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# The Role of Ecosystem to Enhance Sustainable Revitalization: Al-Kifl Historic City Center As a Case Study

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## *Abstract*

**Historic city centers, particularly Al-Kifl, face mounting sustainability challenges. This study critically examines the limitations of current rehabilitation approaches within the historic center of Al-Kifl. The city center exhibits a significant deficiency in ecological sustainability. The research employed a methodology grounded in theoretical frameworks and incorporated analysis of relevant international case studies. Tools such as geographic information systems (GIS), field surveys, and climate simulations (ENVI-Met) were used to assess the city's current conditions. Key ecological indicators evaluated in the study include natural elements, biodiversity, thermal comfort, energy efficiency, recycling, and modern environmental technologies. The findings revealed several ecological shortcomings, such as a severe shortage of green spaces, neglect of riverbanks, declining biodiversity, elevated heat stress due to traditional construction materials, lack of vegetation cover, dependence on inefficient and limited traditional energy sources, absence of recycling systems, and failure to adopt modern environmental technologies such as green roofs and green walls. The study concluded that there is a need to adopt a comprehensive and integrated revitalization model that incorporates environmental considerations into sustainable urban planning. Key recommendations include enhancing natural elements and biodiversity, improving thermal comfort, transitioning to renewable energy, developing infrastructure for resource management, adopting modern environmental technologies, and revitalizing the essential ecological role of the Euphrates River to ensure the sustainable revitalization of Al-Kifl's historic center.**

***Keywords:*** *Sustainable Revitalization, Ecological Sustainability, Historic Centers, Al Kifl City Center, climate simulation (ENVI-Met).*

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## I. INTRODUCTION

The historical center of Al-Kifl, a city of profound cultural, religious, and architectural heritage, currently confronts a multifaceted array of sustainability challenges. These encompass physical degradation, social fragmentation, and ecological instability stemming primarily from decades of neglect, unsystematic urban planning, and the escalating effects of climate change [1], [2] . Such cumulative pressures have not only deteriorated the physical fabric of the historic core but have also undermined its cultural identity and compromised the quality of life for local communities.

In light of these challenges, a shift is required from conventional restoration approaches to a broader ecological perspective that integrates environmental considerations into heritage revitalization. Ecological sustainability provides a comprehensive theoretical and methodological foundation for guiding such a transformation, allowing for context-specific yet globally aligned interventions [3], [4].

A substantial body of research underscores the importance of ecological integration in contemporary urban planning. Urban green infrastructure, particularly green spaces has been shown to effectively mitigate the urban heat island effect and improve environmental quality and residents' well-being [5]. The introduction of ecological corridors is also pivotal in enhancing biodiversity and strengthening the adaptive capacity of urban ecosystems in response to climate disruptions [6].

Vegetative strategies, especially those utilizing advanced horticultural practices, have demonstrated a capacity to enhance thermal comfort and atmospheric conditions within dense urban contexts [7]. In parallel, renewable energy systems especially solar technologies have yielded measurable gains in energy efficiency and reductions in greenhouse gas emissions [8]. Complementing these efforts, recycling systems and circular economy frameworks play a crucial role in reducing environmental degradation and resource depletion [9].

Moreover, green roofs and vertical green walls serve



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multiple ecological functions, including improving energy performance, regulating microclimates, and managing stormwater runoff [10]. Collectively, these interdisciplinary interventions provide a cohesive model for sustainable urban transformation, particularly within historic urban contexts where ecological fragility intersects with cultural significance.

Within this framework, the historic center of Al-Kifl presents a critical case where ecological sustainability remains under-addressed. This research investigates how innovative, integrative strategies can contribute to the ecological revitalization of Al-Kifl's historic urban core an area that continues to suffer from the absence of adaptive, sustainability-oriented solutions.

The study is significant in that it bridges existing theoretical and practical gaps by proposing a conceptual planning model that fuses ecological resilience, cultural heritage preservation, and sustainable urbanism. It critiques the limitations of current revitalization approaches and introduces new pathways for

locally responsive and globally adaptable design and planning practices. Through this lens, Al-Kifl becomes both a subject of urgent intervention and a reference model for similarly endangered historic urban environments across the region.

## II. Research Methodology

This study employs a mixed-methods research design that combines spatial analysis, microclimate simulation, and field-based investigation to evaluate the ecological sustainability of the historic center of Al-Kifl. The methodological approach begins with a theoretical review to identify key ecological indicators green space, biodiversity, thermal comfort, energy efficiency, recycling, and green technologies which guide the analytical framework. Spatial analysis was conducted using GIS tools to map and assess urban morphology, vegetation distribution, and riverfront accessibility through high-resolution satellite imagery and cadastral data. To complement spatial insights, ENVI-met simulation software was used to model microclimatic conditions under current and proposed scenarios, evaluating thermal comfort using variables such as surface temperature, vegetation type, and building materials. Additionally, field surveys and observational studies were implemented to collect data on energy infrastructure, biodiversity, and waste management practices, while stakeholder interviews with local residents and municipal officials provided qualitative validation of observed patterns. The collected data were integrated through a matrix-based scoring system to assess ecological performance and to develop a conceptual model for sustainable revitalization tailored to Al-Kifl's historic and environmental context. This methodology ensures a comprehensive and context-sensitive assessment, offering a scalable framework for similar historic urban centers confronting environmental degradation.

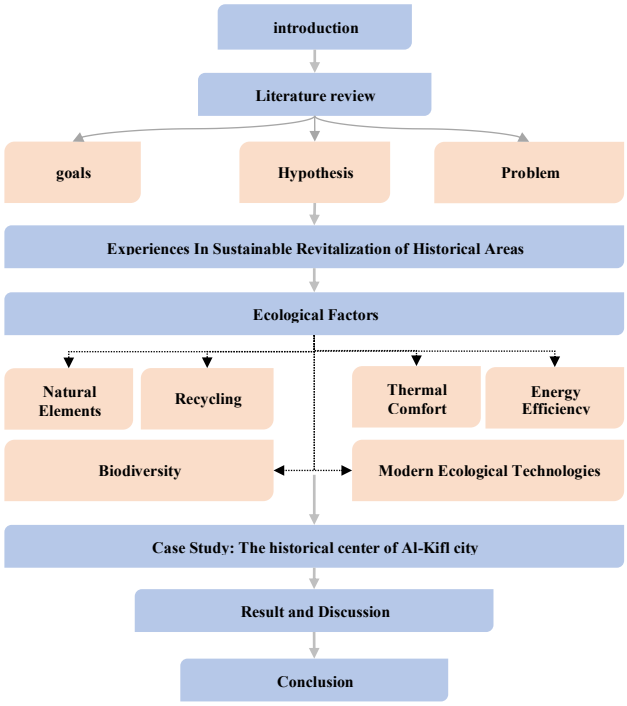


Fig. 1. Research methodology.

