Evaluation of Green Spaces in Hilla City According to Green Network Concept

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Abstract. The study focuses on the feasibility of connecting urban green spaces at an urban scale through a network because of the population growth and land use changes at the expense of green areas, which has led to the fragmentation and destabilization of the ecosystem in the Hilla city center in Babylon province /Iraq. The methodology will be according to two stages: first, the current state assessment was used to determine the encroachment of the areas. Secondly, it uses the gravity model and the least-cost path model in GIS to determine the level of interaction between nodes. Therefore, the research hypothesis was that connecting strong nodes to a comprehensive and integrated network increases the strength of the interaction. According to the results, there is no clear hierarchy in the distribution of urban green spaces within Hilla city, with only two levels: locality and urban on the urban level, there is no possibility of establishing a network between green spaces because of three factors: encroached uses mainly the residential, distance between patches and the node weight.

Keywords: Green open space; green network; connectivity; fragmentation; habitat.

1. INTRODUCTION

Urbanization in parallel with population growth in urban areas at the expense of green areas has led to changes in land uses, especially in green areas, as well as their fragmentation into small, isolated, and disconnected areas. This study investigates the efficiency of green space services in the study area in terms of the principle of connectivity, activating green areas, and including them within a green urban network to preserve the function of green areas in cities (see Appendix 1). Research assumes the possibility of connecting strong nodes to a comprehensive and integrated network increases with the strength of the interaction, which is determined by the nodal weight of the nodes and the least-cost path, Figure 1.

Frederick Law Olmsted (1988) popularized green space planning as a multi-benefit strategy in the US. It is a well-known early response to improving urban design and town planning: "Garden City." To prevent urban sprawl and link the city and the countryside [1]. In 1988, landscape architect Frederick Law Olmsted came to understand the value of urban green spaces in the urban environment (urban parks), and he put out a proposal for Central Park in New York and "Park Prospect" in Boston [2]. Urban green space is “a comprehensive term comprising all urban parks, forests, and related vegetation that add value to the inhabitants in an urban area” [3].

1.1 Green Network Approach

From the theoretical context of the smart city, many studies have emerged that adopt an analytical approach and describe phenomena based on the principles of "network design” [4]. This line of research uses the network theory to identify the principles that regulate the relationships between the different elements of subsystems to improve their functions and manage the complexity of relationships [5]. The term green network is often used interchangeably with green infrastructure, and both focus on the functions of the social, biological, and physical environment of green space and the interactions between them, where networks are a spatial concept of land use planning for sustainable landscapes [3]. Although there are many definitions of "green networks," none provides a comprehensive explanation that contains them all. Some of these have evaluated feasible urban green spaces in a city center in terms of patterns and connections for creating a network[6], and others have analyzed current urban ecological and green networks and greenways in terms of their viability and effectiveness [7]. Then comes a study by [8] which evaluated the current situation and examined the built and natural components of an ecological network in Tehran’s metropolitan area. The USA has developed the concept of the "Green Way" and the "European Ecological Network" as a form of solution to preserve the natural ecosystem of green and open spaces [9]. At present, sustainable development focuses on the "green network" as a key strategic tool. Shih [10] argued that the creation of a multifunctional green structure is a particular challenge in the built city due to the intensive use of land and that it must therefore be planned comprehensively and on a multi-scale with considerations for determining environmental and social factors in the decision-making process.

