AUIQ Technical Engineering Science

Manuscript 1068

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AUIQ TECHNICAL ENGINEERING SCIENCE 2026;3:81–92

REVIEW

Urban Resilience to Environmental Displacement: Sustainable Design Strategies in Samarra and Najaf

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ABSTRACT

This research investigates the critical role of urban resilience as a strategic framework to mitigate climate-induced environmental displacement in hot-arid regions, specifically focusing on the historical Iraqi cities of Samarra and Najaf. As global temperatures rise, these cities face intensifying thermal stress and desertification, acting as primary "push factors" for involuntary migration. The objective of this study is to evaluate the efficacy of sustainable urban design and traditional planning morphologies in enhancing the adaptive capacity of these urban centers. The methodology employs a Variable-based Digital Spatial Analysis utilizing Landsat 8 TIRS and Sentinel-2 satellite imagery. Through advanced geospatial processing, original maps for Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) were generated to quantify the correlation between urban fabric density and thermal performance. The findings reveal a significant thermal disparity between traditional and modern urban layouts. Traditional compact tissues, characterized by narrow winding streets and shaded internal courtyards, demonstrated superior microclimate regulation, reducing surface temperatures by up to 10.5 °C compared to modern open-plan residential blocks. The study highlights that the absence of integrated green infrastructure and high-albedo materials in new developments exacerbates the Urban Heat Island (UHI) effect, directly threatening inhabitant stability. The research concludes that achieving long-term urban resilience requires a hybrid planning approach that integrates the socio-environmental wisdom of ancient metropolis design with modern sustainable technologies, such as nature-based solutions and passive cooling strategies. This integration is essential not only for thermal comfort but as a fundamental necessity for the socio-economic preservation and climate adaptation of Samarra and Najaf, ensuring these cities remain habitable and secure for future generations against the escalating climate crisis.

Keywords: Urban resilience, Environmental displacement, Passive cooling strategies, Traditional Iraqi architecture, Case study: Samarra and Najaf, Climate-induced migration, Hot-arid regions

1. Introduction

The study aims to study the fundamental relation between the urban resilience and the environmental displacement with an interest in the problems of hot and dry cities in Iraq. Specifically, it compares Samarra and Najaf to evaluate the efficacy of various sustainable design strategies in response to the consequences of climate-induced migration and extreme weather conditions. We will look at old and new building techniques and how they can help us control temperatures inside and make our cities more loveable. This comparative analysis underlines the importance of sound urban design in conjunction with the development of sustainable cooperation which can be expected in the near future in the specific urban

Received 2 May 2026; revised 17 June 2026; accepted 18 June 2026.
Available online 24 June 2026

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https://doi.org/10.70645/3078-3437.1068

context. Iraq's second climate has become extremely extreme, with temperatures exceeding 50 Celsius, recurrent drought, and rising dust storms. This is an era when serious revision of traditional building techniques and the development of new approaches to the long-term development of cities are taking place. In order to cope with these rising climate risks, the study proposes a durable urban planning approach encompassing changes to urban infrastructure in order to enhance living conditions and sustainable viability.

The Sheet precisely underlines the importance of Autochthonous Architecture and Non-Mechanical Cooling Approaches to Provide a Content Indoor Climate Without Reliable Gas Conditioning. This is particularly so because there is a constant decline in inspections in Iraq. Therefore, a detailed analysis of their contribution to a pleasant indoor environment and minimal energy use in the absence of electricity is warranted in the light of traditional aspects of regional Iraqi architecture, including the envelop garden, the midst wall for heat absorption and slow release, and the corridor for air circulation. These traditional methods are even more important because the use of mechanical cooling systems is an enormous difficulty due to constant shortages of electricity in Iraq. The need to take these approaches is becoming more intense as Iraq's climate challenges are. This calls for a rethinking of traditional building techniques for efficient building cooling in the context of unreliable access to electricity. Thus it is very important to use such traditional architectural elements in the modern urban development for a better indoor climate control, and less dependence on energy intensive systems.

1.1. The research problem

The motivation of this study is that there are no studies that compare the traditional and modern construction techniques in Samarra and Najaf, especially in terms of the possibility of using the passive cooling elements such as courtyards and thick walls in the modern constructions to improve the urban resilience against the climate migration and power outages. In this context of research gaps, this paper explores the environmental performance and socio-economic implications of the application of these design principles in modern urban construction in these particular sites. This study's treatment of these issues adds to the discourse on the contribution that traditional architectural knowledge could make to sustainable urban development, especially in the face of increasing environmental challenges and infrastructural vulnerabilities in similar arid regions.