## III. Concept Sustainable Revitalization

Sustainable revitalization refers to the transformation of deteriorated urban areas into vibrant, resilient, and inclusive environments through the integration of ecological, social, economic, physical, cultural, and technological dimensions. This concept emphasizes enhancing urban quality of life by addressing urban decay, promoting heritage preservation, and utilizing modern technologies to bridge the past with present and future urban needs. As a strategic planning approach, sustainable revitalization aims to balance social equity, economic progress, and ecological protection by providing comprehensive solutions to both immediate physical challenges and long-term systemic issues confronting urban centers [11], [12]

The concept further involves the renewal and adaptation of urban spaces, enhancing cultural identity and livability through inclusive planning that meets evolving societal demands [13], [14]. It encourages the integration of modern technologies to enrich the urban experience and elevate the sustainability and attractiveness of historic city centers. Sustainable revitalization ultimately seeks to create dynamic, flexible, and future-ready communities [15]. Based on the reviewed literature, six interrelated dimensions define this concept: physical, cultural, social, economic, ecological, and technological, as shown in Fig. 2. This research focuses specifically on the ecological dimension as the core analytical lens.

Historically, the conceptual foundation of sustainable revitalization has evolved through several key milestones [16]. The emergence of ecological awareness began with the publication of "Silent Spring" by Rachel Carson in 1962, which played a pivotal role in raising global environmental consciousness. This momentum was further advanced by the

1972 United Nations Conference on the Human Environment, followed by the influential Brundtland Report in 1987, which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" . These foundational works led to the establishment of global frameworks such as Agenda 21 and the Sustainable Development Goals (SDGs) in 2015, institutionalizing the integration of environmental, social, and economic sustainability [17], [18].

By the 1980s, urban planning had begun to explicitly incorporate ecological concerns. Kevin Lynch (1981), in "The Theory of Good City Form," [19] emphasized mixed-use planning, biodiversity enhancement, and pollution reduction as critical components for environmentally responsible urban revitalization. In parallel, urban planner Thomas R. Hudspeth advanced the integration of ecosystems in revitalization strategies for neglected waterfronts. His 1980 conference paper and 1985 book, "Revitalizing Urban Waterfronts," underscored the importance of visual resource management, adaptive reuse, and community participation to enhance environmental and social outcomes [20], [21] .

Collectively, these theoretical contributions underscore the centrality of ecology in sustainable urban revitalization. As such, the ecological dimension addressing elements like green infrastructure, biodiversity, and thermal comfort serves as the foundation for the analytical framework employed in this study [23] ,[22]. To clarify the theoretical foundation of the study, a conceptual framework was developed to outline the key dimensions of sustainable revitalization, based on synthesized theoretical constructs and operational definitions According to Fig. 2.

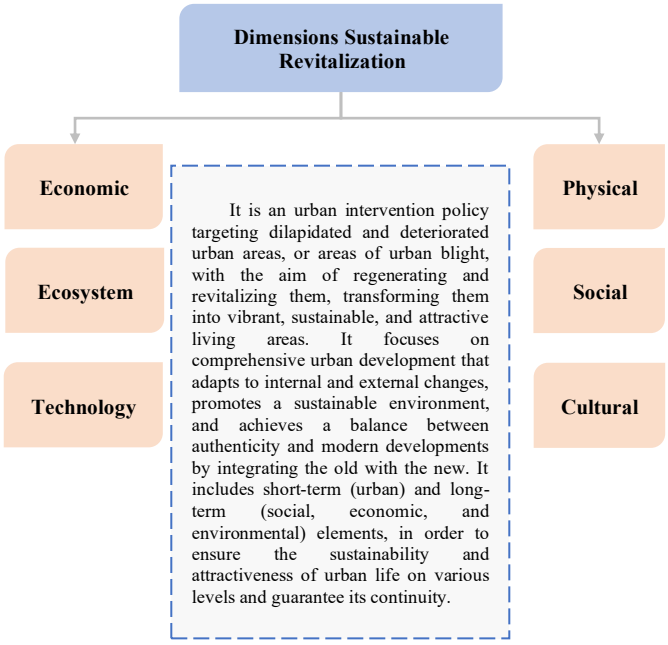


Fig. 2. Conceptual framework developed by the researcher, illustrating the main dimensions derived from the theoretical foundation and operational definitions used to assess sustainable revitalization in the context of Al-Kifl's historic center.

## IV. Ecosystem Concept

The ecosystem perspective in urban planning expands the ecological dimension of sustainable revitalization by focusing specifically on the reintegration of natural processes and biological systems within the urban fabric. Rather than treating green infrastructure as supplementary, it positions elements like vegetation cover, biodiversity, water flow regulation, and climate-responsive technologies (e.g., green roofs and walls) as foundational to spatial and environmental design. This paradigm shift responds to the ecological degradation caused by unplanned urban expansion and the marginalization of nature in conventional planning frameworks. It emphasizes restoring essential ecosystem services—such as air purification, temperature regulation, and habitat provision—as integral components of resilient urban regeneration strategies [24], [25].

Importantly, the ecological framework aligns closely with strategies of climate adaptation and environmental justice, providing mechanisms to address spatial inequities and environmental vulnerabilities across urban districts. Through nature-based and climate-resilient interventions, ecological planning fosters equitable access to clean air, green spaces, and thermal comfort. In historic urban areas, these strategies acquire additional value as they balance the preservation of cultural, historical, and architectural heritage with the need to upgrade the environmental performance of aging urban fabrics [26], [27].

Furthermore, ecosystem revitalization operates as a foundational component of urban resilience, encouraging sustained interaction between people and their environments. It emphasizes participatory governance, inclusive policy frameworks, and long-term environmental stewardship. Consequently, this concept extends beyond environmental repair it constitutes a holistic urban planning strategy that interweaves ecological, social, cultural, and institutional dimensions into a cohesive model for sustainable development [28], [29].

Building upon the preceding conceptual foundations and scholarly discourse, the core components essential for achieving sustainable ecological revitalization are synthesized as follows: integration of natural elements, promotion of biodiversity, enhancement of thermal comfort, energy efficiency, effective recycling practices, and the adoption of modern ecological technologies. The practical implementation of these components will be examined through the analysis of pioneering Arab and international case studies.

