in socio-ecological systems and concluded that they are in crucial need of developing indicators and tools where the relationship between humans and the environment within an urban system is needed, with a primary focus that it can translate theory into practice, and be context sensitive yet flexible to be applicable in other similar

urban contexts. As such, the study resulted in developing a framework that withholds those primary concerns.

- Also, the study looked into the most relevant theories withholding innovative tools to support the applicability of a methodological approach of for this framework. The study resulted into investigating graph theory and methods which can help assess ecosystem, landscape connectivity, centrality, and functionality within fragmented patches of the natural environment within an urban context. This helped to measure and visualize ecosystem relationships, spatial patterns, and conditions toward addressing specific context-based ecological enhancement/restoration areas. This study concluded that this approach can be an effective and efficient approach toward locating specific areas to target ecological restoration, significantly when an ecosystem is highly fragmented in an urban context.
- Moreover, the study looked into space syntax theories and methods and determined that they can be used as an efficient and effective way to measure and visualize human-space relationships so that they are considered a leading contributor in choosing areas for GI implementation. However, space syntax only measures the spatial patterns of human systems. For this, theories and models of human-environment psychology, referred to as pro-environmental behavior, was introduced as a contributory practical tool for assessing several factors such as drivers and barriers to having positive action environmentally. The study has resulted that adding these models from the discipline of the human sciences can help approach large communities in urban contexts to ensure the evaluation of intangible factors such as environmental value, concerns, and willingness to participate or get engaged, which further ensures the reasonable choice of GI within highly inhabited urban areas.

6.3 Contributions of the Research

With the extensive investigation of its main focus through several theoretical disciplines and practice, this research contributes to locating specific limitations in existing studies and the critical relationships between several fields that need further development. While most of this had been explicitly discussed earlier, the researcher explains the main general contribution of this study as follows;

The study brought an evidence-based methodological framework that can bridge theory into practice. The main contribution of this framework is the connection between human-based theories and ecological-based theories that, when merged and tested through a case study, can provide practical and effective approaches toward assessment of a GI-oriented socio-ecological resilience that when taking its context-sensitive elements, can be applicable and generalized through several urban contexts. The methods included graph theory methods, with its up-to-date tools; linkage mapper, and space syntax theory with its popular tool, the depth map. Both those tools bring insights for a fast and easy understanding and identification of human/ecosystem relationships within urban contexts, making approaching resiliency amicable.

Moreover, this framework was tested on a case study, which sets an example of how the methodological approach can be applied as analysis had proven that this framework provided significant results that show that if applied to real urban practice for tactical solutions regarding DRR, it will be a successful approach towards the development of a GI-oriented socio-ecological resiliency. This can further contribute to the development of more theoretical studies between scholars and urban practitioners in the fields of urban planning with this as a base-ground. As such, this new theoretically based methodological framework can be used in theoretical studies and in real practice that opens up new approaches for development in both.

Finally, within testing the methodological approach on the case study, this research further contributed in some guidelines that can be applied to urban planning practices that target the enhancement of urban communities for resiliency and DRR;

- Re-instating greenery within challanging inner city urban contexts even by utilizing specific small-scale urban GI elements can contribute in increasing lanscape connectivity which implies an overall enhanced ecological resiliency which further implies possitivly adapting to and transforming with the climatic based natural disasters that usualy is intinsified in urban contexts with degraded natural environment.
- Even small amounts of urban greening, when well-connected as micro-doses of several urban GI can enhance human health and well being, s well as for implying social resiliency to inner city stressors as anticipated benefits include enhanced air/noise pollution, decreased surface floods, decreased air tempratures and decreased energy consumption, amongst others.
- Integrating urban GI through the spatial network of the human system must be approached with prioritizing publicly accessible and preferably well-connected spaces withholding high human impact for maximum social engagement and involvement.
- For less invasive measures into tackling urban GI, specific locations withholding high ecological barriers and high human impact can be enough to enhance the overall resiliency capacities of the urban communities as a whole. This is practically approached utilizing off-site methods and tools. As such, human spatial networks can be analyzed and studied before providing proper urban GI implementation in a time-effective and efficient manner.

