

Sustainable land use strategies on waterfronts through transforming encroachment into revitalisation: Mosul City

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Abstract:

Rivers are vital to urban open space networks, and it is essential to keep adjacent areas free from permanent structures to maintain their ecological, social, and economic sustainability. This study examines how land use encroachments in open areas affect urban sustainability, focusing on Mosul, Iraq. It underscores the challenges of regulating public open spaces and riverbanks in Mosul, emphasising the need for strategic planning and adherence to stakeholder guidelines. The research evaluates issues related to the description and location of public open spaces and discusses encroachments on Mosul's riverine edges. It notes that the left riverbank has lost its natural characteristics and riverside vistas due to unauthorised constructions like halls, restaurants, and commercial centres. The study aims to revitalise indicators to halt riverbank degradation and restore it as a key element in Mosul's sustainable development. This involves identifying specific problems and proposing a design strategy to create a productive, natural open space for residents. Through comprehensive analysis, the study addresses the environmental, social, and economic dimensions of riverbank encroachments, offering recommendations for sustainable urban planning and development.

Keywords:

urban sustainability, land use encroachment, green infrastructure, sustainable cities, biophilic design, Mosul

1. Introduction

Urban open spaces, particularly rivers, are essential components of the urban fabric, playing a critical role in the environmental, social, and economic sustainability of cities. It is imperative to keep these low-lying areas adjacent to rivers free of permanent structures, designating them as green spaces and parks. This approach ensures the provision of natural, attractive, and comfortable settings for recreational activities. Currently, the city of Mosul faces significant challenges in implementing and adhering to regulations and guidelines that govern public open spaces and riverbank designs [29]. This situation underscores the urgent need for organised planning and management of these vital urban components. This research explores the complexities associated with the description and location of public open spaces, focusing on the encroachments along the riverine edges of Mosul. By evaluating and characterising these spaces, the study identifies both permissible and impermissible types of encroachments. The primary hypothesis is that the left riverbank of Mosul has experienced a loss of its natural characteristics, scenic river views, and environmental, social, and economic sustainability due to changes in land use and the construction of halls, restaurants, and commercial centres. The objective of this study is to revitalise the indicators that can halt the degradation of the riverbank and restore it as a functional element in the sustainable development of Mosul. This involves diagnosing specific problems in the area and proposing a design strategy that can be adopted to create a productive, natural, open space for residents. The research draws on various theoretical frameworks and empirical studies to support its findings and recommendations. The Vancouver Declaration, adopted at the

1976 United Nations Conference on Human Settlements (Habitat I), emphasised that the primary goal of urban development policy is to improve the quality of life for all people. This includes meeting basic needs such as food, shelter, clean water, employment, health, and education. This objective has been reaffirmed over the years, including in the New Urban Agenda of 2016. There is a strong movement towards nature-based solutions, such as urban water management, which not only enhances flood management but also provides recreational opportunities, supports biodiversity, and mitigates climate change by reducing the urban heat island effect [6]. The United Nations report on urban prosperity in 2018 identified Green Urbanism as a model for carbon-neutral and waste-free urban design, supporting integrated urban growth to create socially and environmentally sustainable urban areas. In 2022, the European Bank for Reconstruction and Development's Green Cities Program defined Green Urbanism as a framework for planning and designing cities more sustainably, creating environmentally friendly cities with reduced pollution, emissions, and waste [2]. Green Urbanism suggests that for sustainable urban development and the success of ecological areas at various levels, all components of urban design must interact cohesively and cannot be considered in isolation. It is based on the triple-zero framework: zero fossil-fuel energy use, zero waste, and zero emissions, aiming for low-to-zero carbon emissions. "Zero waste" implies that buildings should be fully deconstructable and recyclable at the end of their life cycle, allowing the site to revert to a greenfield [34]. Understanding the urban landscape is essential for improving the quality of life, as it directly impacts human behaviour, mental health, and social interaction. This understanding contributes to the design of safe, pedestrian-

friendly cities, reducing pollution and balancing urban expansion with natural spaces, thereby enhancing the city's functional and aesthetic efficiency [16]. The encroachment on riverbanks for purposes unrelated to sustainable urban development is a significant issue that affects the entire city, not just the specific area in question. Urban design in Mosul does not currently address natural environments in line with sustainable principles, leading to increased resource consumption and weakened economic planning. The aesthetic and functional value of public open spaces is diminished, reducing opportunities for social interaction and environmental engagement.

2. Related literature

In examining the body of research on urban open space encroachment and its implications for sustainability, several studies provide valuable insights, each with its strengths and limitations. Sinxadi and Campbell [49,50] explore the challenges of urban open space encroachment in a South African township, highlighting how value conflicts and poor enforcement of land-use regimes hinder sustainable neighbourhood development. Their study underscores the importance of community participation in planning processes, while noting the persistent issue of non-participation among community members. Similarly, Kilnarová and Wittmann [31] investigate the influence of open spaces between residential buildings on sustainability in Brno and Vienna. They find that these spaces significantly enhance ecological stability and hygienic qualities, though they call for further studies to address different residential areas and building spaces. Yang et al. [57] contribute to the discourse by analysing the impact of land-use changes on landscape patterns in Qingdao, China. Their research reveals spatial and temporal heterogeneity in urban expansion intensity, emphasising the need for tailored policies to mitigate negative impacts on urban sustainability. However, the study does not delve deeply into specific policy recommendations. Roy et al. [4] assess the dynamic influence of land-use alterations on ecosystem service value in Dhaka City, predicting a decline in ecosystem service value due to rapid urbanisation. Their findings highlight the degradation of water bodies and agricultural land, underscoring the urgency of sustainable land-use policies. Andreasen et al. [38] focuses on urban encroachment in ecologically sensitive areas in Accra, linking ineffective governance and complex land administration to intensified flood hazards. The study advocates improved planning and governance to protect these areas, while acknowledging the challenges posed by overlapping authorities. Wittmann et al. [56] discuss the influence of open spaces on the sustainable development of residential areas in Brno, emphasising their ecological and social value. They note that the potential of open spaces is not always fully utilised, and economic indicators may not align with user expectations. Mrekva [40] examines the relationship between urban land use and flood risk, advocating coordinated land-use planning to enhance urban resilience. The study emphasises the need for holistic approaches to sustainable flood management, though it does not provide detailed case studies. Putri [44] analyses the spatial and temporal changes in green spaces in Bandung, highlighting the threat to ecological quality and sustainability due to urbanisation. The study identifies major green space distributions by topography, though it lacks specific policy recommendations. Sen [47] underscores the importance of urban green spaces for sustainability, noting their role in providing ecosystem services and supporting biodiversity. The study calls for identifying the ecological role and conservation value of