## V. Global Experiences

### A. *Msheireb Downtown Doha*

The Msheireb Downtown Doha project exemplifies an integrated model of sustainable urban revitalization in arid desert environments. Central to the initiative is the regeneration of the historic Msheireb district through environmentally responsive planning. Spanning 31 hectares, the project aimed to mitigate urban heat island effects by implementing green roofs, native vegetation, and high-albedo materials, achieving

temperature reductions of up to 5°C and a 25% decrease in heat accumulation [22], [23]. Air quality was improved via smart monitoring systems, while water efficiency was enhanced through recycled greywater and advanced irrigation technologies, reducing consumption by 35% [24]. Solar panels now supply 60% of the district's energy needs, cutting carbon emissions by 40% [25]. Green spaces, occupying 30% of the area, were systematically distributed to ensure accessibility and ecological connectivity [26]. Beyond technical measures, the project's relevance lies in its holistic integration of ecological indicators thermal comfort, biodiversity, energy, and recycling into the historic urban fabric. This experience offers transferable insights for Al-Kifl, particularly in its alignment with ecological revitalization goals in culturally significant and climatically stressed environments As a regional benchmark in ecological urbanism, Msheireb Downtown Doha demonstrates the effective integration of green infrastructure and renewable energy technologies. Fig. 3 highlights selected strategies that inform the conceptual foundation for revitalizing Al-Kifl's historic center.


Fig. 3. Sustainable ecological strategies implemented in Msheireb Downtown Doha. (a) Spatial organization of green public spaces that enhance pedestrian comfort and microclimatic balance. (b) Installation of green roofs to reduce surface temperature and improve insulation. (c) Rooftop solar panels integrated into residential buildings to promote clean energy use and reduce carbon emissions. These measures serve as transferable strategies for ecological revitalization in heritage urban settings such as Al-Kifl, particularly in arid climates facing similar thermal and environmental challenges. Source: Author, adapted from Msheireb Properties documentation and visual analysis.

### *B. The historic center of Rome*

The historic center of Rome, encompassing 14 km² and home to roughly 200,000 residents, offers a prominent example of ecological revitalization in a dense, historically layered urban setting. In response to long-standing environmental degradation, pollution, and unregulated growth, Rome adopted a sustainability-oriented policy framework focused on enhancing the urban ecosystem without compromising its cultural legacy [30]. Key interventions included the expansion of green infrastructure native tree replanting, pocket parks, and ecological corridors which helped reduce pollution, improve thermal comfort, and restore biodiversity. Notably, eight ecological corridors and five protected micro-reserves were established to strengthen habitat connectivity and increase protected species by 10% [31].water resource efficiency was enhanced through greywater recycling and smart irrigation technologies, contributing to reduced consumption and improved resilience to drought conditions[32]. The integration of green roofs, vertical gardens, and solar panels further decreased energy demand and improved air quality [33]. Public engagement played a central role: more than 10,000 residents participated in awareness campaigns, recycling programs, and environmental education initiatives [34]. As a holistic model, Rome's approach demonstrates the feasibility of integrating ecological, technological, and social strategies into heritage conservation frameworks. These insights are highly relevant to Al-Kifl, where balancing cultural preservation with ecological functionality remains a central revitalization challenge [35], Rome serves as a global precedent in harmonizing ecological elements within heritage urban settings. Fig. 4 presents selected landscape strategies that demonstrate how historic cores can benefit from integrated, climate-sensitive urban design.

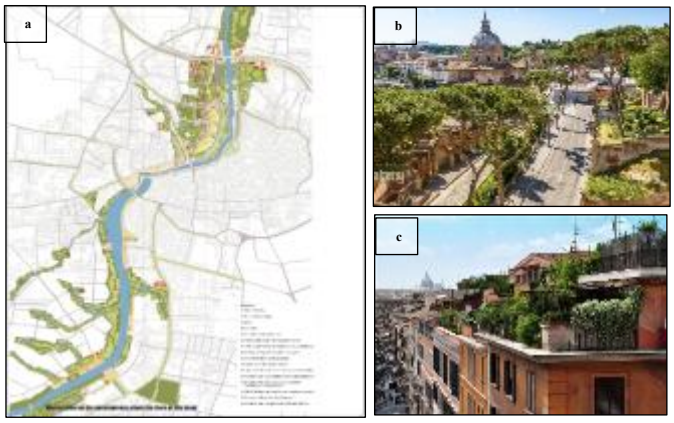


Fig. 4. Sustainable landscape interventions in the historic center of Rome. (a) Restoration and integration of historical water channels to improve environmental cooling and heritage continuity. (b) Protection and expansion of urban green zones through native vegetation and micro-reserve networks. (c) Application of rooftop vegetation systems on traditional structures to regulate thermal load and enhance ecological aesthetics. These strategies offer relevant models for improving thermal comfort and biodiversity in Al-Kifl's dense, historically layered urban context. Source: Author, based on environmental planning documentation and case study analysis from the Rome Municipality (2024).

Drawing upon insights from leading international case studies on ecological revitalization in historic urban contexts, a

set of key operational indicators has been synthesized. These indicators reflected in (Table 1) represent core environmental dimensions such as green infrastructure, biodiversity, thermal comfort, energy efficiency, water and waste management, and the use of eco-technologies. They serve as a foundational reference for evaluating ecological performance in Al-Kifl's historic center.

TABLE I. ECOSYSTEM REVITALIZATION INDICATORS

| Revitalization | Factor | Indicators |
|---|---|---|
| Ecosystem | Natural Elements | Green spaces, blue infrastructure. |
| | Biodiversity | Plant diversity, Animal diversity. |
| | Thermal Comfort | Feeling of thermal comfort while walking in open spaces. |
| | Energy Efficiency | Energy patterns, Energy intensity. |
| | Recycling | Waste recycling, Water recycling. |
| | Modern Ecological Technologies | Green roofs, green walls. |

## VI. METHODS OF MEASURING INDICATORS

Table II shows the methods of measuring the indicators specific to ecosystem restoration, showing the measurement method and the adopted standard.