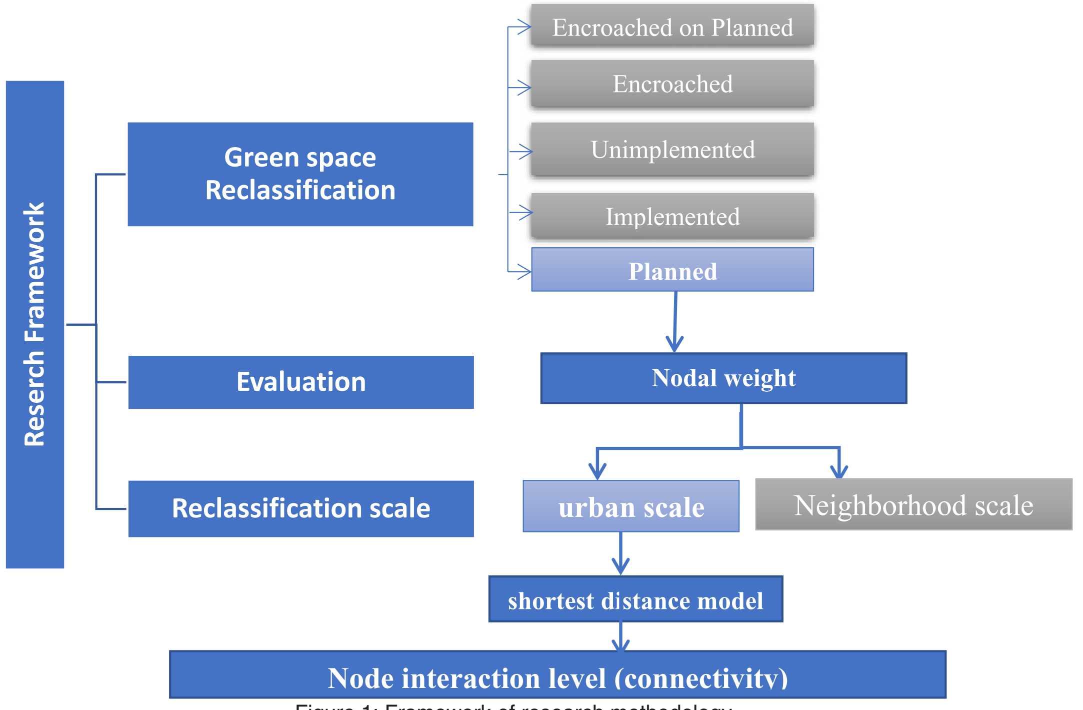

Figure 1: Framework of research methodology.

Globally, most network development initiatives are in the start-up stage; therefore, none have been fully implemented.

1.1.1 Green Network Components

Green networks are made up of three components:

- A patch is a non-linear area that is fairly homogeneous and different from its surroundings. It is situated within a "matrix" (a type of background ecology or land use), and corridors may connect it to nearby patches.
- A corridor is any space, often linear in shape, that makes it easier for creatures to migrate between different habitat patches [10]. There are two types of corridors: natural and artificial. Natural includes rivers and conservation corridors; artificial connectivity may be an essential element of the network in urban areas. The effective design of artificial corridors can provide complementary links because it is likely that many natural corridors have been removed or damaged [7].
- A matrix is the most extensive and dominating landscape element. This study expresses it through a greater relative area of urban green patches, the most connected portion of the landscape, which is always somewhat heterogeneous [6].

Important green spaces like urban parks, community gardens, playgrounds, and vacant lots might be connected by urban roadways, river lines, or drainage ways. Therefore, we will study the connectivity indicator. From above, it concluded that no separate and isolated garden, regardless of size or design, can provide the benefits of nature to its inhabitants; instead, they must be connected as well as to surrounding neighborhoods. Howard confirms this in his famous phrase:

"No single park, no matter how large and well designed, would provide the citizens with the beneficial influences of nature" [2]. These networks represent the integration of three categories of networks in practice: a river network (or blue) (acting as edges), a green space network (acting as nodes), and a green transport network (green spaces along roads acting as links), Figure 2 [12].

1.1.2 Green Network Multi-Scale Approach

The green network ranges from the smallest area of the city to the most significant part of the landscape:

- Site scale**:** This level focuses on two separate elements (the building and the street), emphasizing their fusion and integration in a way that is consistent with the nearby urban open spaces. The three most important are green roofs, green street techniques, and sidewalk and street design.
- Urban scale: This scale covers resident neighborhood sods, suburbs, and sectors in the urban area. To maintain a balance and consistency between green and gray features in all network elements, it connects the areas to enable multiple connection and continuity characteristics.

- Regional scale: It encompasses rural or largely forested, arid, marshy, and wild habitats in and around urban areas [2].

By combining the third level, a network is reached at the national level, which in the future can be linked with the green networks of other countries.