green spaces, though it acknowledges limitations in size, quantity, and quality. Lopes et al. [35] discuss the impacts of increased impermeable areas on urban sustainability, emphasising the need for compensatory measures like permeable pavements and retention reservoirs. They note the limitations posed by high groundwater levels and low soil permeability. Thorne et al. [51] evaluate the effectiveness of smart urban growth policies in conserving open space, finding that these policies perform only marginally better than business-as-usual scenarios. The study highlights the need for more effective policy measures to protect natural lands. Egidi et al. [14] unravel the latent aspects of urban expansion, emphasising the risks of desertification and the need for effective spatial planning. They note the challenges posed by unregulated urban expansion on less constrained land. Bratley and Ghoneim [7] model urban encroachment on agricultural land in the Eastern Nile Delta and predict significant urban growth by 2050. Their study highlights the limitations of early 2010s imagery and the need for updated data. Senetra et al. [48] analyse the spatial distribution and quality of urban green spaces in Tczew, noting uneven distribution and limited access to high-quality public green spaces. They emphasise the need for continuous support for open space development. Cai et al. [8] examine the spatiotemporal patterns of urban encroachment on cropland in China, highlighting the loss of potential agricultural productivity. Their study underscores the need for policies to protect agricultural land. Conway [11] evaluates the effectiveness of broad land-use policies in maintaining connections among protected green spaces, noting the challenges posed by urban development. The study calls for more effective policy measures to enhance ecological sustainability. Kurbanova et al. [33] discuss the role of green spaces in ensuring a sustainable future through effective urban and environmental management. They emphasise the benefits of integrating smart city concepts, though they do not provide detailed case studies. Valiyeva et al. [54] quantify the effects of urban green spaces on biodiversity and ecosystem functions, highlighting the ecological benefits of diverse and varied green spaces. They note the need for larger, more varied green spaces to enhance biodiversity. Overall, these studies provide a comprehensive understanding of the challenges and opportunities associated with urban open space encroachment. They emphasise the need for effective governance, community participation, and tailored policies to enhance urban sustainability. However, they also highlight the limitations and weaknesses of current approaches, calling for further research and more effective policy measures.

3. Theoretical framework

3.1. Concept of urban open spaces

Urban open green spaces are integral components of urban networks, essential for maintaining and enhancing environmental qualities. These spaces provide numerous opportunities for recreation and leisure, facilitate the creation of wildlife habitats, and promote activities such as walking and cycling, thereby reducing vehicle use. Such attributes contribute significantly to the characteristics of successful, sustainable cities, reducing crime rates and antisocial behaviour, improving air quality, and mitigating the effects of urban heat islands, pollution, and water wastage [22]. There are strong links between human activities, behaviours, social interactions, and the physical environment in urban areas, particularly in open spaces. Land use plans should incorporate transportation and public spaces to enhance

productivity and livability in cities [32]. For instance, unplanned settlements have resulted in only 10% of urban areas being allocated as public open spaces in African cities, compared to approximately 30% in other global cities [10]. Urban open space refers to areas that are generally accessible, free of charge, and designated for human activity and enjoyment. These include parks, children's play areas, green corridors, city squares, pedestrian streets, and markets. Lynch describes open space as accessible; for example, a fenced waterfront area or a market closed at night would not be considered an urban open space [15]. The extent to which people feel safe and comfortable significantly influences their use or avoidance of open spaces in urban areas. The World Conference in Berlin introduced international concepts of sustainability and approved several points for the sustainability of urban areas with waterfronts, including ensuring water and environmental quality. Waterfronts are part of the urban fabric and have their own unique identity and character. Public access is a fundamental requirement, and waterfronts are long-term projects [20]. Biophilic planning represents a creative blend of urban design that involves protecting, restoring, and enhancing green and blue infrastructure in urban areas. It promotes human interaction with nature and creates spaces where individuals of all ages can gather, thereby achieving social and environmental sustainability [39]. Rivers and their banks in urban centres are prime examples of the biophilia concept. The term "biophilia" was first used in 1964 to describe the psychological attraction to all living, vibrant, and natural things. It was introduced into Webster's Dictionary in 1979, combining "Bio" and "Philia" to denote positive feelings individuals have toward nature and related activities.

3.2. Green infrastructure

Green infrastructure enhances the quality of urban and rural structures by providing broader functions than traditional open-space planning methods. The European Commission defines green infrastructure as the strategic use of ecosystems, green spaces, and water in land-use planning to provide environmental benefits and enhance the quality of life. Green infrastructure can mitigate climate change impacts, adapt to them, reduce the risks of natural disasters, protect against floods and erosion, and preserve biodiversity. It also includes blue infrastructure elements such as sustainable urban drainage, wetlands, floodplains, rivers, canals, their banks, and other water cycles [53]. Green infrastructure comprises natural resources within, around, and between urban areas, including streams, lakes, parks, natural areas, schoolyards, cemeteries, and private yards. Components of green infrastructure include trees, shrubs, grasses, soil organisms, and aquatic life, manifested in green roofs, gardens, rain gardens, and water harvesting systems [13]. Addressing environmental needs and challenges is crucial in urban design. Many cities have begun restoring and protecting rivers and their banks to establish a physical connection with nature. Green urbanism intersects with green infrastructure, aiming to create more sustainable places, communities, and lifestyles. Cities that embrace green urbanism principles minimise negative environmental impacts by functioning similarly to natural systems and following circular metabolism rules [1]. Recycling waste, treating wastewater, achieving economic self-sufficiency, promoting regional food and energy production, and considering local climates to optimise land assets such as sunlight and wind flow contribute to more sustainable and healthier community lifestyles [58].

3.3. Land use planning to address urban development challenges

As cities expand and grow, land is at risk of being exploited without coordination. Without supportive infrastructure and clear development policies, basic infrastructure and services become prohibitively expensive, leading to unplanned urban sprawl [30]. Policy plays a crucial role in establishing public and private land ownership rights, urban land use planning, developing long-term visions, monitoring land use over time, and reviewing land use plans every five years. Economic analysis identifies five key principles for improving livability and productivity in planning: determining residential and commercial densities, ensuring sufficient space for transportation and other public areas, studying and coordinating positive and negative indirect effects, linking land use planning with strategic planning, and emphasising proactive planning [10]. Land use planning encourages the preservation of ecosystems such as green spaces, prevents construction on lands prone to natural disasters, and protects riverbanks and city peripheries [36], as part of the "green belt," as seen in cities like London and Medellín, to curb urban sprawl.