TABLE II. METHODS OF MEASURING INDICATORS

| Factor | Indicators | Measurement Approach | Adopted Standard |
|---|---|---|---|
| Natural Elements | Green Spaces | Within GIS | Spatial gap for green spaces: Service range = 500-800 m, Time taken = 5-10 minutes |
| | Water Bodies | Within GIS | Extent of waterfront revitalization in the urban center |
| Biodiversity | Diversity of living organisms (flora and fauna) | Quantitatively according to Shannon index, using the following equation: | Shannon index value = 0.5-1 |
| Thermal Comfort | Extent of individuals' feeling of thermal comfort | Descriptive analysis of individuals' feeling of thermal comfort through map analysis, and quantitatively within ENVI-Met software environment | UTC= 16-26<br>PMV = -0.5 - 0.5, PPD = less than 10% |
| Energy Efficiency | Energy Patterns | Descriptive analysis to identify energy patterns used in the urban center | Renewable energy (clean energy) |
| | Energy Density | Quantitatively and in the energy consumption density equation: Consumption Density = Total Consumption / Total Production | The lower the indicator is compared to total production, the more efficient the energy use |
| Recycling | Waste Recycling | Quantitatively according to the equation (Recycling Rate = (Quantity of Recycled Waste / Quantity of Produced Waste) * 100), and represented within a GIS environment | Recycling rate (40-50%) of the quantity of produced waste |
| | Water Recycling | Quantitatively according to the equation (Recycling Rate = (Quantity of Recycled Water / Total Quantity of Produced Water) * 100), and represented within a GIS environment | Water recycling rate (30-40%) in environments with a river and (40-60%) in environments without a river |
| Modern Ecological Technologies | Green Roofs | Use of sensors and modern technologies to measure potential environmental impacts and GIS | House temperature reduction less than 35 degrees, external temperature reduction less than 3 degrees, rainwater harvesting by 50%, air pollutant reduction less than or equal to 0.2 gram/m²/day |
| | Green Walls | (Implicitly similar to Green Roofs, but no specific measurement details provided in original text) | (Implicitly similar to Green Roofs, but no specific measurement details provided in original text) |

## VII. CASE STUDY

The city of Al-Kifl is an Iraqi city of great heritage and religious significance. It is distinguished by its spiritual status, which is linked to the Shrine of Prophet Dhul-Kifl (PBUH) and numerous shrines of righteous saints, earning it the title "The Holy City". Its urban structure harmonized with the religious and social values that influenced its spatial layout. The city is characterized by its cohesive urban fabric, which highlights social and urban solidarity, and its movement paths are oriented towards the Qibla, with building orientations consistent with religious and spiritual values. This multitude of

religious landmarks reflects the city's integrated cultural structure and underscores its role as a center for religious coexistence and cultural interaction [37] ,[36].

The city of Al-Kifl is one of the urban settlements within the Al-Kifl District of Babylon Governorate in Iraq. Geographically, it is strategically located between three major provinces: Babylon, Najaf, and the holy city of Karbala. The city is situated at coordinates 32° 13′ 36″ N latitude and 44 ° 22′ 2″ E longitude, at an elevation of approximately 30 meters above sea level. Al-Kifl lies about 30 kilometers southwest of the center of Al-Hillah, 10 kilometers north of the city of Kufa, and 60 kilometers south of the Hindiya Dam. It is bordered to the north by the city of Al-Hillah, to the west by the Euphrates River, to the south by the city of Najaf, and to the east by expansive agricultural lands belonging to Babylon Province [38], [39]. To provide spatial context, the study identifies the exact geographical position of Al-Kifl's historic core within the larger urban fabric, serving as a foundation for subsequent ecological and spatial analysis, See Fig. 5

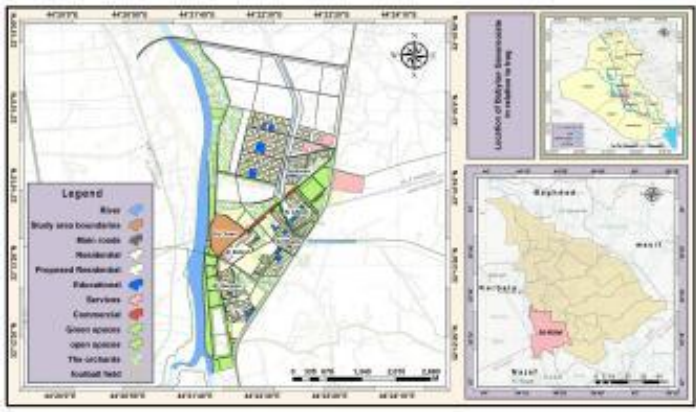

Fig. 5. Geographical location of Al-Kifl's historic center within the broader urban context, highlighting its spatial relation to surrounding features and its significance in the ecological and cultural landscape of the city.

The old quarter represents the historical core of Al-Kifl, around which the city evolved over time. It is home to 4,245 residents 15.9% of the city's total population of 26,614 across 1,033 households, with an average household size of 5.4. Covering 34.7 hectares, the old quarter accounts for 10% of Al-Kifl's total planned area (429 hactar) and 17.2% of its residential zones (202.3 ha). With 805 housing units, the area exhibits a population density of approximately 233 people per hectare. The quarter stands as a living example of religious and cultural coexistence, containing landmarks from various faiths and historical eras [36], [40]. As part of the spatial analysis, this study maps the existing land uses in Al-Kifl's historic center, offering critical insights into the current functional structure and its implications for ecological revitalization, see Fig. 6.


Fig. 6. Land use distribution in the historic center of Al-Kifl, illustrating the spatial arrangement of residential, commercial, religious, and vacant zones, which form the basis for ecological and functional assessment within the revitalization framework.

### *A. Natural Elements*

**Green Spaces:** The study area within Al-Kifl's historic center contains two designated green spaces: the "Visitors' Garden" (2,900 m²), located adjacent to the historic Al-Nukhaila Mosque, and "Jannat Al-Ahlam Garden" (1,900 m²), situated near the southern boundary of the district. Together, they comprise a total of 4,800 m² of green space. When evaluated against the international urban standard of 2.25 m² of green space per capita, the district demonstrates a significant shortfall of approximately 4,750 m², underscoring an ecological service gap in terms of environmental quality, public health, and urban resilience. Despite this deficiency, spatial accessibility remains relatively high GIS-based service area analysis indicates that 98% of the population resides within an 800-meter radius of these green areas. As part of the ecological assessment, this figure illustrates the spatial relationship between green space availability and the reach of essential services in Al-Kifl's historic core, shedding light on critical gaps affecting the prospects of ecological revitalization, see Fig. 7. However, accessibility alone does not compensate for the inadequate provision of green infrastructure, which limits opportunities for thermal regulation, social interaction, and biodiversity enhancement. Addressing this spatial-ecological imbalance through nature-based urban interventions is critical to the ecological revitalization strategy proposed for Al-Kifl.

**Water Bodies:** The historic core of Al-Kifl is naturally bounded on the west by the Euphrates River a key environmental and cultural asset. Despite its geographical prominence and visual value, the riverfront remains underutilized in the current urban configuration. Its ecological, recreational, and socio-economic potential is largely untapped. A sustainable waterfront revitalization framework is essential

to reactivating the urban edge and reinforcing the relationship between the built environment and its natural setting. Such a strategy envisions transforming the riverfront into an integrated ecological corridor and public amenity space, supporting tourism, community engagement, and cultural identity expression. This approach would elevate the Euphrates from a passive boundary to an active engine of regeneration, aligning with global best practices in heritage-based ecological planning.