- Specific choice of original greenery and vegetation typologies with national bioclimatic considerations can highly contribute to the long term sustainability and of urban GI.

6.4 Limitations/Weaknesses and Recommendations

This new methodology can be used between theoretical studies and practical practices. However, because it merges theories from several disciplines, actual studies on applying the framework with its methods require a team from those several fields so that all specified factors are considered accurately.

Moreover, the tools and software used in the analysis require specific knowledge for developing reliable results. Specifically, linkage mapper tools are very new and still developing. They are not commonly used to model landscapes in an urban context, mainly used to study vast ecological areas like forests.

Most importantly, this study focuses on resiliency, which within theory emerged into urbanism for the purposes of providing tactical solutions to deal with DRR. However, even though this study addresses this matter, the final analysis and results do not provide the basis for practically measuring disasters that are introduced within the case study chapter as mostly climate-related natural disasters that are happening due to the suffering of the urban system from the after-effects of its intensified urban expansion on behalf of its natural environment. In this matter, this study recommends further research that can integrate specific analysis of disaster areas that can be overlapped within human-ecosystem networks. Such integration is seen to provide more insight to a more specific location that if ecologically restored with proper GI in a multi-functional way, will provide stronger evidence towards successfully planning for resiliency and natural DRR.

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APPENDICIES

Appendix A: Questionnaire Survey Samples

Questionnaire survey sample – page 1.

Dear Respondent

As part of the Phd of Architecture Program of Eastern Mediterranean University, I am conducting a research survey to investigate the perception/cognizance of local community members and local citizens towards the implementation of Green infrastructure strategies/features in the built environment of the city center of Amman – Jordan. As well as measuring their willingness in participating in their management.

Your kind participation is highly appreciated. This survey is anonymous; the data obtained will be presented as general conclusions. If you have any query, please contact me.

Thank you in advance for your time and support.

Islam Alshafei

1. **Educational Level?**
2. ☐ Non-educated ☐ University
3. ☐ Middle/High school ☐ Master's Degree
4. ☐ Diploma ☐ PhD

2. What is your cultural back ground, ethnic representation?

☐ Local citizen ☐ Immigrant

☐ Other; please state: ……………………………………………

3. Are you aware of GI strategies/features and its associated benefits?

☐ Yes ☐ No

If Yes, please elaborate how…?

………………………………………………………………………………………………

4. According to you which of the strategies below are related to Green Infrastructure (GI)?

☐ Street trees/Tree canopy ☐ Green walls/roofs

☐ Community gardens ☐ Private gardens

☐ Public parks/ Recreational areas ☐ Urban farming

☐ Green Spaces ☐ Neighborhood parks

☐ Preamble pavements ☐ Rainwater harvesting systems/ Swales

Questionnaire survey sample – page 2.

5. Does your private residence/neighborhood use any of the above strategies?

☐ Yes ☐ No

If NO, **what GI strategies/features would you like to see at your place of residence/ neighborhood?**

…………………………………………………………………………

6. If you do not use these strategies/features can you, please mark the relevant reason or reasons?

a) I find them unnecessary
b) Application is expensive
c) Individual resistance when designing within private plots
d) It is irrelevant to my life style/ preferences
e) most of the plot sizes does not give enough area for application
f) The built environment does not offer sufficient spaces of application of GI
g) other ……………………………………………………………….

7. Do you believe in the significance of GI in urban design and planning, therefore are you willing to personally participate if necessary in its application?

☐ Yes ☐ No

If yes can you describe in short how this experience might benefit you as a community member?

……………………………………………………………………………………

8. Are you willing to pay extra costs on your infrastructure governmental pills if application of GI became mandatory by the municipality?

☐ Yes ☐ No

If yes can you describe in short why GI is worth paying for?