3.4. Sustainable cities

A sustainable city achieves social, economic, and physical development milestones and must have a continuous supply of natural resources to sustain development [59,3]. It should be protected from environmental hazards that threaten developmental achievements, while maintaining a dynamic balance among its environmental, social, and economic characteristics [5]. Sustainable development meets present needs without compromising future generations' ability to meet their own needs [23]. It is essential to distinguish between development and growth; growth refers to the quantitative physical expansion of the economic system, whereas development is a qualitative concept focused on cultural, social, and economic improvement and progress. Needs are linked to resource distribution and vary significantly based on socio-economic differences. The emphasis on future generations introduces the concept of intergenerational equity, implying that we have borrowed the Earth from our children rather than inheriting it from our ancestors [5]. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 agreed on Agenda 21, a blueprint for sustainable development actions, the Framework Convention on Climate Change, and the concept of sustainable development first defined in the 1987 Brundtland Commission report, "Our Common Future, Agenda 21 established a significant link between development and the environment. Sustainable development requires forming connections between economic growth, poverty reduction, job creation, and the protection of natural life resources. The Intergovernmental Panel on Climate Change (IPCC) has indicated that human activities, including fossil fuel combustion, deforestation, waste disposal and incineration, and various agricultural practices, contribute to significant global warming. Based on the three-dimensional goal structure of Agenda 21, local policy actions address three main dimensions: resource conservation and management for green global policies, economic dimensions to make cities more competitive and livable, and social inclusion [12]. The goals of a smart and sustainable city include improving the quality of life for its citizens, ensuring economic growth with better job opportunities, enhancing citizen well-being by ensuring access to social and community services, adopting an environmentally

responsible and sustainable approach to development, ensuring efficient delivery of basic services and infrastructure such as public services, transportation, water supply, sanitation, wired and wireless communications, and other utilities, addressing climate change and environmental issues, providing a vibrant and scenic landscape, fair policies, and ensuring the city is environmentally healthy [42,52].

4. Encroachment

The use of land and urban land structure is crucial in determining individuals' access to jobs, services, and productive growth. Encroachment on land without proper authorisation and economic feasibility studies can severely damage all city functions. Encroachment can be defined as "intrusion on a person's land or rights" and as "minor infringements on our individual freedoms" [41] or "gradual or stealthy intrusion into the property or rights of others" [37]. The term "encroachment" is used in various contexts, whether related to authority, natural resources, or property (private or public), but it commonly refers to the illegal use of resources. Encroachment can be described as the construction of structures within property boundaries that may belong to the government, an individual, or any institution [45].

4.1. Encroachment permit

An encroachment permit is a contract between a governing body or responsible entity, such as the state, and the applicant. The contract outlines the terms and conditions under which the right to encroach on state property is granted. Conditions of an encroachment permit include prohibiting transfer to another party and not considering it a property right. The permit cannot be transferred with the sale of the property, and a new owner must obtain a new encroachment permit. Encroachment permits are issued for a reasonable duration and are not permanent [9].

4.2. International agreements for habitat conservation and climate change

Habitats are natural sites where flora and fauna, particularly wild species, live and are influenced by climatic factors, soil, and natural ecosystems that provide food and shelter (Iraqi Protected Areas System 2 of 2014, Iraqi Facts 4316, 24/3/2014 [25]). Iraq has joined several international agreements aimed at reducing and mitigating the effects of greenhouse gas emissions and supporting sustainable development. These agreements necessitate the protection of natural resources, green infrastructure, and riverbanks in Iraqi cities, prohibiting encroachment and changes in their use. Key agreements include:

First: Iraq's accession to the Paris Agreement under the United Nations Framework Convention on Climate Change of 1992, which obliges it to adhere to the agreement's principles. These principles include mitigating greenhouse gas emissions, advancing sustainable development, keeping the global average temperature rise below 2 degrees Celsius above pre-industrial levels, and adapting to the adverse effects of climate change (Law No. 31, Iraqi Facts, 2020 [26]).

Second: Approval of Iraq's Nationally Determined Contributions document on climate change, which emphasizes the importance of preserving green fields and open areas, constructing earthen dams and reservoirs for water collection, mitigating flood risks, ensuring water shares during droughts, sustaining groundwater recharge, implementing integrated management to combat natural forest fires, rehabilitating burned and degraded areas, establishing protection and maintenance systems for natural and industrial forests, increasing their area, and creating green belts (Iraqi Cabinet Resolution No. 376 of 2021 [24]).

Third: Protected Areas System 2 of 2014, which emphasizes the protection of wetlands, the establishment of natural reserves, ecotourism, biodiversity, geodiversity, the conservation of plant and animal species and their habitats, and achieving sustainable development (Iraqi Protected Areas System 2 of 2014, Iraqi Facts 4316, 24/3/2014 [25]).

The U.S. National Intelligence Council's report, "Climate Change and International Responses Increasing Challenge to US National Security through 2040," which includes views from all U.S. intelligence agencies, considers climate change linked to national security. The report highlights that eleven countries, including Iraq, are at risk in the energy, food, and freshwater sectors. Drought and heat waves will strain infrastructure, which will be affected by climate change, impacting the water sector, political stability, and economic conditions (Iraqi Ministry of Foreign Affairs, Document No. 1452, dated 23/11/2021 [27]). Open spaces along riverbanks can be categorised as linear open spaces, urban squares, green axes, pocket parks, and mooring sites created by building docks or floating platforms that provide direct river access [43]. Lands adjacent to rivers should be protected and managed by state systems as they enhance the city's identity and economy.

5. Global experiences in addressing riverbanks and open spaces

Revitalising waterfronts is important in the urban recovery process to mitigate pollution, treat and manage stormwater, and protect riverbanks and habitats. Below is a review of two global experiences to illustrate some aspects that can be benefited from:

5.1. The Halifax Urban Greenway Association and Halifax Regional Municipality Vision

The Halifax Urban Greenway Association's (HUGA) 2017 vision aims to develop a multi-use, family-friendly trail that integrates with the natural environment. This project has been in development for the past fifteen years, and the identified priority was to connect the green network from Quinpool Road to Point Pleasant Park and achieve full north-south connectivity. As shown in Fig. 1, the project provides a safe and comfortable environment for pedestrians and cyclists of all ages and backgrounds. The Halifax Urban Greenway (H.U.G.) is a multi-use waterfront trail serving active transportation and recreation purposes, providing direct access to nature, seating, recreation, and breathing space for residents, and providing green infrastructure services [19,46].



Fig. 1. HUGA vision [19]

5.2. Waller Creek Greenway

Waller Creek is an urban stream located in the heart of Austin, Texas. The area contains many old-growth landscapes, such as large oaks and willows, which line steep banks. Tree species that can withstand frequent heavy flooding are common. (Greenways Incorporated Bicycle & Pedestrian Planning Environmental Design Landscape Architecture, 2000). In the 1970s, Waller Creek was a series of urban spaces. Dismantled, the long-distance hiking trail with no recreational activities was an underutilised urban resource that many Austin residents considered unsafe and unsuitable for everyday use. The action plan included two important aspects: 1, the Waller Creek Tunnel Project, and 2, the design of the urban greenway and its integration into the community, as shown in Fig. 2.