Fig. 7. Spatial layout of existing green areas and their distribution within Al-Kifl's historic center. The figure visually supports the ecological analysis by mapping the limited green infrastructure relative to the urban fabric, helping to contextualize gaps in environmental quality and public space provision. Source: Author, based on GIS spatial analysis (2024).

### *B. Biodiversity*

Field surveys and stakeholder interviews conducted in the historic center of Al-Kifl indicate a marked reduction in urban biodiversity. Observed fauna were limited to a narrow range of species including stray dogs, domestic cats, and a few fish highlighting an impoverished ecological presence. In contrast, the peri-urban agricultural zones surrounding the city center demonstrate greater species richness and ecological resilience. This biodiversity gap is largely a consequence of dense urbanization, habitat fragmentation, and the absence of ecological infrastructure within the historic core. The resulting loss of biodiversity carries multiple implications: it undermines ecological equilibrium, exacerbates pollution and poor air quality, and constrains potential for eco-cultural tourism and nature-based urban regeneration. Left unaddressed, this deficit may accelerate long-term environmental degradation and diminish the livability of the historic center. Strategic interventions such as habitat restoration, integration of green corridors, and protection of native species are essential to reverse this trend and realign urban biodiversity with sustainability goals.

### *C. Thermal Comfort*

To assess thermal comfort in the study area, three representative zones within the historic center of Al-Kifl were selected for microclimatic simulation using ENVI-Met software. The simulation was conducted for July 27, 2024—a date selected based on its alignment with the peak of Iraq's summer holiday period, during which ambient temperatures typically reach their annual maximum. Climatic input data, including temperature, relative humidity, wind speed, and wind direction, were obtained from the Babylon Meteorological Authority and verified using local online platforms. Surface characteristics were modeled to reflect actual urban materials, including exposed soil, asphalt-paved roads, and traditional masonry construction materials used in the historic buildings. The simulation focused on peak daytime hours (12:00–15:00), during which thermal stress is most pronounced. To evaluate thermal comfort within the historic environment, specific field measurement points were selected and analyzed using ENVI-met simulations, forming the basis for environmental performance assessment, see Fig. 8.


Fig. 8. Locations of thermal comfort measurement points in the historic center of Al-Kifl, as identified during field surveys and simulated using ENVI-met software to assess microclimatic conditions.

Analysis was conducted for peak thermal hours (12:00–15:00), revealing that surface and air temperatures frequently exceeded 51°C in exposed zones with minimal shading. The lack of vegetative cover and limited architectural shading intensified thermal stress, with Predicted Mean Vote (PMV) indices indicating severe discomfort and heat stress for pedestrians. These outcomes highlight the critical role of green infrastructure and climate-sensitive materials in improving outdoor thermal conditions As shown in Table 3..

The findings are consistent with global examples such as Msheireb Downtown Doha and Rome's historic center, where strategic integration of shading, vegetation, and reflective materials significantly improved thermal comfort. Therefore, climate-responsive urban design—including green corridors, reflective surfaces, and passive cooling interventions—must be considered a core priority within Al-Kifl's ecological revitalization framework to ensure environmental resilience and livability.

TABLE III. METHODS OF MEASURING INDICATORS

| site | Date | the time | Temperature (c) | Wind speed (m/s) | PMV | PPD | UTC |
|---|---|---|---|---|---|---|---|
| First site | **27/7/204** | 12:00 PM | 39 - 40 | 0.14 - 3.84 | 4.66 - 7.73 | 100% | 49 C˚ |
| | | 13:00 PM | 38 - 45 | 0.10 - 3.84 | | | |
| | | 14:00 PM | 43 - 48 | 0.10 - 3.85 | | | |
| | | 15:00 PM | 33 - 47 | 0.10 - 3.84 | | | |
| Second site | **27/7/204** | 12:00 PM | 41 - 43 | 0.44 - 4.92 | 5.31 - 8.32 | 100% | 51 C˚ |
| | | 13:00 PM | 37 - 45 | 0.43 - 4.69 | | | |
| | | 14:00 PM | 43 - 49 | 0.43 - 4.69 | | | |
| | | 15:00 PM | 42 - 45 | 0.44 - 4.69 | | | |
| The third site | **27/7/204** | 12:00 PM | 40 - 44 | 0.45 - 4.38 | 4.23 - 7.64 | 100% | 48 C˚ |
| | | 13:00 PM | 39 - 48 | 0.45 - 4.55 | | | |
| | | 14:00 PM | 42 - 46 | 0.45 - 4.56 | | | |
| | | 15:00 PM | 41 - 44 | 0.46 - 4.58 | | | |

*Source: Using ENVI-met.*

Following the thermal comfort analysis, a series of spatial maps were generated to visualize the distribution of surface temperatures across the three selected sites. These maps are based on the climatic and material data presented in Table 3 and illustrate temperature gradients using a color scale ranging from red to blue. Areas shaded in red indicate zones with the highest thermal intensity, corresponding to severe heat accumulation, while areas in blue represent cooler zones with better microclimatic conditions.

Fig. 9 displays the temperature simulation results for the first site, Fig. 10 corresponds to the second site, and Fig. 11 presents the third site's data.

This color-coded visualization facilitates an intuitive understanding of thermal stress patterns and highlights the spatial disparities in heat exposure across the urban fabric.