1.2. Significance of research

The choreography is a critical point in the comparative analysis of Samarra and Najaf assembly techniques and shows how the use of traditional passive cooling features, including the inner court and the heavy walls of modern-day skyscrapers, can enhance indoor safety, lower energy use during a blackout, and enhance the urban adjustment to demographic change, which is brought about by climate in the arid regions of Iraq. The present research is vital to elaborate the urban planning strategies in shaping the group green balance and happiness through incorporation of climate flexibility and a proper energy management of the powerless locality.

1.3. Objectives of the research

The objectives are: - To analyze efficiency of heat control of traditional and modern buildings in Samarra and Najaf through computational modeling and measurements for natural cooling systems such as inner courtyards and massive walls at ground level. Observe how contemporary city planning integrates features of native legacy, like ventilation shafts and heat-absorbing substances, to improve interior comfort and lessen power demands in power failures. 3. To determine the socio-economic feasibility of these strategies for improving resilience of the above-mentioned Iraqi cities to climate induced displacements and extreme heat events. The aim of this study is to contribute to the development of policies for sustainable cities by demonstrating how the application of passive traditional cooling strategies can be integrated into the existing design of buildings to improve indoor temperatures and reduce energy consumption in desert-type cities.

2. Review of the literature

This section reviews major academic studies on urban resilience, sustainable architectural methods and climate-driven population shifts in arid areas, with particular emphasis on examples from the Middle East. The article examines the basic principles and practical uses of resilient urban design, underscoring its essential function in adapting to and alleviating environmental challenges in a variety of urban environments. In this section, we discuss practical research and conceptual models that highlight the importance of resilient urban design in mitigating the impacts of climate change and supporting sustainable urban development. It emphasizes the significance

of resilient urban design as a proactive strategy to address upcoming environmental challenges through the integration of theoretical models with practical solutions [1].

2.1. Urban resilience concept

Urban resilience is the capacity of city systems, including people, structures and organizations, to prepare for, absorb, adapt to and recover from shocks and pressures, particularly those connected with climate change. It is the capacity to tolerate shocks in the near term and the capacity to alter and adapt to continuing ecological change. Hence, a precise and practical description of this idea is required for practitioners in urban planning and policymakers to execute its key concepts with genuine success. This includes understanding the ways in which cities may recover from unexpected shocks and adapt over time to persistent environmental stresses.

2.2. Displacement environmental et management du territories

The spatial planning of today is often underpinned by data analytics and advanced modelling technologies to enhance the prediction and monitoring of urban vulnerabilities such as climate-driven migration, extreme weather events and resource scarcity. The integration allows urban planners to leverage big data to identify covert perilous zones and tailor interventions for improved operational efficiency and resource planning in urban settings [2]. Such a proactive strategy leads to adaptive methods that effectively address the immediate impacts of environmental displacement, while simultaneously driving sustainable urban development and inclusive growth [3]. These are crucial to the development of interventions that facilitate both “bouncing back” from disturbances and “bouncing forward” through adaptive transformations, based on the understanding of resilience from the ecological and evolutionary perspectives [4, 5].

2.3. Sustainable design for hot dry climates

Here we explore building and city planning strategies that are effective in desert conditions. This includes natural cooling techniques, intelligent water conservation strategies and cunning material choices that repel excess heat while minimizing energy requirements. Technological solutions such as cool roofs, permeable surfaces and urban greening initiatives are seen to reduce the urban heat island effect and promote thermal comfort under such conditions [6]. In dry climates such as in Iraq, the combination of the components with better urban morphologies such as street orientations, courtyards, and high albedo surfaces have been shown to reduce mean radiant temperatures by up to 10.5 ˚C over 90% of urban locations, while improving overall thermal comfort as compared to traditional urban forms [7].