- Waller Creek Tunnel Project: The tunnel project improves the river environment. The tunnel is 6 meters in diameter and 1,650 meters long. The project removes 42 commercial and residential buildings and 12 road crossings from the floodplain. This maintains and increases the natural base flow by recirculating water through the tunnel, which benefits water quality and stabilises eroded stream banks.
- - Waller Creek Walking and Bicycle Trail: The walking trail is a linear greenway that begins at Lady Bird Lake. These greenways provide recreational, health, and social opportunities, as well as bicycle and pedestrian transportation links to the city centre. They are the "lungs" of the city, and parks that directly connect people to nature must be preserved as natural environments [55].

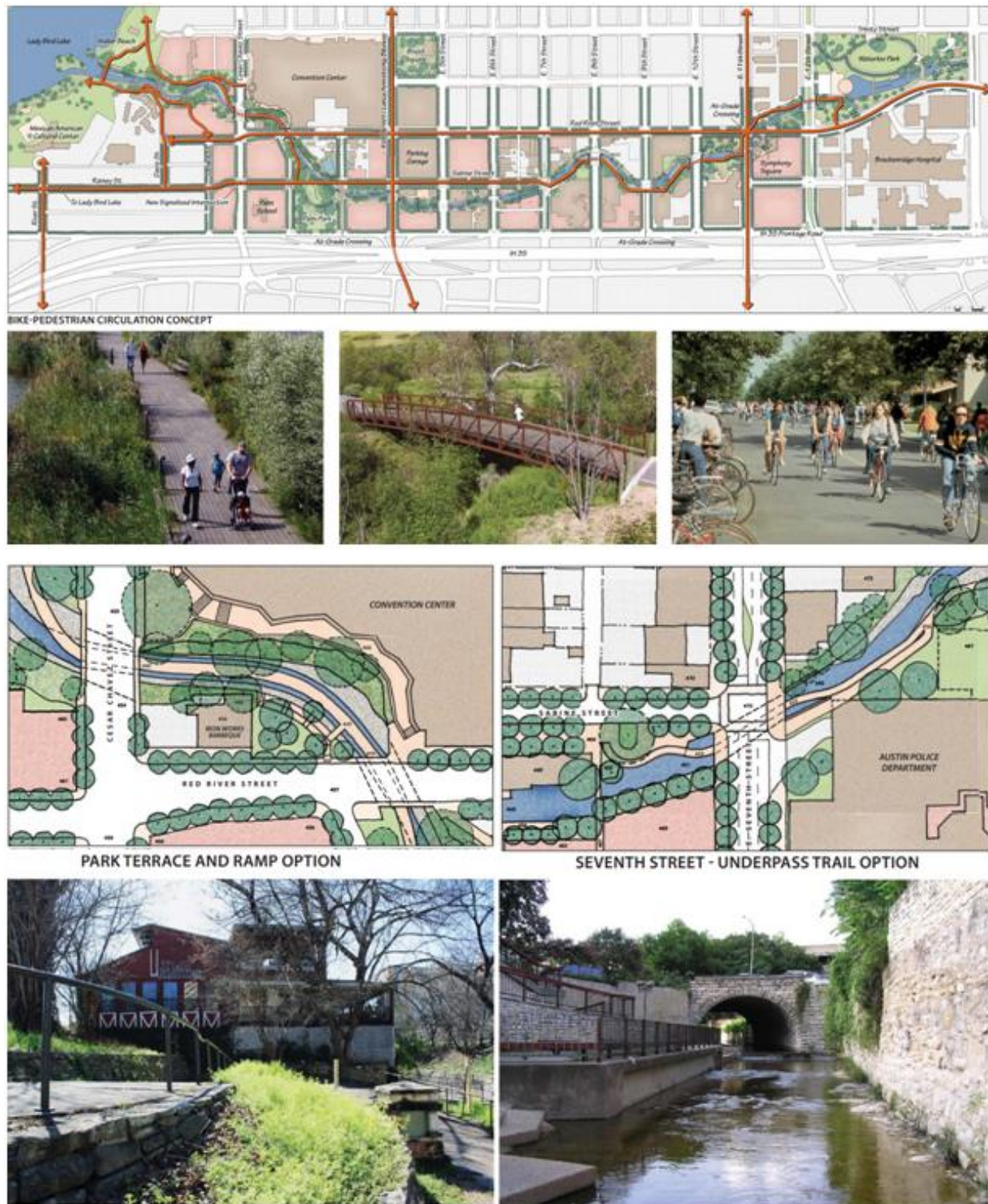


Fig. 2. Waller Creek Greenway [18]

6. The case study

The city of Mosul is distinguished by its location on a plateau bisected by the Tigris River, with a historic riverfront on the right western side and a natural recreational area on the left eastern side [21]. The study area was selected within the forested district and the Tigris River bank on the left side of Mosul, the area between the Old Bridge and the Rashidiya neighbourhood. The riverbank is a free right for all members of society; it is a social space, a natural area, a river outlet, and a breathing space for the city. Any action, whether positive or negative, impacts not only the area but also the city as a whole. However, the left riverbank

of Mosul has undergone a change in its use through the construction of halls, restaurants, commercial centres, and indoor events. This has been largely concentrated in the study area. The area, its exploitation controls, and trespassing permits will be identified. The goal of the research is to halt the changing nature of the riverbank and its deterioration, and restore it to become an effective element in the city's sustainable development. The aforementioned area was chosen because it is an open green area in addition to its location, as it is the area on the edge of the Tigris River on the left side of the city of Mosul, and it begins from the Rashidiya area at point (A) to the old bridge at point (B), as shown in Fig. 3.