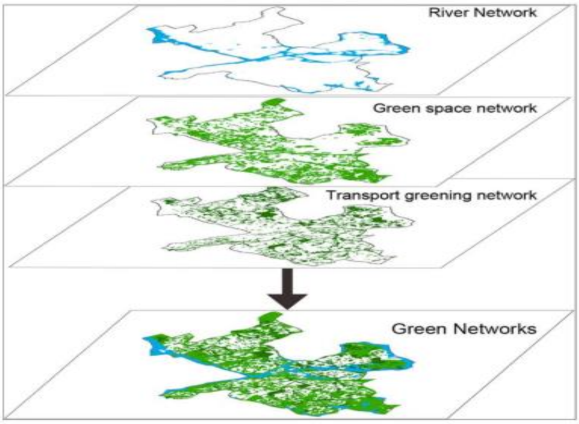

Figure 2: Green network layer [12].

1.1.3 Connectivity Indicator

Green networks are derived from linking up spaces into a network or just as a continuous linear feature leading to natural areas outside the urban area [8]. Several researchers mentioned the concept of connectivity in its physical (spatial or structural) and behavioral (functional) types. The first author [12] describes the concept of connectivity as "a measure of how spatially a corridor, network, or array is connected." This is a "structural connection." A physically connected system throughout the landscape is called "spatial connectivity" [13]. As for functional connectivity, the behavioral response of landscape features indicates the degree to which the landscape enables or obstructs the exchange of living creatures, energy, materials, and information among landscape features[14]. It represents the extent to which an area is connected to a process, such as analyzing species movement patterns in the landscape [12]. Some divide the connectivity into scalar, institutional, and spatial connectivity.

The physical connectivity between green areas is at the core of most landscape ecology literature. Because of the ecological benefits it offers To minimize the effects of landscape obstacles on species populations and prevent the fragmentation of natural habitats in urban areas, efforts are required to develop a network of easily accessible urban green spaces [15]. In an urban context, connecting green areas improves the microclimate, increases the amount of green cover, and enhances other environmental functions. It also brings people closer to nature, promoting greater physical and mental health. Additionally, it improves the quality of the living environment and enhances economic values like tourism potential and urban landscape quality. Understanding how urban green spaces are distributed and delivered can assist in identifying crucial habitat patches that must be kept connected to improve people's enjoyment and leisure [16]. From an operational perspective, creating a linear network of urban green spaces in a dense urban area is not easy due to the current built environment. Therefore, strategic efforts are needed to address this challenge. It was noted that "successful green networks also require linkages between programmers and staff of various agencies, NGOs (Non-governmental organizations), and the private sector. One way to achieve this is through a continuous planning process "for people to come together, build connections, and reach consensus on what needs to be accomplished and what strategies to use" [15].

The Gravity Model analysis:

Network Connectivity index analysis. According to [17], is based on the interaction between two nodes in the gravity model, represented in Equation (1):

$$\mathbf{Gab} = \frac{\mathbf{NaNb}}{(\mathbf{Dab})^2} \quad (1)$$

Gab = Gba; where Gab is the degree of interaction between nodes a and b, Na is the weight of node a, Nb is the weight of node b, and Dab is the distance in kilometers between node a's centroid and node b's centroid[17]. Node weight was calculated in Equation (2):

$$\mathbf{Na} = \{\mathbf{X}\,(\mathbf{ha})/\mathbf{S}\,(\mathbf{ha})\} \bullet \mathbf{10} \quad (2)$$

Where: S= the minimum area necessary for the indicator species; here, we take 15 m²/people depending on the area between Baghdad standards 17 m²/people and Al-Dywania 14.7 m²/people according to the population density and area of the city. Therefore, this standard is smaller than in British cities of 23 m²/people [18]. Na = the node weight for the green space; X = the area of the green space measured in hectares; and scaling by a factor of 10 normalizes data [17].

The weight of the node (The nodal weight) determines the relative significance of the nodes in the study area with a note to the minimum habitat requirements [19].

2. PRACTICAL STUDY

Hilla City Center has been chosen as a case study. The existing situation of the study (Figure 3B) will be examined and prepared, as well as the master plan for Hilla City (2009-2030), by the Dar Al-Handasah consulting company. The green network indicators will be used to achieve this.