2.4. Research gap

While there is a great advancement in urban resilience and sustainable design strategies for arid climates, the integrated application of these strategies to mitigate climate-induced migration and enhance adaptability in specific contexts in Iraq such as Samarra and Najaf is still not systematically tested. The current research is trying to fill this gap by looking into current design methods and their efficacy in making urban areas more resilient to climate-induced displacement in these specific hot and arid urban settings. This study contributes to our understanding of the convergence of historical and modern methods [8, 9]. The study evaluates the feasibility of employing green infrastructure components like green roofs and other vegetation-oriented strategies for urban heat island effect alleviation and thermal comfort improvement in Samarra and Najaf [10]. To appreciate the importance of this study, it is important to appreciate the limitations of the current research literature. There are many studies on the urban sustainability in general. A detailed review of the literature shows that there are several gaps in terms of the specific climatic and demographic challenges for Iraqi cities. Table 1 summarizes the geographic, transdisciplinary, and chronological research gaps and specific contributions made by this research to fill those gaps.

The main step towards developing the distinctive features of the thesis is to identify study inconsistencies. There’ll be a lot of prose on the climate crisis and city planning, although it’ll be separated in its own specificity to the Iraqi context.

- the Nexus gap, the most important space to detect the lack of synergies in terms of discipline. During my work as an interior designer at the top of the thermal relax and sociologists at Migration Drivers, there was a great educational peace about the obligation of Urban Design intervention as a mandatory Mitigation tactic to reduce the “Push elements” of climate migration. This study seeks to fill the gap by moving forward with a conceptual paradigm that explicitly associates construct setting performance with community sustainability.

Table 1. Justifications of the present study and gaps in the previous literature.

Gap Type	Description of the Existing Gap in Literature	Specific Contribution of Your Research
Geographic Specificity Gap	Most studies on climate migration focus on global or regional scales (MENA), with limited micro-scale analysis of Iraqi cities like Samarra and Najaf.	Provides a localized, high-resolution analysis of the climate-migration nexus specifically within the Iraqi urban context.
Interdisciplinary Linkage Gap	Existing literature often separates "Sustainable Urban Design" (Technical/Architecture) from "Climate Migration" (Social/Demographic).	Synthesizes these two fields, treating urban design as a proactive strategy for population retention and social resilience.
Policy & Implementation Gap	Previous research highlights climate problems but lacks practical, design-based policy frameworks aligned with contemporary Iraqi planning laws.	Proposes a set of applicable urban design guidelines and policy recommendations (Green Building Code) tailored for Iraqi municipalities.
Temporal Data Gap	Reliance on outdated climatic data or purely theoretical models without integrating recent GIS/Remote Sensing (2015–2026) indices.	Combines real-time satellite information (NDVI, UHI) and regular field surveys (300 households) to represent the reality in 2026.

- the Contextual Divide: a number of eco-friendly design notions are borrowed from the non-arid western context. The objective of the study is to bridge the Geographic Specificity interval by using localized resilience indexes to cope with the challenges of extreme heat and desertification in sectors such as Najaf and Samarra, creating an Iraqi Model of Toughness.

This analysis progresses from a descriptive analysis to a planned application in order to bridge such discrepancies, which provides a way for "buoyant Iraqi Cities" to deal with the challenges of the 21st century climate. Unlike global surveys that see the climate as complete, the study is Iraqi in the sense that it links the absence of data on plots (2015–2026) and urban design strategies as a foresight utensil in order to prevent the demographic collapse of desert cities.

3. Methodology

The study converts concepts of the resilience theory, socio-spatial trends, socio-technical transformations and complex systems analysis to practical urban planning instruments to formulate adaptive and dynamic abilities within cities that face intense environmental stresses. This study is based on the mixed-methodology, which incorporates both quantitative and quantitative analysis of the effects of urban heat islands and the management of water resources and qualitative assessments of community participation and governance systems in Samarra and Najaf cities. This analogy deals with the contribution of different actions, whether at the grassroots community projects or extensive government initiatives, into the resilience of the interconnected systems of social, environmental and technical infrastructure in these desert cities.

3.1. Spatial and quantity analysis

In order to perform a comparative analysis and quantify the intensity of urban heat islands and the impact of green infrastructure in mitigating thermal stress in the two cities with different urban morphologies, Landsat satellite images were processed using GIS to determine the land surface temperature, normalized difference vegetation index, and impervious surface area percentages for Samarra and Najaf [11–13].