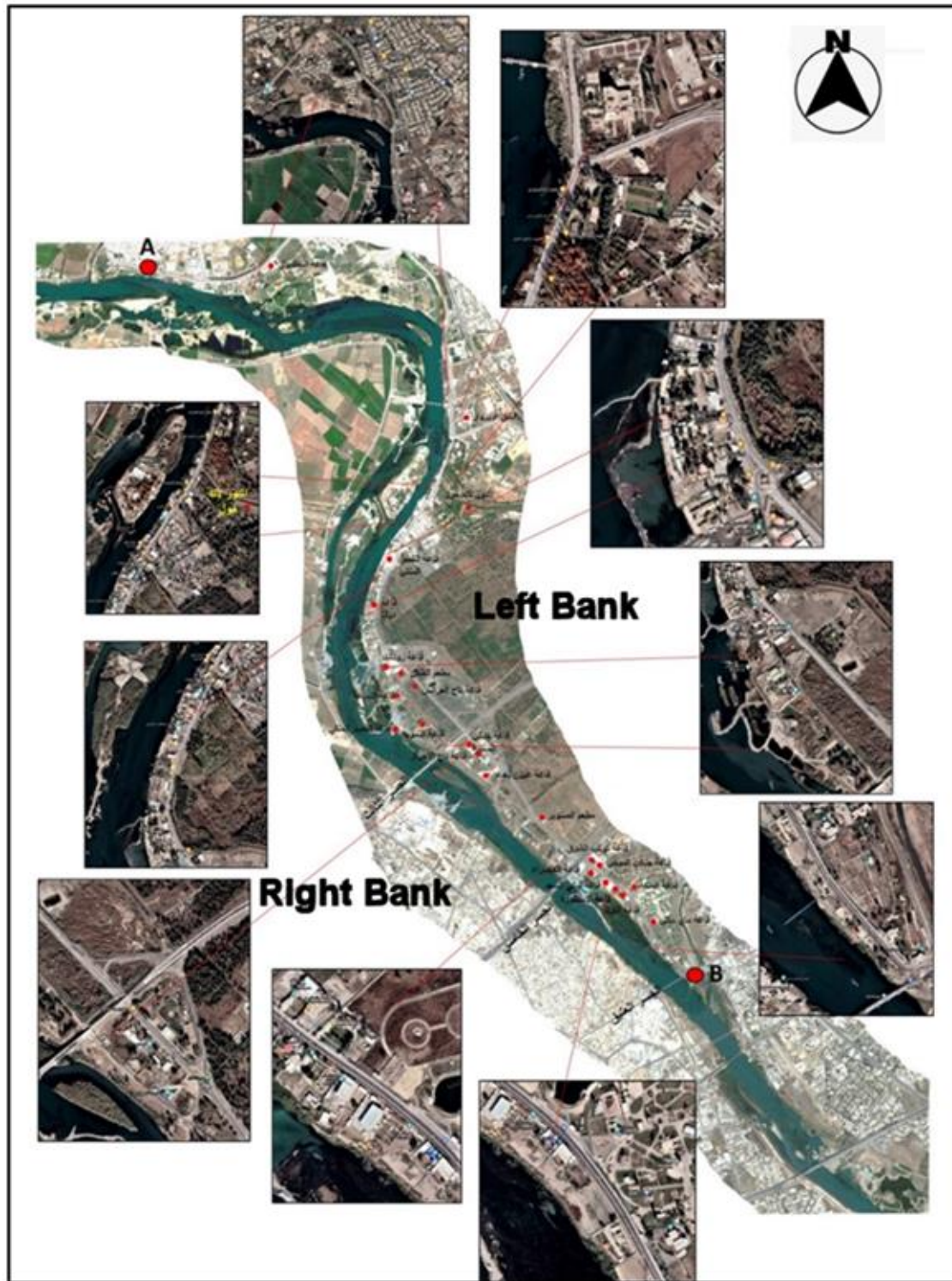


Fig. 3. Illustrates the location and overview of the case study "the Tigris River left bank" in Mosul [Researchers]

After conducting a field visit and examining the current situation in the study area, it became clear that there are many concrete buildings with closed functions, such as wedding and special event halls, closed restaurants, and casinos scattered along the riverbank, with roofs and unnatural sidewalks. Accordingly, two questionnaires were developed: the first included a specialised sample of urban planning specialists and decision-makers, and the second included a diverse group of city residents and area visitors. The questions were determined based on the theoretical framework of the research and the current situation in the area. Measurement methods and mechanisms were identified, encompassing social, economic, and

environmental aspects, to achieve planning and organisational goals that would enhance the area's reality and the services it provides to the city. Interviews were conducted with the included samples. The questionnaire was administered to participants, covering a variety of aspects (environmental, social, economic, planning, and organisational).

6.1. Permitted encroachment permits in open areas along the riverbanks in Mosul

The following is a set of regulations issued by the Mosul Municipality regarding encroachments in the study area. These regulations govern the use of green, recreational, and open areas:

- Regulations for the Use of Green, Recreational, and Open Areas [28]:
 - a. Approval from the Water Resources Department must be obtained when requesting the use of open areas along riverbanks.
 - b. Recreational and tourism uses are permitted within green and open spaces based on the city's needs and the nature of the site, and in accordance with Table 1 approved by the General Directorate of Urban Planning.

Table 1. Directorate of urban planning: land use of open and green areas [Researchers]

Type of Activities and Services	Type of Land Use within the Master Plan
1 Casinos and Restaurants	Green, Recreational, and Open Areas
2. Parks	Green, Recreational, and Open Areas
3. Amusement Parks	Recreational and Open Areas
4. Swimming Pools	Recreational and Open Areas
5. Nurseries of all kinds	Green, Recreational, and Open Areas, and Orchards
6. Five-a-side Football Fields	Green, Recreational, and Open Areas
7. Orchards may be established in the green belt areas specified in the basic design.	

- Note1: The percentage of non-permanent constructions shall not exceed 15%.
- Note2: Regarding playgrounds, they shall be determined by the municipality in the above areas, and the distance between them shall not be less than 1km.

The above table shall take into account that the planning standards approved in the city's basic design for the number and types of activities required to be allocated within the city shall not be exceeded. In the event that activities compatible with the specified green, recreational, and open areas are needed and are not included in the above table, a study shall be prepared and submitted to the General Directorate of Urban Planning to assess their suitability. The number of activities shall not exceed. The percentage of non-permanent buildings should not exceed 15% of the area, and non-permanent buildings should be single-story. Fences should be open and compatible with use. The nature of the green area should be preserved, while the river banks should

be preserved as natural reserves. Permanent construction is prohibited in these locations. Most of Mosul's riverside is a natural area and is considered a valuable resource that will enhance the city's social, economic, and environmental reality. The aforementioned study area includes a main street adjacent to and along the riverbank. Numerous event halls (such as wedding and graduation parties) are distributed along it, along with concrete-built cafes and restaurants, on both sides of the street. These are outside the specific regulations for this area mentioned in the previous paragraph, as illustrated by the aerial photographs attached in Fig. 4.



Fig. 4. Cases in two different locations along the river bank and the current usage pattern in the study area, the yellow points are restaurants, and the blue points are celebration halls [Researchers, based on [17]]

The criteria that must be considered and adopted for developing an area of such importance must include aspects of sustainability (social, economic, and environmental) to achieve

sustainable planning and organisational structure that encompasses the city with all its needs and functions. The study area must not be separated from the city of Mosul and treated as

a separate entity, as the forest area and the river bank are the city's breathing space and lungs, its strength and attractiveness. [Table 2](#) illustrates the aspects adopted by the research to develop the area. The study area was visited, and the current situation was

documented by researchers. The river edge has been divided into 4 blocks (Blocks 1, 2, 3, and 4) to clarify the activities and nature of the current use, as shown in [Fig. 5](#), [Fig. 6](#), and [Fig. 7](#).