2.1 Data and Information Collected Through

The study relied on three main sources of information; the first was the corrected satellite image of the city of Hilla Visual 1 (Figure 3C) using the GIS program. Second: government departments represented by the Department of Urban Planning, the Department of Hilla Municipality, and the Directorate of Gardens and Parks of Babylon. The above two sources serve as references for spatial data. Third: The final report to update the master plan.

2.2 Description of the Study Area

The city of Hilla (the center of Babylon province) occupies an area of (5979,1933 hectares), and its population is estimated at 795,545 in 2025 [21].

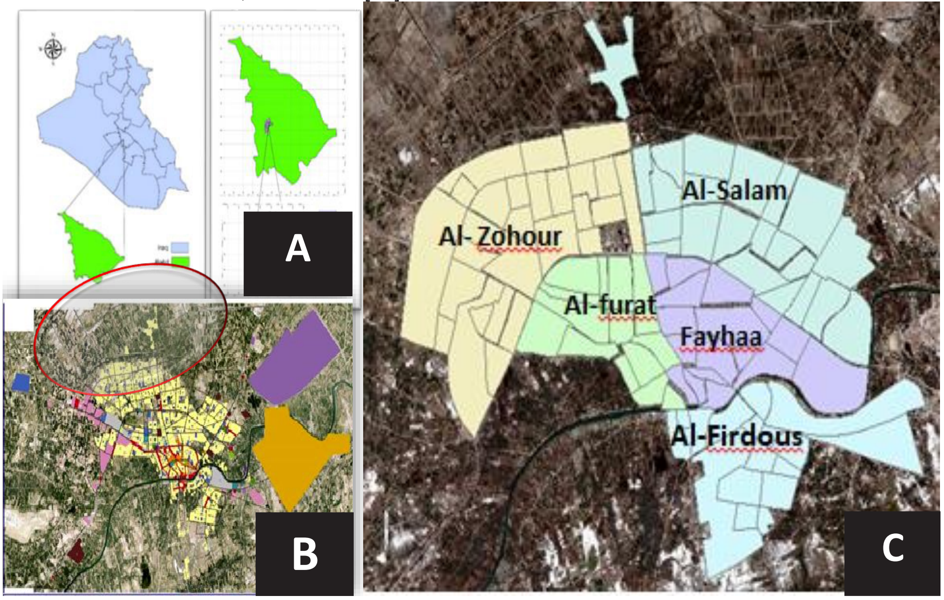

Figure 3: Administrative map of Iraq showing Babylon province to the middle of Iraq and borders of the center of Hilla by GIS map [21].

The Hilla River divides the city into two unequal parts. The biggest is western, and the smallest is eastern. The average citywide density is 56 people per ha [20]. The district was divided into four sectors (Figure 3C) by the municipality of Hilla in 2016 under the sectorial arrangement known as "Al-Firdous," "Al-Fayhaa," "Al-Salam," and "Al-Furat" and "Al-Zohour" [21].

2.3 Evaluation of Urban Green Spaces in Hilla

The pattern of land use in the city, which is dominated by residential use and amounts to 34.13% of all uses, there are currently 80 hectares available, with Timberland accounting for 52.2 hectares or approximately 67%. Thus, the per capita area does not encroach (0.032 m²/person), which is a very low area, and the percentage of disability is 33% [22]. See Figures 4 and 5. The areas were classified to know the percentage and number of areas that are planned and not encroached upon so that the research methodology can be applied (Table 1).

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Table 1: Evaluate and reclassification of urban green spaces in Hilla City center, (source) the researcher.

Green space Reclassification					
The district	**Un Implemented**	***Encroached**	**Implemented**	**Encroached**	**Planned**
Al-Salam	50	12	14	2	22
AL- Furat and Al-Zohour	98	28	10	2	58
Al-Firdaws	22		11	2	5
Al-Fayhaa	24	4	14	5	3
Tradition fabric	15	2	4	0	6
*NOTE: The Encroached areas were counted by the municipal engineer on 23/8/2022					

Figure 4: Current state of urban green spaces and the ratio of encroachment compared with Figure 5.