3.2. NDVI (Normalized difference vegetation index) calculation

The index, which is a common technique for the estimation of plant number and vigor in urban settings, is calculated as the ratio of the reflectance of the red band to the reflectance of the near infrared band. Quantifying this is crucial for the distribution of nature-based solutions such as urban vegetation and their effectiveness in alleviating urban heat stress and improving overall urban resilience [14, 15]. The Normalized Difference Vegetation Index [16] makes it possible to undertake a detailed comparative analysis of the contribution of green infrastructure to thermal comfort in urban environments. In dry and semi-arid areas such as Najaf, it gives a direct measure of urban greenery's impact on the microclimate, particularly the reduction of the urban heat island effect [17].

An essential ecological indicator that may be utilized to gauge the resilience of urban environments in Najaf and Samarra is the mapping of the Normalized Difference Vegetation Index (NDVI) in Fig. 1. When the NDVI hits its lowest points, the graph shows how the amount of greenery around new urban settlements has decreased. The effect of the Urban Heat Island (UHI), which was previously identified in the LST mapping, is becoming worse due in large

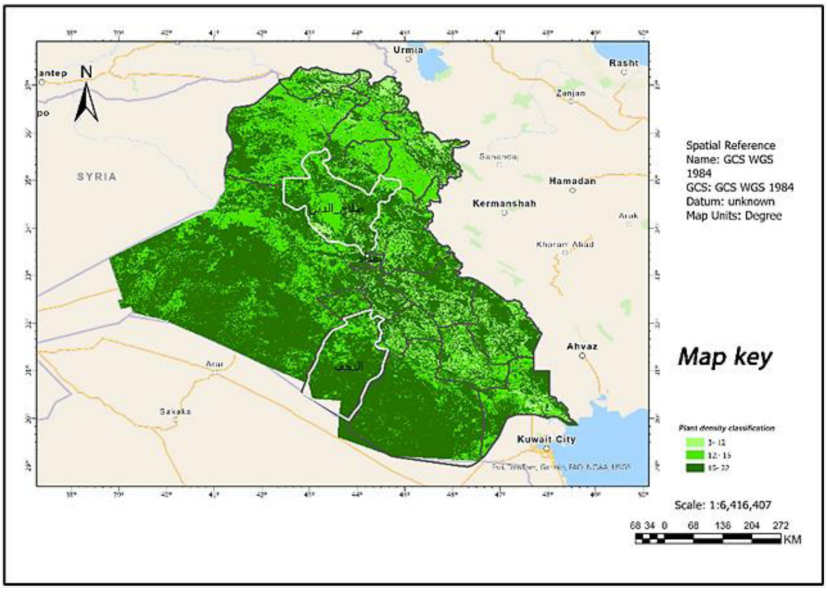

Fig. 1. NDVI vs loss of "Ecological Buffers".

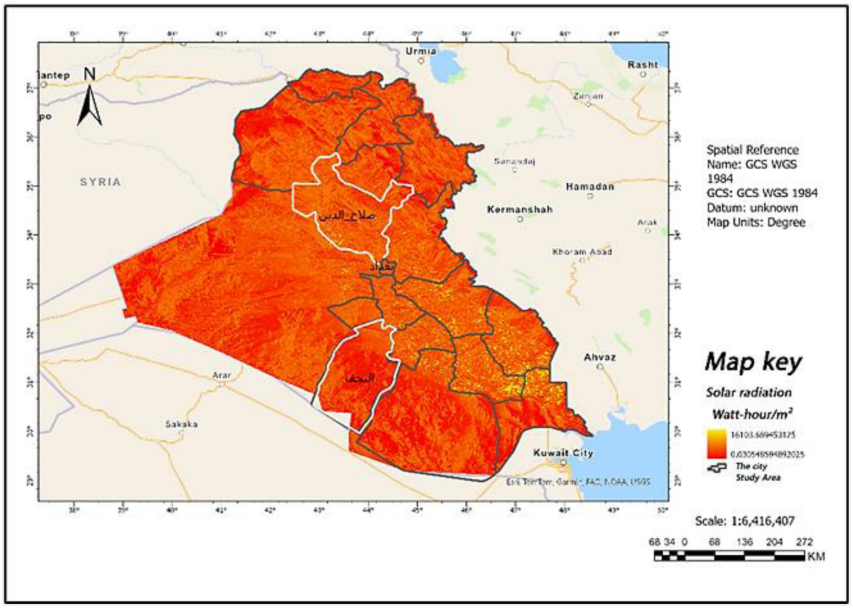

Fig. 2. Hotspots mapping of solar radiation and land surface temperature LST.

part to this loss of vegetation. From the data obtained it is possible to see that the transition of peri-urban agricultural fields and orchards into fragmented discontinuous built-up regions has eliminated the natural cooling impact of "Evapotranspiration" in these cities. The minimum NDVI values correlate to the maximum surface temperatures of the examined cities. This vegetation scarcity results in not only a greater temperature discomfort but also a decrease of the environmental "stay ability". Thus, the loss of vegetation is a quiet driver of climate-induced migration. The population do not have the biological insulation to deal with the increasing solar heat gain, due to the dry environment of Iraq.