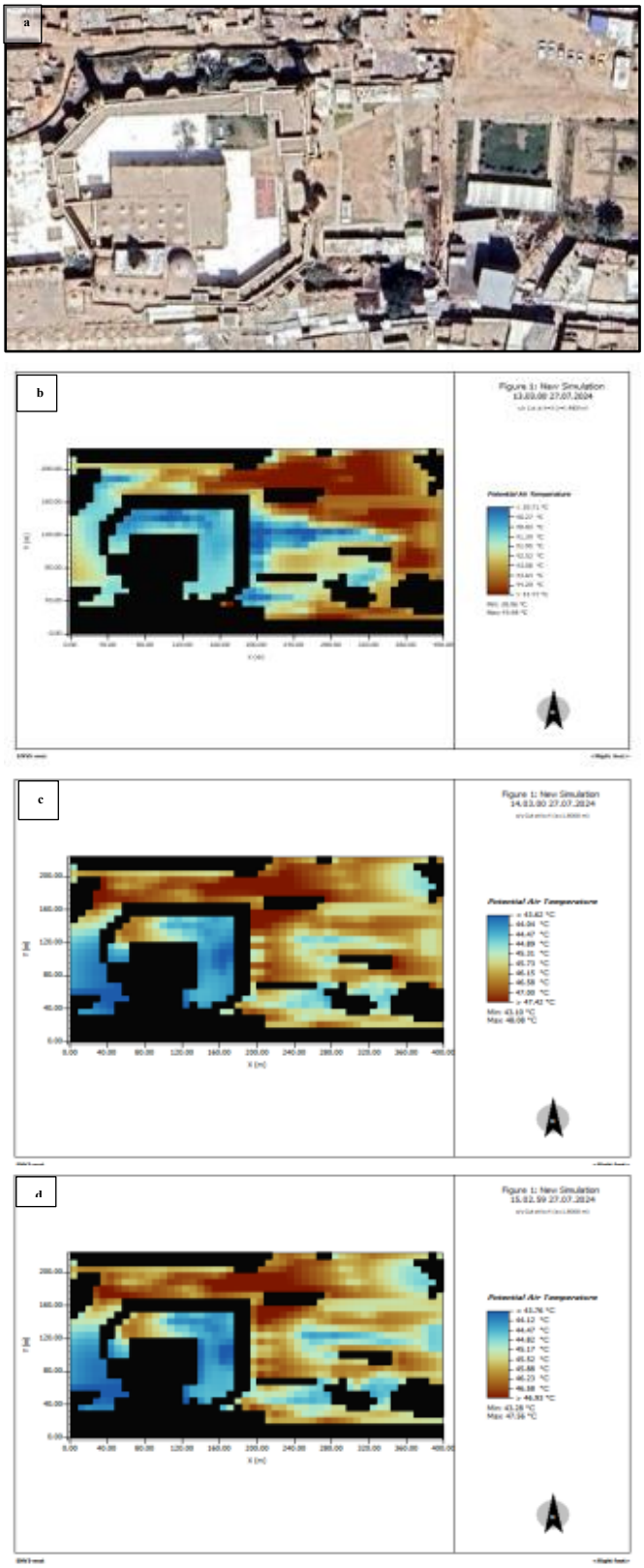


Fig. 9: ENVI-met simulation of temperature variation at the first measurement site in Al-Kifl's historic center on July 27, 2024, showing (a) the analysis site, and temperature snapshots at (b) 1:00 PM, (c) 2:00 PM, and (d) 3:00 PM.

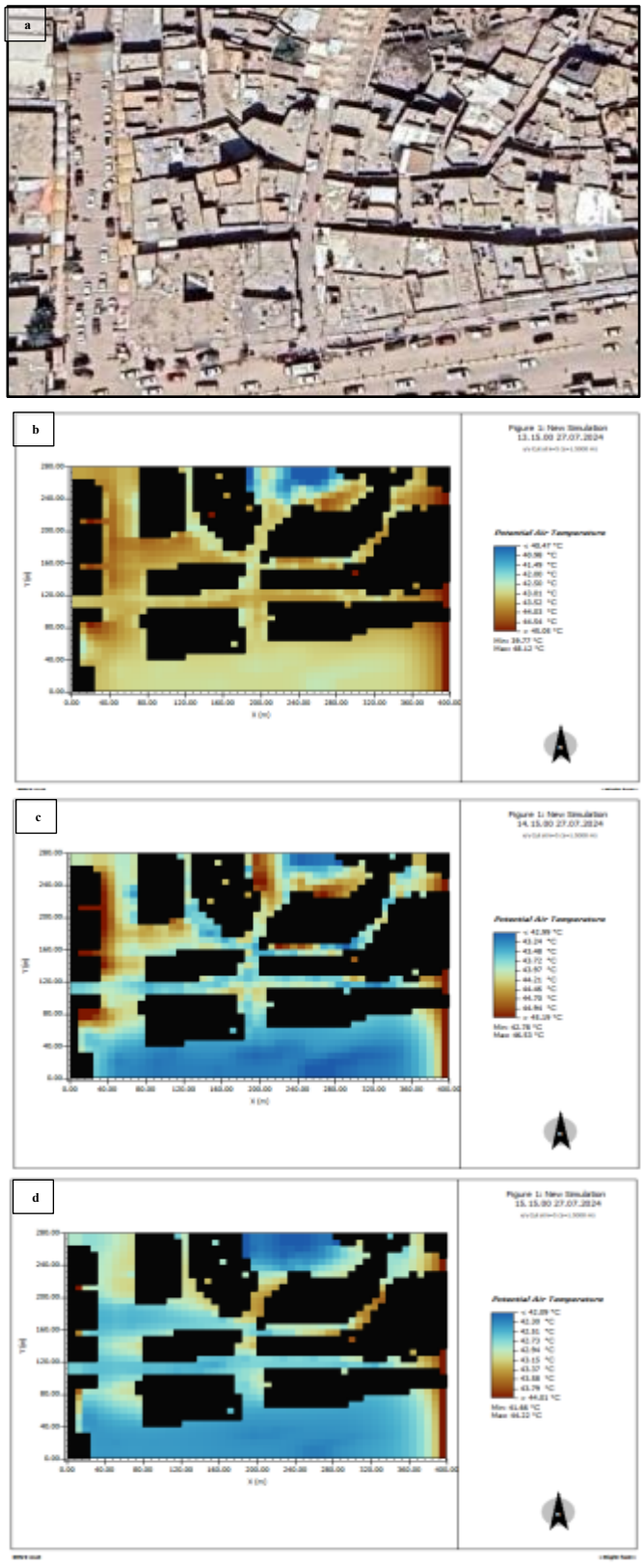


Fig. 10. ENVI-met simulation of temperature variation at the second measurement site in Al-Kifl's historic center on July 27, 2024, showing (a) the analysis site, and temperature snapshots at (b) 1:00 PM, (c) 2:00 PM, and (d) 3:00 PM.