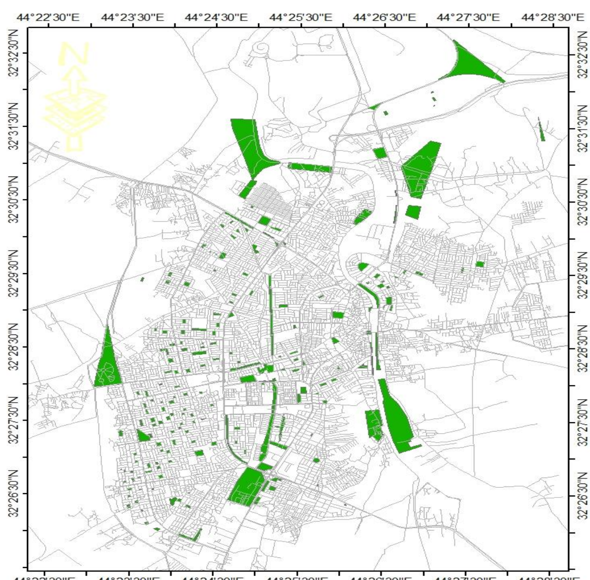

Figure 5: The Master plan of Hilla city center showing the planned urban green spaces in upgrading the master plan 2009 [23].

3. RESULTS AND DISCUSSION

There were 25 urban green spaces with a combined area of 394.104 ha (Table 2) in a zone of about 5979.1933 ha. Patches in this study are defined as areas of habitat or greenery larger than 2 hectares to facilitate the study and counting because small spots are useless. The largest, or mother, is far more than the city, 57.14 ha in the Zuiar region, 37.22 ha in the al-Tahmazia region, and 37.71 in the al-Jameiah region. The smallest green spaces are 2.36 ha in Al-Askari neighborhood. The larger area of corridors is 13.91 ha parallel the river, while the smallest corridor is 2.29 ha. Nodal weights ranged from 22,026.6 to 380,933.3 (Table 2). These weights reflect the various green space sizes and highlight their significance in the research area about the 0.0015 ha minimum habitat need. The mean area for patches is 18.37 ha; due to its proximity to the average and its representation of half of the green areas under study, the area of 18 ha was chosen as the assessment criterion. To assess green spaces larger than 18 ha, patches A, B, G, K, N, R, and S were chosen to form an urban scale network. The average area for corridors is 7.1 ha, but we take all of them as larger than 2 ha because their numbers are few. The traditional fabric (AL-Kasaba AL-Kadema) has very little green space and is less than 2 ha in size; as a result, it has been neglected. This is about the area weight, whereas we were reclassifying reality use and encroachment ratio based on its state (Table 1).

We notice from this that there is no hierarchy of green spaces in the city of Hilla, but only at the urban level, which will be analyzed according to gravity modeling, as well as the local level, and that what surrounds the city is agricultural areas that do not contain regionally linked elements such as forested, arid, marsh, and wild habitat to connect with near cities.

Table 2: Evaluate and reclassification of green spaces in Hilla City.

The district	Patch no.	Area (hectare)	Nodal weight	Corridor no.	Area (hectare)	Nodal weight
Al-Salam	A	37.22	248,133.3	C1	12.52	83,466.6
	B	57.14	380,933.3			
	C	5.85	39,000			
	D	3.304	22,026.6			
AL-Furat and Al-Zohour	G	37.71	251,400	C3	13.91	92,733.3
	H	3.87	25,800	C4	3.66	24,400
	I	4.08	27,200			
	J	4.11	27,400			
	K	18.61	66,655			
	L	2.36	15,733.3			
	M	3.37	22,466.6			
Al-Firdaws	N	54.4	362,666.6	C5	2.29	15,266.6
	O	2.47	16,466.6	C6	3.84	25,600
	P	5.1	34,200			
	Q	6.78	45,200			
	R	55.43	369,533.3			
Al-Fayhaa	E	5.74	38,266.6	C2	6.49	43,266.6
	F	3.32	22,133.3			
Other	S	38.24	254,933.3	Note: The patch larger than 2 hectares		

Table 3 shows the reality state of selected green spaces on urban and neighborhood scales. On an urban scale, all patches have encroached; only patch A in the Al-Salam sector has not encroached; it represents the larger area but is far from the city. Only three patches are encroached on. A neighborhood scale: the C patch in the AL-Salam sector, the J patch in the Zohour sector, and the Q patch in the Al-Firdaws sector. This result demonstrated no possibility of establishing an urban-scale network of green spaces because residential uses encroached on those of the planned green spaces. But on the neighborhood scale, there is a possibility of building a green network (Figure 6). In terms of the corridor, all of them have not encroached, but it needs more connection and attention from those in charge of it and users.