……………………………………………………………………………………

9. If you are considering GI and its applicable strategies/features at your private residence/ neighborhood on the other hand and you are having problems by their application can you please mark the relevant reason or reasons?

a) Application found expensive
b) Lack of awareness and sufficient community participation
c) Inexistence of compelling urban design/planning policies
d) There is not enough application inspection by authorities
e) Inexistence of appropriate technology for applying non-traditional infrastructure locally

e) other …………………………………………………………………………………………

Thanks for your Valuable Cooperation.

Appendix B: Original Greenery; National Bio Climate

This part of this case study discusses the type of urban greenery from the perspective of vegetation typologies. From the standpoint of developing a resilient type of green infrastructure and restoring the natural ecosystem within the area, it is imperative to acknowledge that choosing original types of vegetation that are native and most suitable within the bioclimatic region can be more effective and sustainable than choosing to introduce and cultivate hybrid species that may not sustain, thrive or withstand environmental factors of the area as natural as the native species. To this end, the study will be conducting research about the native species within the region, with a high limitation due to the insufficient documentation of the extinct types due to the rapid urbanization that left the study area with some fragmented leftovers of its natural ecosystem—noting that this data, within the scope of the framework of the study, is fundamental yet highly case and context-sensitive.

As in the whole of Jordan, Amman does not compromise a country-wide flora. The flora here is defined as all the native plant life that exists through a specific region and time naturally occurring. Unfortunately, a minimal effort has been put towards documenting the Jordanian flora, (Maani,2008, Al-Eisawi, 1998 & Al-Eisawi 2013), which is acknowledged to be highly uncomprehensive by the Royal Jordanian Botanic Garden Kew, who has recently put efforts towards comprehending an annotated checklist of the plants of Jordan as a reinforced corporation with a European research area (RJB, 2014).

Their initiative towards conserving Jordan's native flora was unfortunately faced with the fact that there is insufficient, very fragmented, and sometimes non-existing information. To this end, their annotated checklist of Jordan's flora was developed based on previous field research and the current knowledge of the wildlife that was found in the Royal Society for the Conservation of Nature database "RSCN" to conserve Jordan's native flora and is the only documentation that brings together the fragments of available data and will be used as a trusted reference within this part of the study. However, the list includes all families of flora that were sited in Jordan, citing the location by cities as a whole, while the study area is the oldest and smallest part of the city of Amman. Therefore, the researcher will be referring to the bioclimatic region's suitable flora as the closest reference of which native species are ideal for the area.

To this end, the study will start with identifying the bioclimatic regions of Jordan, and locating where Amman lies, then place the plant species that are typically naturally present within. However, each bioclimatic zone is known to have multiple categories of vegetation types and plant communities within. Therefore, for this purpose, the study will look into Jordan's bioclimatic zones and identify vegetation categories within each one by governance/city.

Several authorities have described the regional vegetation of Jordan between 1956 and 1988 by several scholars and filed studies. However, the most efficient descriptions were made in the late 20th century and are those that best contributed to the knowledge of Jordan's vegetation and habitats (RJB, 2014). Detailed identification of Jordan's ecology, vegetation, and habitats in 1996 by Eiswi. His classification of Jordan's vegetation included ten categories based on; Altitude range, Land classification, Representative governorates "cities", Vegetation types, and Bioclimatic regional zone. The fact that this classification contributes to identifying the vegetation types according to Governorate "city" will help further identify which species with the bioclimatic zone are naturally found within the study area; Amman governorate/city.

The researcher summarizes them in table number 40, altitude range and bioclimatic zones with the most relevant vegetation are identified as following.

Table 40: Summary of Vegetation Type Categories of Jordan. As adapted from RJB, 2014 and Eisawi, 1996. Developed by the author.