Table 2. Aspects and criteria for developing the study area [Researchers]

Aspects	Criteria
Environmental	Enhancing green and open spaces
	Reducing pollution
	Enhancing the riverbank
	Increasing afforestation
	Enhancing natural habitats and wildlife
	Enhancing green infrastructure services Managing stormwater Reducing the impact of the heat island phenomenon
Social	Enhancing social activities
	Enhancing social cohesion and meeting places for people
	Enhancing the preservation of the identity and spirit of the place
	Reviving and strengthening the collective memory of the place among city residents
	Enhancing individuals' connection with the geography and nature of their city
Economic	Matching functions and activities to the nature of the place
	Economic feasibility of the nature of the activities on the site relative to the site and the city
Legislative and administrative laws	Enhancing land use within the city's master plan
	Preserving open and green areas from encroachment and change of use
	Enhancing the planning and organisation of city activities and functions and supporting sustainable development
	Fluidity of traffic and ease of access to the place

7. Results and discussion

It was found that the percentage of afforestation is very low, as is the percentage of constructed buildings, and several high floors and the remaining open spaces are neglected, and most of the trees have been cut down, and the lots are used as parking spaces. The neglect of the riverbank in the areas of Blocks 3 and 4 can be observed, appearing as a barren area devoid of any vegetation or green cover. This district corresponds to the old historic area on the right side, and it is also the edge of a river within the city.

The results of the first and second questionnaires were completed and were as follows: Regarding the first questionnaire, which included a specialised sample in urban design and decision-makers, and included 62 individuals, the results showed that the quality of green infrastructure services in the study area is very low. The quality of rainwater management achieved the following percentages: (93.3% weak), (6.7% average), and (0.0% good). The percentages for the extent to which global warming was reduced were: (63.3% weak), (33.3% average), and (3.4% good). The region's role in reducing pollution achieved percentages: (76.7% weak), (11.7% average), and (11.7% good).

As for the social aspect, the extent to which the region is a social communication area achieved percentages: (48.3% weak) and (45% average) and (6.7% good), while the extent to which the area was considered a place of rest compared to what it was 25 years ago was (56.7% weak), (25% average), and

(18.3% good), and the percentages for attracting tourists from outside the city compared to what the area was previously as an open forest area were (35% weak), (50% average), and (15% good). As for the economic, planning, and organizational aspects, the possibility of visually viewing the river and the right side achieved percentages of (48.3% impossible), (45% possible with difficulty), and (6.7% easily possible), and the extent of compliance with overtaking permits achieved (78.3% weak), (18.3% average), and (3.4% good), and the extent to which the construction of indoor halls and restaurants for the study area achieved the following percentages (78.3% unsuitable), (18.3% suitable), and (3.4% very suitable), while the percentages for the extent to which Mosul's benefits from the construction of halls and restaurants in this area are as follows: (58.3% poor), (31.7% average), and (10% good), as shown in [Fig. 8](#).

Regarding the second questionnaire, which included a diverse group of city residents and area visitors, 106 people were asked about their views of the area and their hopes for what it should be. The results showed that (88%) of the people rejected the presence of these buildings in the area, (80%) supported the transfer of the halls to other parts of the city, and that only (4%) saw a smooth and easy movement in the area after the construction of the halls and restaurants. (76%) believed that it was the duty of the municipality and relevant departments to remove these buildings and restore the area to its natural, open, and green spaces. (84%) strongly agreed with the redesign of the study area to allow people to enjoy the riverbank without visual or movement obstructions, as shown in [Fig. 9](#).

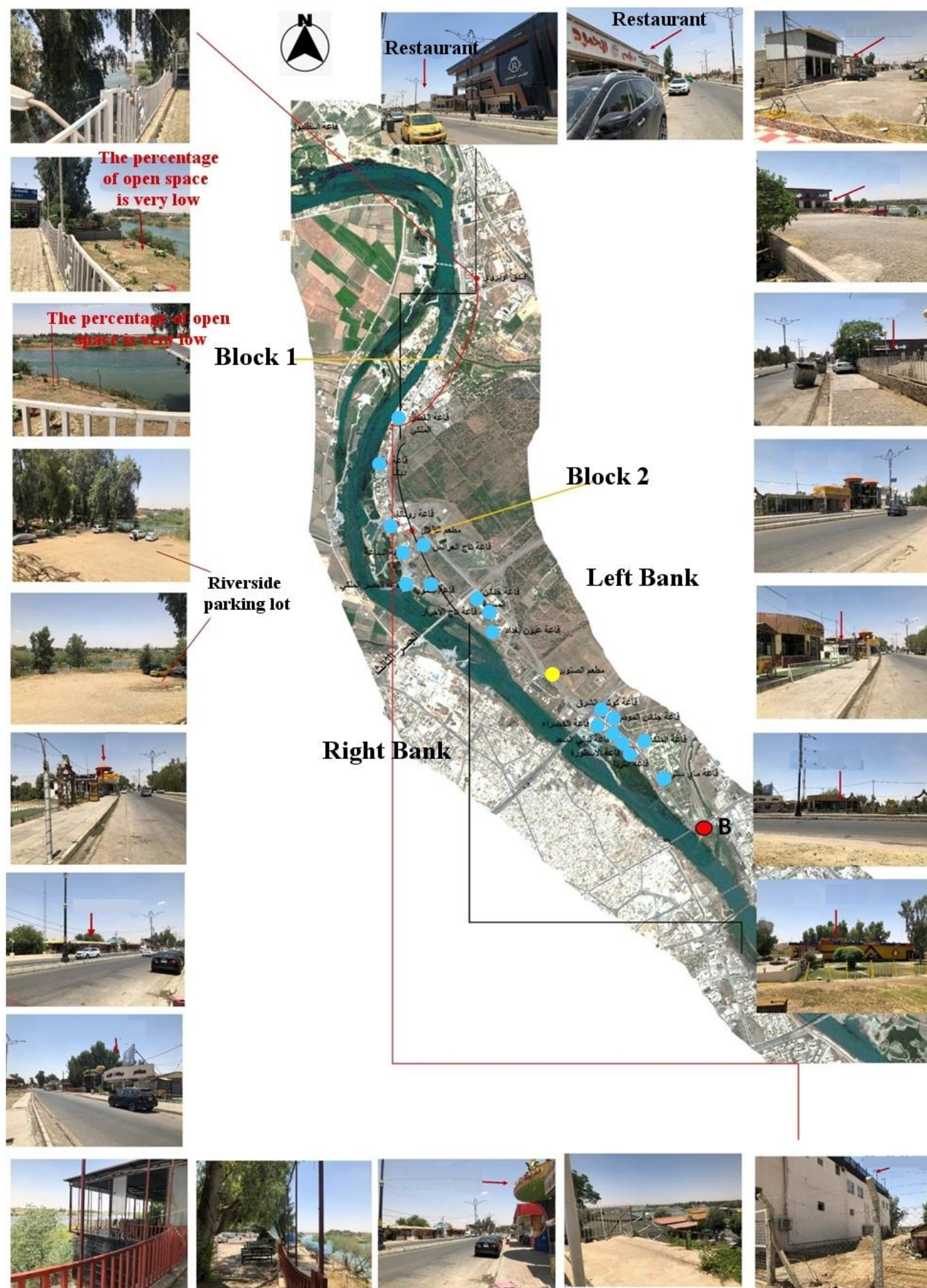


Fig. 5. The current use and activities of the river edge (Blocks 1 and 2). The figure shows a range of land uses and buildings (blue dots: celebration hall, yellow dots: restaurants) constructed on the left bank of the Tigris River in Mosul. Other images illustrate vacant spaces that could be utilised. [Researchers]