3.3. Analysis of land surface temperature (LST)

This assessment measures the change in heat from the urban core to the rural edge by identifying vegetation cover, urban development and bare areas using Landsat 8 optical and thermal infrared data and converting the raw spectral radiance to the brightness temperatures observed by the sensor. The conversion technique uses the value of K1 and K2 of Landsat 8

OLI TIRS which is 774.89 W m^{-2} Sr μm and 1321.08 W m^{-2} Sr μm correspondingly [18]. This technique enables the full mapping of the urban thermal environment and therefore the detection of specific areas of high heat stress and the assessment of the proposed solutions [19]. The granular temperature data concerning land cover classifications offers a critical basis for assessing the performance of urban green infrastructure in managing surface temperatures and guiding spatially targeted interventions [20].

The map is a graphic illustration of extreme hyper arid on the urban centres in central and southern Iraq. The so called Hotspots are Deep Thermal Repulsion Points. These area-wide LST increases are an important environmental source of climatic migration, and have immediate repercussions of human thermal ease and urban habitation. This highlights that extreme exposure to heat and cooling necessitate robust microclimatic strategies, and that sustainable urbanism is needed.

3.4. Qualitative/descriptive analysis

This component will include a detailed review of urban planning reports, policy guidelines and community programs in Samarra and Najaf, semi-structured interviews with urban planners, local leaders and citizens to explore the subtleties of resilience and adaptive capacities. The qualitative data will be important to provide a contextual interpretation of the quantitative outcomes, to reveal the socio-political and cultural processes shaping the application and the success of the sustainable urban design strategies. Local knowledge and stakeholder perceptions will also be used to provide further insights on practical challenges and opportunities of implementing resilient urban interventions and this will improve the relevance and applicability of findings in the research.

4. Area of case study: Samarra and Najaf (Study area)

Both Iraqi cities lie in different but similar climatic zones, which are dry and semi-arid. They face similar environmental challenges and different urban development paths, which make them good case studies to assess urban resilience strategies. There are many historical fabrics in the city of Samarra and a research can be done on the effect of vernacular architecture and traditional urban fabric on thermal resistance. The city of Najaf with the rapidly expanding religious center is an illustration of the problems of modern urbanization and prospects of the nature-based approach to reduce thermal stress [21, 22]. Thus, the comparison between the cities will provide valuable information about the applicability of the alternative urban design strategies in the arid areas, in the encouragement of thermal comfort and resistance to the effects of climate change. The comparison with each other allows to highlight good practices and to create concrete adaptation strategies adapted to the social, cultural and ecological specificities of Samarra and Najaf.

The research is mainly focused on two Iraqi cities as shown in Fig. 3. The choice of these two cities is

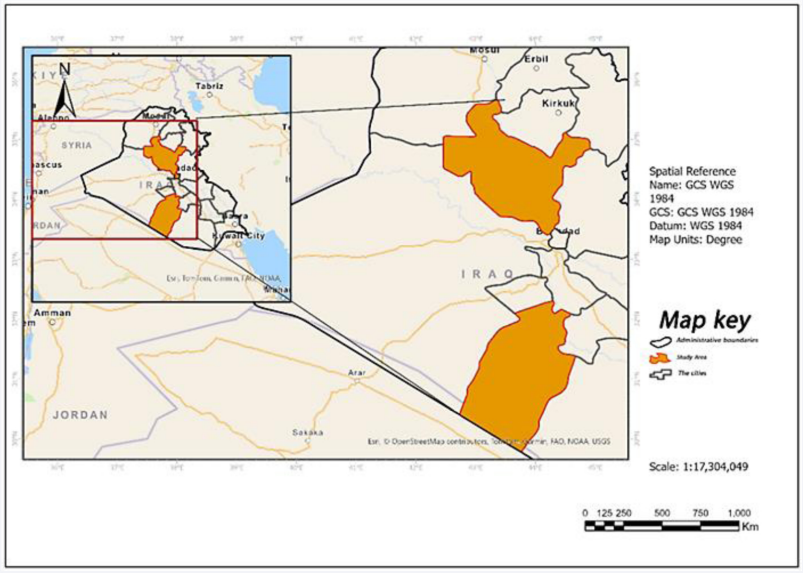

Fig. 3. Map of Iraqi cities indicating study cities (Najaf and Salah al-Din).