Category	Bio-climatic zone	Altitude range, Governorate	Vegetation " Plant Community"
1 - Pine Forest	Mediterranean	550-1000m Ajloun, Jerash, Balqa, Dibeen	**Climax forest;** *Pinus halepensis* (Aleppo pine), *Quercus coccifera*
			Trees &shrubs; *Arbutus andrachne, Qyercus coccifera, Pistacia palaestina*
			Low shrubs; *Calycotome villosa, Cistus villosus, C. salvifolius, Smilax aspera*
			Herbaceous cover; *Fumana arabica, Thesium hergeri, Helianthemuim lavandulaefolium*
			Orchids; *Ophrys, Lemodorum, Cephalanthera*.
2 – Ever Green Oak Forest	Mediterranean	600–1200m Amman; Irbid Best represented near Ajloun; Tafila	**Forest (Dominant with associated trees);** *Quercus coccifera*; associates *Pistacia palaestina, Pyrus syriaca, Arbutus andrachne, Crataegus azarolus, Phillyrea latifolia, Ceratonia siliqua. & C. silique;* associated with *Juniperus phoenicea, Pistacia atlantica* and *Amygdalus korshinski*
			Low shrubs; *Amygdalus communis, Asparagus aphyllus, Lonicera etrusca, Sarcopoterium spinosum, Rhamnus palaestinus, Rubia olivieri, Calycotome villosa, Cistus villosus, Clematic cirrhosa*.
			Herbaceous; *Dactylis glomerata, Anemone coronaria, Echinops spp., Lecokia cretica, Orchis anatolica, Poa bulbosa, Cyclamen persicum, Linum pubescens, Adonis palaestina.*
3 - Deciduous oak forest	Mediterranean	Low altitude Forest Um-Qeis and Yarmuk river; Ajloun; Jarash; Salt; West Mahes, West Amman.	**Trees;** *Quercus ithaburensis,Styrax officinalis,Ceratonia siliqua,Pistacia atlantica,Olea europaea.*
			Shrubs; *Crataegus azarolus, Olea europaea, Amygdalus communis, Calycotome villosa, Rhamnus palaestinus, Retama raetam.*
			Low shrubs, climbers, grasses and geophytes; *Alcea* spp., *Carlina hispanica, Euphorbia hierosolymitana, Salvia* spp., *Sarcopoterium spinosum, Asparagus aphyllus.*
			Grasses; *Dactylis glomerata, Poa bulbosa*; geophytes: *Drimia maritima, Colchicum* spp., *Tulipa* spp.

4 - Juniper woodland	**Mediterranean**	**600–1700 m** **Tafila: Dana, Shobak, Wadi Musa, western slopes extending to Petra, Wadi Musa and Wadi Rum**	**Woodland (Dominant with associated trees);** *Juniperus phoenica* associated with veteran trees of *Cupressus sempervirens . Pistacia atlantica, Rhamnus palaestinus, Thymelaea hirsuta, Daphne linearifolia, Amygdalus korschinskyi, Colutea istria, Crataegus azarolus;* a few trees of *Ceratonia silique.* **Shrubs:** *Globularia arabica, Helianthemum vesicarium, Sarcopoterium spinosom, Osyris alba, Noaea mucronata, Achillea santolina, Artemesia sieberi, Zosima absinthifolia*; grasses: *Dactylis glomerata..*
4 Mediterranean shrub land	**Mediterranean**	**900–1500 m** **Tafila, Karak, Jarash, Ajloun**	The secondary degraded forest and shrub land generally borders. **Dominant shrubs:** *Rhamnus palaestinus, Sarcopoterium spinosum, Calicotome villosa* and *Cistus* spp. in the north, and *Artemisia sieberi* in the south with other associates.
6 - Mixed shrub land	**Irano-Turanian; Mediterranean or Saharo-Sindian in parts**	**600–1500 m** **strip surrounding the Med-iterranean shrub land region** **Tafila, Shobak, Ma'an, Karak**	**Large shrubs with occasional tree;** *Artemesia sieberi* and scattered trees as *Pistacia atlantica* and *Crategus azarolus.* **Shrubs;** *Retama raetam, Ziziphus lotus, Z. nummularia, Ferula communis, Pistacia atlantica, Anabasis syriaca, Artemisia sieberi, Sarcopoterium spinosum, Noaea mucronata, Gypsophila arabica, Astragalus spinosus;* geophytes: *Crocus moabiticus, Asphodelus aestivus, Drimia maritima, Moraea sisyrinchium.*
7 - Acacia woodland	**Arabian regional subzone and Nubo-Sindian local centre of endemism.**	**200–400 m** **Aqaba; Ma'an; Tafila; Karak. Wadi Araba, Wadi Yatum, Wadi Rum.**	**Woodland (Dominant with associated species);** *Acacia* associated species include: *Acacia raddiana, Acacia tortilis, Anabasis articulata, Hammada scoparia, Cassia italica, Zygophyllum dumosum, Caralluma, Traganum nudatum, Fagonia* spp., *Reaumuria hirtella, Gymnocarpos decandrum, Helianthemum lippii, Asteriscus graveolens, Sclerocephalus arabicus, Anastatica hierochuntica* **Forested Areas;** *Ziziphus spina-christi, Maerua crassifolia, Salvadora persica, Balanities aegyptiaca, Calotropis procera, Acacia tortilis, A. raddiana* and *Ochradenus baccatus*.