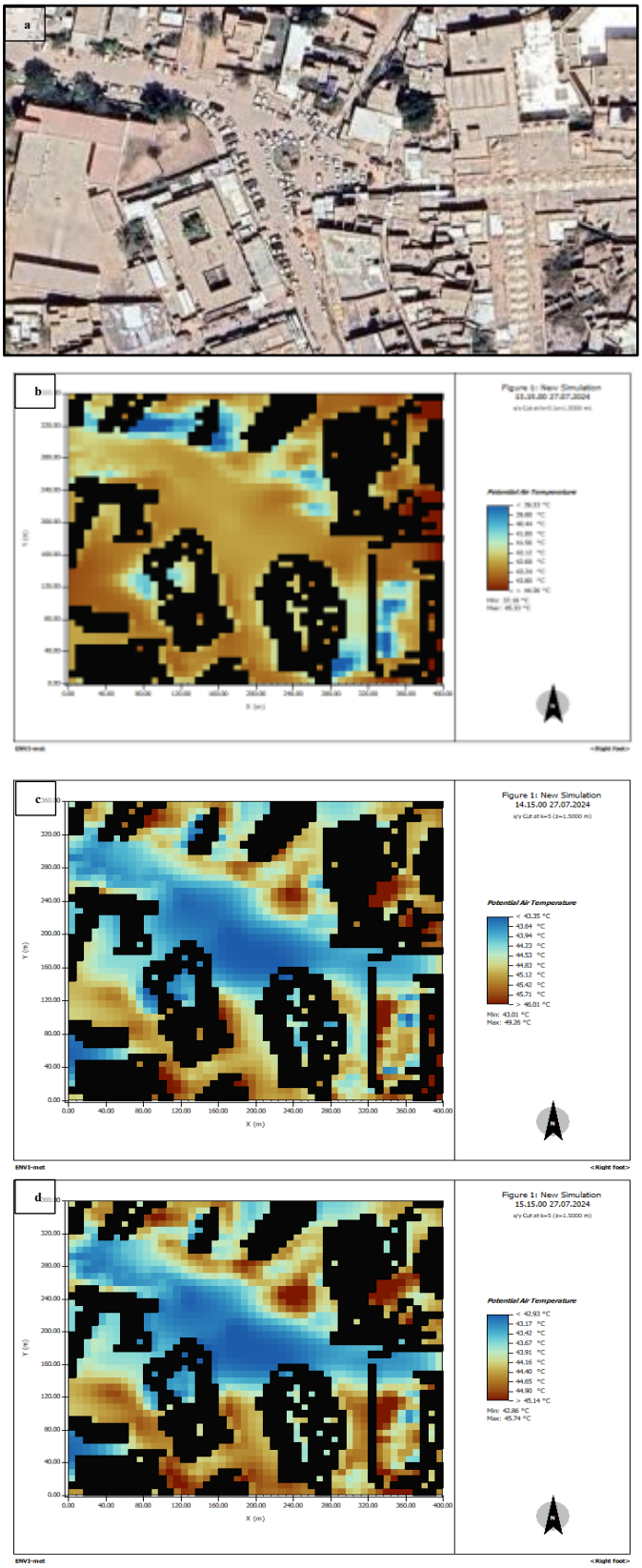


Fig. 11. ENVI-met simulation of temperature variation at the third measurement site in Al-Kifl's historic center on July 27, 2024, showing (a) the analysis site, and temperature snapshots at (b) 1:00 PM, (c) 2:00 PM, and (d) 3:00 PM.

### D. Energy Efficiency

**Energy Patterns:** The city of Al-Kifl is currently dependent on conventional energy sources, primarily supplied by the electricity generation plant located south of Al-Hilla. Power is transmitted through a regional network of transformers and overhead lines to meet urban demand. This conventional infrastructure contributes significantly to carbon emissions and air pollution due to the fossil fuel-based generation process. Within the framework of sustainable revitalization, it is essential to transition toward renewable and cleaner energy sources, The condition of existing electrical systems in Al-Kifl's historic core reveals clear gaps in infrastructure quality and energy resilience. Fig. 12 highlights elements that undermine both functional efficiency and the visual harmony of the urban environment.

**Energy Density:** According to field data, Al-Kifl receives an overall electrical supply of 28 megawatts (MW), of which only 4.66 MW is distributed to the historic center, referred to as "Al-Qasaba Al-Qadima." However, energy demand within this area reaches 8.8 MW, creating a significant shortfall of 4.2 MW equivalent to 47.7% of the required load. This supply-demand mismatch results in a high energy intensity index of 1.88, indicating overburdened infrastructure and inefficient energy distribution. These findings highlight an urgent need for upgrading the energy network, enhancing demand-side management, and integrating renewable technologies to bridge the deficit, optimize consumption, and reinforce the sustainability goals of the revitalization strategy.


Fig. 12. Existing electrical infrastructure in Al-Kifl's historic center. (a) Transformer station with outdated and inefficient design contributing to energy loss and operational instability. (b) Overhead electrical wiring systems that disrupt the visual harmony of the heritage streetscape and reflect infrastructural fragility. These images highlight critical technical and aesthetic challenges that necessitate the adoption of decentralized and sustainable energy solutions within the ecological revitalization framework. Source: Author, field documentation (2025).

### E. Recycling

Recycling of waste and water resources is a fundamental pillar of ecological system regeneration within sustainable urban centers. However, field survey data and official reports revealed a complete absence of structured recycling initiatives in the historic center of Al-Kifl. Solid waste continues to be managed through conventional methods collected manually by municipal vehicles and transported to external landfills without any form of sorting, reuse, or material recovery. This practice significantly deviates from international benchmarks, which recommend a recycling rate of 40–50% of generated solid waste in ecologically revitalized urban contexts. The presence of unregulated waste in Al-Kifl's historic core reflects severe environmental neglect and the absence of circular waste systems. Fig. 13 highlights these deficiencies and supports the case for integrating sustainable waste management into the revitalization strategy.

Similarly, water recycling is non-existent, as wastewater is discharged directly into the Euphrates River without undergoing any treatment or reuse. This contradicts sustainable management standards for water-rich urban centers, which require 30–40% wastewater recycling to support ecosystem balance and resource circularity. The absence of these practices underscores an urgent need for the implementation of integrated environmental management strategies. Promoting solid and liquid waste recycling not only mitigates pollution but also enhances resource efficiency and aligns with broader sustainability objectives in the revitalization of Al-Kifl's historic core.

Fig. 13. Evidence of unmanaged solid waste in the residential alleys of Al-Kifl's historic center. The image reveals the absence of structured waste collection and recycling systems, reflecting institutional and infrastructural deficiencies. The visual and environmental impact underscores the urgency of integrating circular waste management into the city's revitalization strategy, particularly in culturally sensitive areas. Source: Author, field photograph taken during site visit (2025).

### F. Modern Ecological Technologies

Field investigations conducted in the historic center of Al-Kifl reveal a complete absence of modern ecological technologies, particularly green roofs and living walls. Rooftop surfaces across the study area are uniformly constructed using conventional, non-sustainable materials such as cement,

"Farshy" (a traditional local surface material), and baked bricks. Similarly, building façades are predominantly covered in ceramic tiles and cement-based finishes, reflecting an outdated construction paradigm devoid of environmental considerations. Fig. 14 demonstrates the widespread use of traditional surfaces that exacerbate thermal accumulation and underscore the need for eco-efficient retrofitting strategies.

This lack of integration of green technologies stands in stark contrast to global best practices, where vegetated roofs and vertical greenery systems are increasingly employed to enhance ecological resilience. These systems are known to improve air quality through pollutant absorption, contribute to urban cooling by mitigating the heat island effect, regulate stormwater runoff, and support local biodiversity. In addition, they offer aesthetic and cultural value, enhancing the visual identity of historic districts.