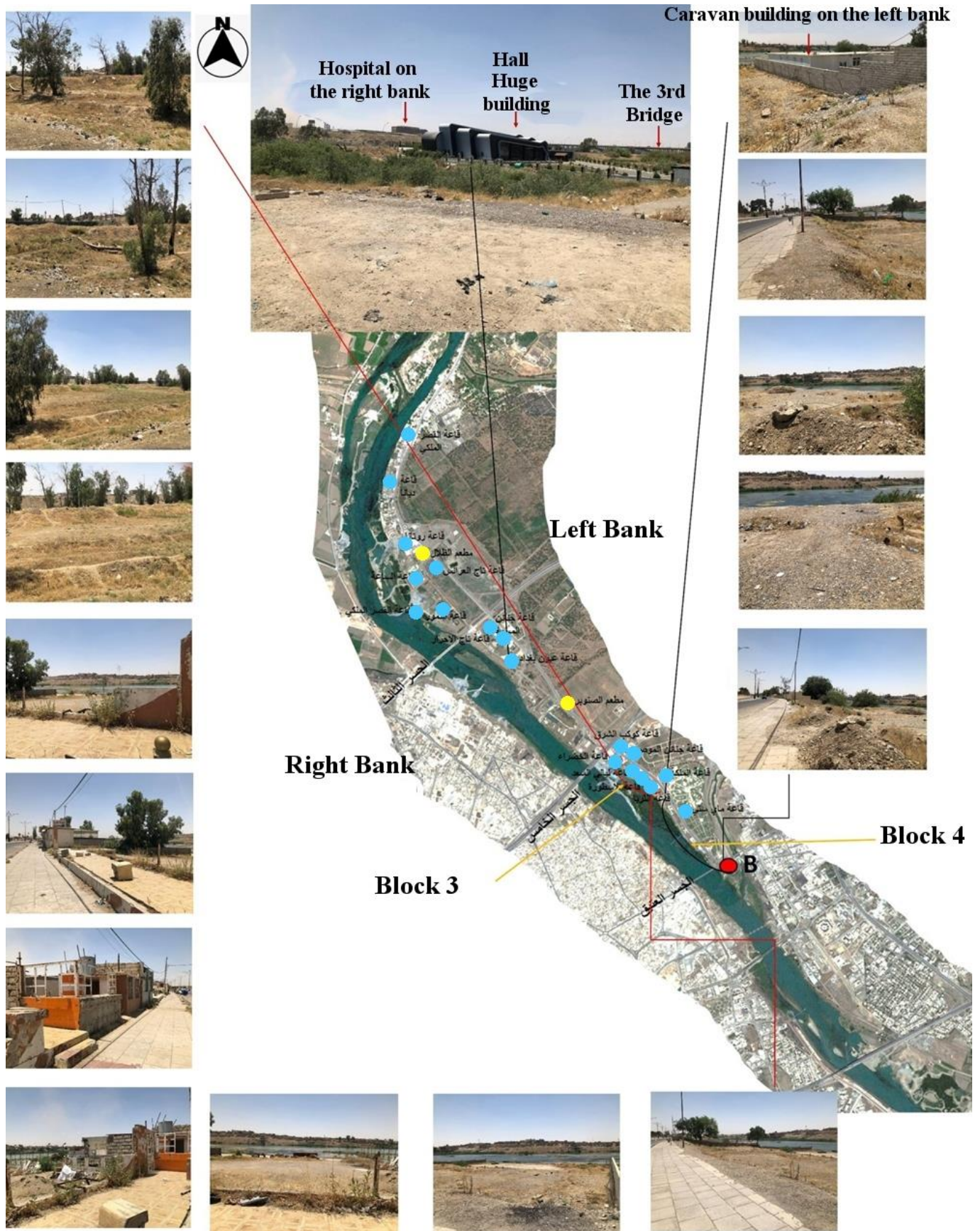


Fig. 6. The current use and activities of the river edge (Blocks 3 and 4). The figure shows a range of land uses and buildings (blue dots: celebration hall, yellow dots: restaurants) constructed on the left bank of the Tigris River in Mosul. Other images illustrate vacant spaces that could be utilised. [Researchers]



Fig. 7. Some of the celebration halls built on the left bank of the Tigris River in the city of Mosul

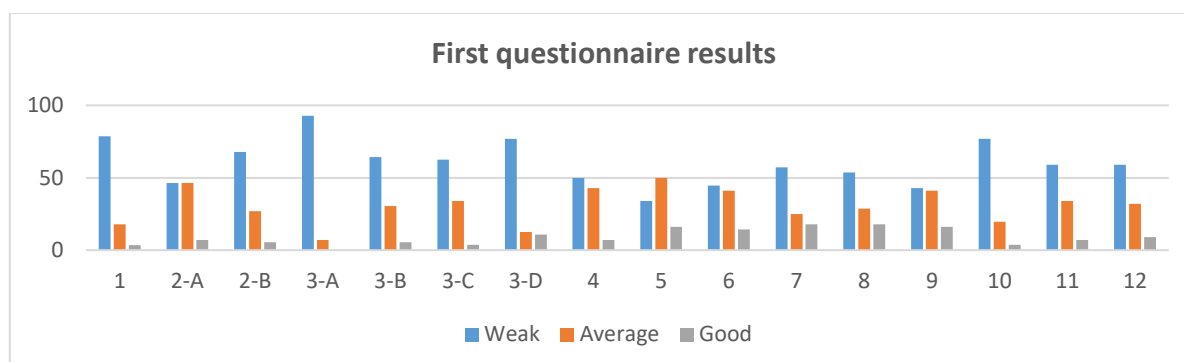


Fig. 8. First questionnaire results [Researchers]