8 - Hammada and sand dune vegetation	**Saharo-Sindian**	**600–700 m** **Aqaba;** **Ma'an;** **Amman;** **Zarqa;** **Mafraq**	**Wadis;** *Acacia tortilis, A. raddiana, Tamarix* spp., *Artemisia judaica* and *A. monosperma, Retama raetam, Nitraria retusa, Prunus arabicus, Atriplex halimus, Lycium europaeum, Artemisia sieberi, Achillea fragrantissima, Phlomis brachyodon, Tamarix* spp., *Peganum harmala, Astragalus* spp., *Anabasis articulata, Atractylis mutica, Moraea sisyrinchium*. **Gravelly areas:** *Seidlitzia rosmarinus, Spergularia diandra, Herniaria hirsuta, Aaronsohnia factorovskyi, Anthemis deserti, Asteriscus pygmaeus, Mesembryanthemum nodiflorum, Filago desertorum, Gymnarrhena micrantha, Trigonella stellata*. Grasses: *Stipa capensis, Bromus* spp. **Areas with small stones and pebbles:** *Salsola vermiculata, Anabasis articulata, Linum album, Thymus bovei, Paracaryum rugulosum, Zilla spinosa, Halogeton alopecuroides, Diplotaxis harra, Euphorbia retusa, Alcea chrysantha, Atriplex leucoclada, Lepidium aucheri* **Sandy places and sand dunes:** *Haloxylon persicum, Seidlitzia rosmarinus, Atriplex spp.,Artemisia sp., Anabasis articulata, Achillea fragrantissima, Halocnemum strohilaceum, Ephedra transitoria, Deverra triradiata, Calligonum tetrapterum, Zilla spinosa.*
9 - Dry Tropical vegetation	**Saharo-Sindian**	**200–400 m** **Balqa; Madaba: Dead Sea area, Lower Jordan valley; Aqaba & Ghor**	Vegetation confined to alluvial soils of the Rift valley greatly altered with many cultivated areas. **Trees:** *Acacia raddiana, Ziziphus spina-christi, Balanites aegyptiaca, Maerua crassifolia.* Lianas: *Cocculus pendulus.* Shrubs: S*alvadora persica, Moringa peregrina, Calotropis procera, Ochradenus baccatus, Aerva* spp., *Forsskaolea tenacissima, Capparis decidua.*
10 - Halophytic vegetation	**Saharo-Sindian**	**- 400 to -500 m** **Zarqa, Azraq, Ma'an, Ajloun. Ghor Wadi Araba, Wadi Sirhan. Wet marsh: eastern slopes of the Dead Sea, Azraq pools, coastal Aqaba**	**species of dry saline areas:** **Trees & large shrubs:** *Tamarix tetragyna, T. macrocarpa, Nitraria retusa.* **Shrubs:** *Anabasis setifera, Atriplex halimus, A. turcomanica, Suaeda fruticosa, S. palaestina*. **Species of wet saline areas:** **Trees:** *Tamarix nilotica*. **Shrubs:** *Seidlitzia rosmarinus, Inula viscosa.* Grasses & reeds: *Panicum turgidum, Phragmites communis*.