In the context of Al-Kifl's revitalization, the absence of such technologies signals a critical gap that hinders the achievement of ecological sustainability. Adopting modern ecological technologies should be a strategic priority within the broader regeneration policy, aligning with international benchmarks such as those applied in Msheireb (Doha) and Rome's historic center. Their implementation could significantly enhance environmental performance, elevate quality of life, and contribute to the long-term resilience and cultural integrity of the historic urban fabric.

Fig. 14. Aerial view of traditional flat-roof structures in Al-Kifl's historic center, highlighting the dominance of thermally inefficient roofing materials and their contribution to urban heat stress. Source: Author, based on Google Earth Pro.

## VIII. Results And Discussion

This study conducted a comprehensive ecological assessment of the historic center of Al-Kifl by employing six interrelated indicators: natural elements, biodiversity, thermal comfort, energy efficiency, recycling, and modern ecological technologies. The integration of GIS analysis, ENVI-Met simulation, field observations, and stakeholder interviews enabled a multi-scalar and evidence-based diagnosis of the environmental performance of the study area. The findings reveal critical deficiencies across all ecological dimensions, demonstrating the urgent need for an integrated sustainable revitalization strategy.

Natural Elements (Green and Blue Infrastructure): GIS-based spatial analysis revealed a stark shortage of green spaces, amounting to only 4,800 m², whereas the international minimum standard (2.25 m² per capita) requires nearly double that amount. While 98% of residents are within walking distance of existing parks (800 m radius), the overall ecological function remains deficient. Moreover, the Euphrates River, despite its proximity and historic value, remains underutilized as a blue infrastructure asset. This diverges significantly from global benchmarks like Msheireb, Doha, where the riverfront is an integrated ecological and socio-economic corridor. Revitalizing the riverfront in Al-Kifl is thus essential not only for environmental health but also for heritage, recreation, and tourism enhancement.

Biodiversity: Field surveys and qualitative data revealed a profound decline in biodiversity, with only a limited presence of domestic animals (e.g., cats, dogs) and some aquatic species. This is in contrast to the surrounding agricultural landscapes, which host richer ecological diversity. The historic center's high-density morphology and lack of vegetation have disrupted ecological niches, leading to habitat fragmentation and biological isolation. In comparison to Rome's historic center, which successfully implemented urban ecological corridors and native reforestation, Al-Kifl lacks foundational biodiversity-supporting policies. The inclusion of micro-habitats, native species, and green corridors is imperative to restore urban ecosystem resilience.

Thermal Comfort: ENVI-Met climate simulations conducted for July 27, 2024, reveal alarming thermal stress levels, with recorded surface temperatures between 48°C and 51°C across three sampled sites. Predicted Mean Vote (PMV) values ranged from +4.66 to +8.32 far beyond the comfort threshold of -0.5 to +0.5 corresponding to 100% Predicted Percentage of Dissatisfaction (PPD). The findings point to the compounding effects of low albedo construction materials, vehicular heat emissions, and the near absence of shading elements. These conditions not only compromise public health and comfort but also limit pedestrian activity and social interaction. Adopting heat-mitigation interventions—such as permeable pavements, vertical greening, and climate-adaptive urban design—is a non-negotiable priority for future planning.

Energy Efficiency: Energy audit results indicate a critical mismatch between energy supply and demand. Although the historic center receives 4.66 MW, the actual demand is 8.8 MW, representing a 47.7% deficit and an intensity index of 1.88. This inefficiency underscores the dependency on centralized, non-renewable electricity from Al-Hillah's thermal plant, with evident implications for carbon emissions and energy insecurity. International models such as Msheireb's solar integration strategies offer replicable lessons. Al-Kifl's revitalization should thus prioritize decentralized renewable energy systems (solar panels, smart grids) and retrofitting of existing structures for energy conservation.

Recycling: Data from municipal authorities confirmed a complete absence of both solid waste and wastewater recycling. Waste is collected and transported to landfills without segregation or reuse, while untreated wastewater is discharged directly into the Euphrates. These practices deviate significantly from the international sustainability threshold of 40–50% waste recycling and 30–40% water recycling for riverine environments. The consequences are not only ecological (e.g., pollution, biodiversity loss) but also public health-related. Institutionalizing circular economy infrastructure sorting, composting, wastewater treatment—is essential for compliance with the Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities).

Modern Ecological Technologies: Site inspections revealed a complete absence of green roofs and green walls. Traditional materials (cement, "Farshy", ceramic tiles) dominate the built environment, contributing to high thermal loads and low ecological performance. In contrast, international case studies (e.g., Rome and Doha) highlight the significant benefits of these technologies in reducing indoor and outdoor temperatures, purifying air, and managing rainwater. Their adoption in Al-Kifl would contribute substantially to heat reduction, visual aesthetics, and environmental resilience.

Collectively, the results articulate an urgent ecological crisis within the historic core of Al-Kifl. Each of the six indicators exposes structural, policy, and design failures that have inhibited sustainable development. The observed conditions heat stress, biodiversity collapse, energy inefficiency, and environmental pollution call for a paradigm shift in urban management. To remedy these issues, the research supports the development and implementation of an integrated revitalization model grounded in nature-based solutions, renewable energy technologies, ecological restoration, and community driven environmental planning. This model should harmonize local cultural identity with global environmental standards, ensuring the long-term livability and heritage preservation of Al-Kifl's historic center.

## IX. Conclusions

This study examined the ecological revitalization of the historic center of Al-Kifl through an integrated analytical framework based on six interrelated indicators: natural elements, biodiversity, thermal comfort, energy efficiency, recycling, and modern ecological technologies. The findings demonstrated severe ecological degradation, characterized by the acute shortage of green infrastructure, diminished biodiversity, critical thermal stress levels, energy supply deficits, lack of recycling systems, and the absence of green technologies. These outcomes confirm the research hypothesis, which posited that ecological revitalization requires the integration of sustainability components into urban strategies.

The results reveal that the current revitalization policies in Al-Kifl are fragmented and insufficient, failing to address both the heritage preservation and environmental performance of the city center. By comparing the Al-Kifl context with international case studies such as Msheireb (Doha) and the historic center of Rome, the study highlighted successful ecological models that can serve as reference points for future interventions.

To mitigate the ecological deficiencies, this research advocates for the implementation of a comprehensive and adaptive revitalization model that incorporates nature-based solutions, renewable energy technologies, and participatory urban governance. This model must align with global environmental standards while respecting the historical and cultural identity of the site.

Despite its contributions, the study is limited by data availability in some technical indicators and the constraints of modeling future climate scenarios. Future research should expand the analysis to include long-term monitoring of ecological impacts and explore scalable applications of the proposed model in other historic Iraqi cities. The ecological sustainability of historic urban centers is not merely a design challenge it is a strategic imperative for cultural resilience, environmental justice, and urban livability.

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