According to Table 4, the level of interaction between nodes decreases as the distance between them increases (shortest distance). Note the large interaction between nodes N and because of distance proximity (Figure 7). The level of interaction is also affected by nodal weight. Hence, the smallest interaction is between nodes S and K rather than S and G, even though S and G are farther apart in distance because node G is larger than node K. From that table, we conclude that the far distance between nodes decreases the interaction level, which is the result of fragmentation. Also, the large area weight increases the interaction level, enhancing the motivation to maintain large patches and not prefer small scattered areas.

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Table 3: Evaluate the reality state of green spaces in Hilla City.

District	**Urban scale**			**Neighborhood scale**				
	Patch no.	**Current state**	**Current use**	**Patch no.**	**Current state**	**Current use**	**Corridor no.**	**Current state**
AL-Salam	A	Not Encroached	Unused	C	Encroached	Residential	C1	Not Encroached
	B	Encroached	Residential	D	Not Encroached	Unused		
Al-Fayhaa				E	Not Encroached	Al-Jameiah park	C2	Not Encroached
				F	Not Encroached	AL-Janaan al-mualaqa park		
AL-Furat and Al-Zohour	G	Encroached	Not Residential	H	Not Encroached	Arth Babil park	C3	Not Encroached
	K	Encroached	Residential	I	Not Encroached	Unused	C4	Not Encroached
				J	Encroached	Residential		
				L	Not Encroached	Unused		
				M	Not Encroached	Al-Zakora park		
Al-Firdaws	N	Encroached	Residential	O	Not Encroached	Hay Babil park	C5	Not Encroached
	R	Encroached	Residential	P	Not Encroached	Playground	C6	Not Encroached
				Q	Encroached	Residential		Not Encroached
Other	S	Encroached	Residential					

Table 4: Node interaction based on gravity model for regional scale, source.

Node/node	**B**	**G**	**K**	**N**	**R**	**S**
A	1,336.7	528.7	406.1	5,886.2	1,186.4	1,407.4
B	0000	2,227.4	822.7	1,260	1,882.6	556.2
G		0000	1,250.6	804.4	1,364.6	318.2
K			0000	797.9	1,299.8	234.7
N				0000	2,640.6	4,205
R					0000	754.2
S						0000
Note: the bold value Is the largest and smallest level of interaction.						