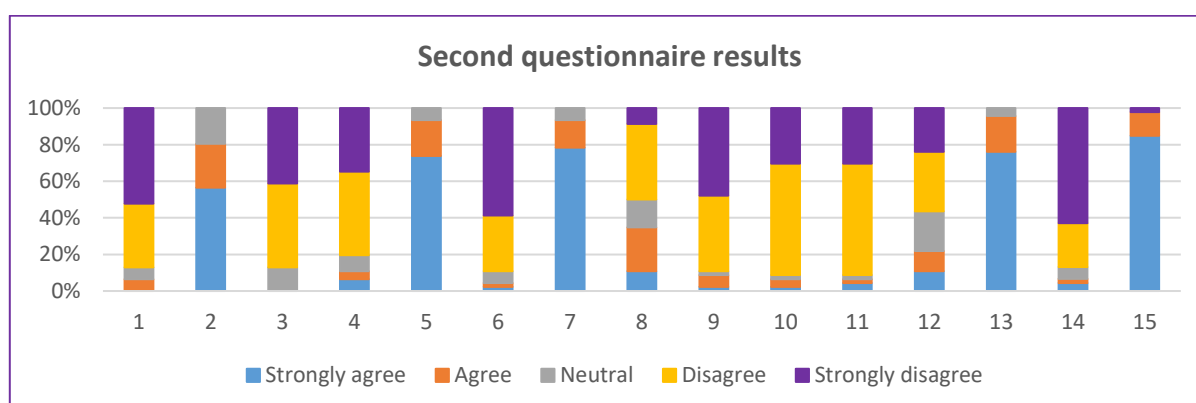


Fig. 9. Second questionnaire results [Researchers]

The results of the practical application showed the following: The current uses (restaurants, halls, and concrete buildings) in the study area are unsuitable, as are poor visual and kinetic permeability, poor green infrastructure services, failure to comply with trespassing permits for the study area, and the

deterioration of the riverbank and the loss of its natural character. The presence of numerous fixed and non-fixed buildings scattered along the riverbank obscures the view of the river and the city panorama on the right side, which includes important sites overlooking the river, such as Bashtabiya Castle, Qarsaray,

and the historically rich Old City. These activities could have served other areas and preserved the environmental, social, and economic value of the riverbank. The process of setting a price for entry to these areas has divided them into private and semi-private sections. The clustering of activities and their confinement to the study area without distributing them in a manner that serves the city has led to stifling congestion and increased pressure on its infrastructure.

8. Conclusions

The study investigates the impact of land use encroachments on the sustainability of urban environments, focusing on Mosul, Iraq, where unauthorized constructions such as halls and restaurants have led to the degradation of the Tigris River's left riverbank, resulting in the loss of its natural characteristics and ecological value. This encroachment has not only diminished the aesthetic and functional value of public open spaces but also reduced opportunities for social interaction and environmental engagement, highlighting significant challenges in regulatory enforcement and strategic urban planning. The research underscores the urgent need for comprehensive planning that integrates environmental, social, and economic dimensions to restore and preserve the riverbank as a vital urban component. Community participation is identified as crucial for successful sustainable urban planning, ensuring that developments meet local needs and preferences. The study recommends restoring the riverbank to its natural state, enhancing green infrastructure, and fostering integrated urban development that promotes biodiversity and social well-being. Strengthening policy frameworks and governance, alongside raising public awareness and education on sustainable practices, is essential for achieving urban sustainability. Collaboration among government agencies, the private sector, and civil society is advocated to effectively leverage resources and expertise. Continuous monitoring and evaluation are necessary to assess the progress and impact of sustainable initiatives and ensure they align with the city's long-term sustainability goals. The study calls for a holistic approach to urban development in Mosul, emphasizing the preservation of natural and cultural heritage to enhance the quality of life for its residents.

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Appendices

Appendix (1): First Questionnaire:

1. How suitable are the current uses of the study area, specifically referring to restaurants and indoor halls?
2. To what extent does the study area achieve visual and kinetic permeability?
 - o 2-a. What is the feasibility of accessing the riverbank?
 - o 2-b. What is the level of visual visibility of the river and the opposite right side (are there significant obstacles preventing visual continuity)?
3. What is the quality of green infrastructure services in the study area?
 - o 3-a. How effectively is rainwater managed and utilized?
 - o 3-b. What is the availability of natural habitats in the study area, considering it is a riverbank and an open area?
 - o 3-c. To what extent has the study area achieved mitigation of global warming and the urban heat island phenomenon after changing its use?
 - o 3-d. What role does the study area play in reducing pollution after changing its use from a green area to one containing constructed buildings?
4. To what extent is the study area accessible to all residents of the city, regardless of age and gender, and considered a meeting place and area for social interaction?
5. To what extent does the study area attract tourists from outside the city, compared to its previous use as a green forest area?
6. To what extent is the study area considered a place where individuals can connect with nature and the river?
7. To what extent is the study area considered a place of rest, recreation, and an outlet for the city, compared to 25 years ago?
8. To what extent has the study area succeeded in preserving the identity and spirit of Mosul, and to what extent are Mosul's forests currently considered a symbol or landmark of the city?
9. To what extent has the collective memory of the study area been consolidated?
10. To what extent is there compliance with encroachment permits in the study area?
11. To what extent has the study area currently benefited from changing its usage pattern and constructing indoor halls and restaurants?
12. To what extent would Mosul benefit from changing the pattern of use and constructing indoor halls and restaurants in this area?

Appendix (2): Second Questionnaire:

1. Do you concur with the current existence of indoor buildings within the study area?
2. Would it be more beneficial to relocate the majority of indoor activities, such as restaurants and halls, to alternative areas rather than their current location within the study area?
3. From your perspective, does the presence of concrete structures within a green space, such as a forest, enhance the area's value as a recreational outlet for the city's residents?
4. Is the quantity and number of currently constructed buildings within the riverfront area on the left bank considered natural and non-detrimental to the aesthetics of this uniquely natural area?
5. Do you support the idea of redesigning the riverfront study area into parks that are accessible and usable by citizens?
6. Do you agree with the proposal to convert the riverfront on the left bank into multi-story buildings, akin to those found on the right bank cornice?
7. Do you consider the former Mosul Forests to be a landmark that represents a significant memory and a source of pride for you as a citizen of the city?
8. In your opinion, do the Mosul Forests currently serve as a landmark that represents the local community?
9. In your view, is access to the riverbank currently as smooth and accessible as it was 25 years ago?
10. In your opinion, is the enjoyment of the river view and the natural scenery still feasible and in good condition?
11. Is the movement within the area's streets smooth and unaffected by changes in land use and the construction of halls and restaurants?
12. Do the efforts of government departments have a positive impact on the development of the area?
13. In your opinion, is it the responsibility of the Mosul Municipality to remove encroachments and restore the area to its natural open spaces?
14. Should government agencies, in your opinion, develop the area, increase the number of buildings, and transform it into a commercial zone?
15. Does the riverfront require redesigning to facilitate citizen access to the riverbank without impeding movement or visibility?