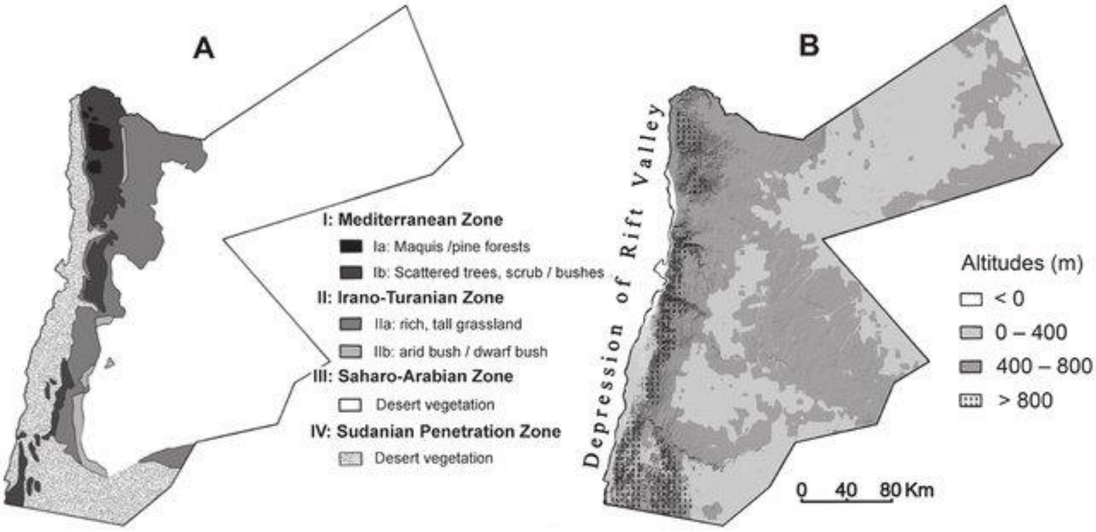

Figure 134: (A) Map of vegetation and bioclimatic areas of Jordan, (B) topographic map of Jordan. (As adapted from Kravchenko et al., 2015)

The study area lies within the bioclimatic Mediterranean zone, with several vegetation type categories (1 through to 6). However, those within the Governorate of Amman where our study area is located are 2; Ever Green Oak Forest. Note that Category 3 also mentions Amman. However, it is specific to West Amman, where the study area lies in the center closer to East Amman. Also, category 9 notes Amman. However, it is associated with Amman city extensions towards the north lower altitude lands away from the study area's center.

Furthermore, more specific citations will be conducted based on research about the early Holocene woodland vegetation and human impacts in the arid zone of the southern Levant (Asouti et al., 2015), which identifies the carbon residue of wood fuel use that was found in anthropological remains within site close to the area of this study. This will give insight into the extinct native plants used to habitat its degraded ecosystem. According to RJB, (2014) excessive wood cutting, excessive grazing and extractor mining also destroyed GI. Therefore, looking for evidence from the anthropological remains will also show which species from the several ones that generally exist within its bioclimatic region were inhabiting the study area more closely.

According to the table 39, there is proof that vegetation types; Pistacia, Quercus deciduous, Quercus evergreen, Salicaceae, Tamarix, and Fraxinus were used as a source of fuel by the anthropological remains analyzed. Accordingly, associated species are expected to have been inhabiting the area, and plants are known to exist as communities. The highlighted area within the table refers to Ain Ghazal and is the closest to the study area of downtown Amman.