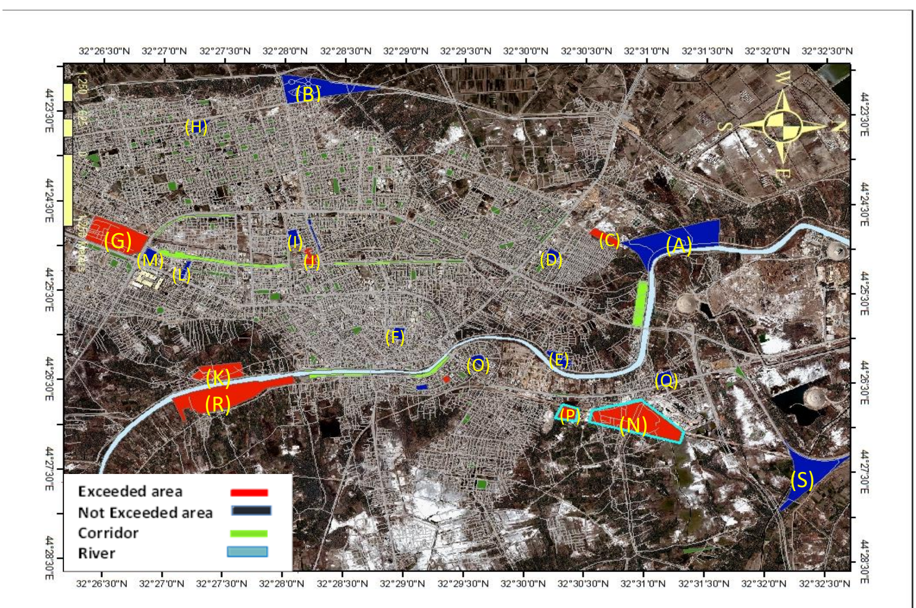

Figure 6: Spatial distribution of the selected areas and the realities of their situation.

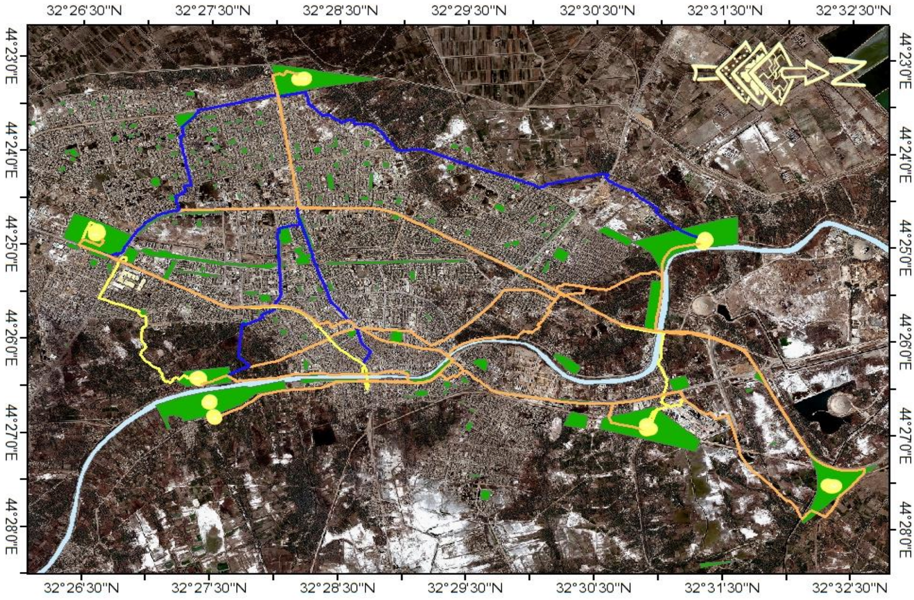

Figure 7: Network of least-cost paths on the urban scale.

4. CONCLUSIONS

The planning of green networks is a response to urban expansion that aims to protect existing green spaces, create new spatial forms, and maintain connectivity between different green spaces. This study has shown how to evaluate the degree of connectivity index for green space in Hilla City center of Babylon province. The gravity model and least-cost path were used to test the connectivity on an urban scale to create a multifunctional green network framework that promotes ecological and social sustainability. These indices mentioned above revealed a region's connectivity weakness due to fragmentation. They changed uses of green space, such as residential, due to urbanization and population growth. The following conclusions were drawn from the research:

- During the urbanization process, many green spaces were occupied, which led to their fragmentation and, thus, the spatial pattern change.
- No separate and isolated patches, no matter their size or design, can give the inhabitants the benefits of nature.
- The lack of effective and comprehensive planning has led to uncontrolled urban expansion; as a result, a lot of green lands have been converted into construction lands.
- There is no clear hierarchy in the distribution of green spaces within Hilla City. From 1993-2023, there were only two levels: locality and regional.
- The traditional fabric (AL-Kasaba AL-Kadema) contains very few green spaces, almost neglected and not involved in establishing the network.
- On the urban level, there is no possibility of establishing a network between green spaces because of the encroached uses especially the residential.
- The amount of connectedness (interaction) between the patches increases with their nodal weight, and this is what we observed in the level of interaction between node A and node N since they have a big nodal weight.
- The amount of interdependence (interaction) between two patches increases with the decrease in the distance between them, and this is what we noticed in the level of interaction between node S and node N because of the spatial proximity between them.

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