Table 41: Late Pleistocene and early Holocene sites published anthropological remains adapted from Asouti et al., 2015 and developed by the author

	Nahal Neqarot[a]	WF16[b]	Ma'aleh Ramon[a]	Abu Salem[a]	Saflulim[a]	Ramat Harif[a]	el-Hemmeh (PPNA)[c]	Dhra'[d]	Tell Qarassa N[e]	Tell es-Sultan[f]	'Ain Ghazal[g]	Basta[g]	el-Hemmeh (LPPNB/PPNC)[c]
Pinus					0.72								
Juniperus	82.72	57.58	40									65.5	
Pistacia		3.16	58	99.95	61.59	99.62	70.71	+	59.48		<3	72.7	6.30
Quercus deciduous											>43		
Quercus evergreen		2.17					2.99	+	+		<3	3.7	0.65
Rhamnus	9.69	0.12	0.2	0.03		0.03	0.63						
Amygdalus/Prunus			0.2	0.02			2.84		37.25	+		10.9	1.94
Maloideae							0.16			+	+		0.48
Olea										+			
Punica										+			
Ceratonia										+			
Capparis		1.38								+			0.48
Leguminosae		0.67						+		+			
Ephedra	6.28	0.12	1.2			0.35		+					
Chenopodiaceae	0.79	3.99	0.4				7.24	+		+			6.30
cf. Asteraceae													1.13
cf. Labiatae													1.94
Ziziphus/Paliurus					37.66		1.73			+			1.29
Zygophyllum		0.26											0.48
Salicaceae		15.51					7.56	+	0.65	+	+	+	20.52
Tamarix	0.26	7.14					0.63	+		+	+	+	14.70
Fraxinus							1.57	+		+	+	+	34.73
Platanus										+			
Ficus		6.31					3.94	+		+			9.05
Total ID charcoal fragment count	382	2534	500	6620	138	6766	635	26	153	~160	~1300	~1535	619

To conclude this part of the study, evidence from sited vegetation indicates the presence of vegetation plants associated with the evergreen oak forest vegetation family, such as Pistacia and Quercus. However, and closest to the study area, there is evidence that other vegetation types existed, such as Salicaceae, Tamarix and

Franxinus which are not mentioned within the cited references because they are probably extinct in the area. It is worth noting that due to the appropriateness of the land cover, perception levels, and bioclimatic region, planning for re-introducing greenery to the study area may succeed if plants associated with the Mediterranean climatic zone and precisely vegetation types associated with the evergreen oak forest plant community are most preferable for a long term life span as they are expected to show more resiliency than other vegetation types that are not suitable for the climatic zone studied. And are summarized in Table 40 as follows;

Table 42: Summary of Vegetation types most suitable for Greening of the study area. (Researcher)

<table>
<tr><td rowspan="4">Ever Green Oak Forest</td><td rowspan="4">Mediterranean bioclimatic zone</td><td rowspan="3">Altitude range; 600–1200m

Annual rainfall: 400–500 mm

Representative Governorates;

Amman; Irbid Ajloun; Tafila</td><td>Forest (Dominant with associated trees); Quercus coccifera; associates Pistacia palaestina, Pyrus syriaca, Arbutus andrachne, Crataegus azarolus, Phillyrea latifolia, Ceratonia siliqua. & C. silique; associated with Juniperus phoenicea, Pistacia Atlantica, and Amygdalus korshinski</td></tr>
<tr><td>Low shrubs; Amygdalus communis, Asparagus aphyllus, Lonicera etrusca, Sarcopoterium spinosum, Rhamnus palaestinus, Rubia olivieri, Calycotome villosa, Cistus villosus, Clematic cirrhosa.</td></tr>
<tr><td>Herbaceous; Dactylis glomerata, Anemone coronaria, Echinops spp., Lecokia cretica, Orchis anatolica, Poa bulbosa, Cyclamen persicum, Linum pubescens, Adonis palaestina.</td></tr>
<tr><td colspan="2">Evidence to extinct vegetation; Salicaceae, Tamarix and Franxinus</td></tr>
</table>

**Note the vegetation types are appropriate to the annual perception of Amman, which is also an important indicator of suitability when choosing vegetation types for urban greenery in the study area.