Table 2. Comparative environmental and planning indicators between the two case studies.

Indicator	Najaf City	Samarra City
Urban Fabric Pattern	A mix of traditional organic fabric and modern gridiron settlements.	A rich historical fabric characterized by traditional urban layouts.
Vegetation Cover (NDVI)	Critical deficit; constitutes less than **4.3%** of the urban area.	Relatively better performance due to its location on the Tigris River.
Climate Stress Index	Higher severity due to proximity to the Western Desert (Al-Badiya).	Extremely severe (Average 4.68/5), but slightly lower than Najaf.
Thermal Mitigation Capacity	Limited; narrow canyons and sprawl exacerbate heat island effects.	Higher; varied street orientations promote better nocturnal cooling.
Hydrological Resilience	Vulnerable; located in a hyper-arid desert environment.	More resilient; benefits from a hydrological margin via the Tigris River.
Urban Resilience Score	Very Weak (recorded lower scores in most indicators).	Very Weak (but outperforms Najaf by 0.3 to 0.6 points).

due to their similarities and differences in terms of environmental and urban conditions and to assess the role of urban design in the phenomenon of climate migration in terms of thermal stress and its effects on the stability of the population.

- **Najaf City:** A representative example of the hyper-arid regions where there are two urban fabrics, which consist of both an organic traditional town and new gridiron settlements. Such a selection allows comparison between two types of urban design (compact and sprawling).
- **Salah al-Din (Samarra/Tikrit):** Representative examples of the central-northern arid region. These regions have witnessed significant changes in both their population and urban structures and thus studying them provides some insight into the effect of regional climatic variations in Iraq and sustainable urban designs.

Boundaries of these two regions were identified using GIS systems. Selected geographical coordinates make sure that research is conducted in different areas regarding urbanization and the level of vegetation (NDVI). The latter are important elements in establishing the thermal repulsion points and their effect on displacement of people. To provide a comprehensive overview of the environmental and spatial disparities between the two cities, Table 2 presents a comparative analysis of the key indicators derived from the remote sensing data and urban fabric assessment.

4.1. Regional and climatic characteristics

Both Samarra and Najaf cities are located in the arid zones of Iraq which have very hot and dry summers and cooler winters with occasional rain. The urban areas are hotter and the people living there are more thermally uncomfortable because the summer temperature is often above 40 degrees Celsius. Besides extensive areas of impervious surfaces, the absence of sufficient green infrastructure in these cities aggravates the urban heat island effect, thereby raising the burden on local ecosystems and human populations [22, 23]. In this tough climate scenario, there is a need for an immediate study of sustainable design strategies to enhance environmental quality and to reduce the adverse effects of extreme temperature on urban residents [24].

Fig. 4 Quantitative comparison of the severity of climate change indicators of the cities of Samarra and Najaf on the 5-point scale. The statistical result gives a clue on the significant localized environmental stresses influencing climatic migration in hot-arid areas.

- Climate Stress Overall: Each indicator is rated on a 1–5 scale, 5 being the most severe, and the average of all indicators is 4.68, meaning the climate impact is “extremely severe” based on our scale of measurement. This implies that the populations of the two cities are now exposed to environmental conditions that are effectively beyond the natural human adaptive capacities, as a key structural driver of climate-induced displacement.
- Relative Vulnerability (Najaf vs. Samarra) The longitudinal analysis of the chart reveals a consistent trend of higher mean scores for Najaf relative to Samarra across all seven indicators. This persistent statistical difference is an empirical confirmation of the hypothesis of the reality of the climate in Najaf, which is more acute, and this is mainly due to the geographic proximity of the western desert (Al-Badiya), which aggravates the local effects of heat and drought.

4.2. Characteristics of population and urban

Najaf is one of the world’s premier Shia pilgrimage centers, with millions of pilgrims arriving each year. The rapid growth of the city’s population has

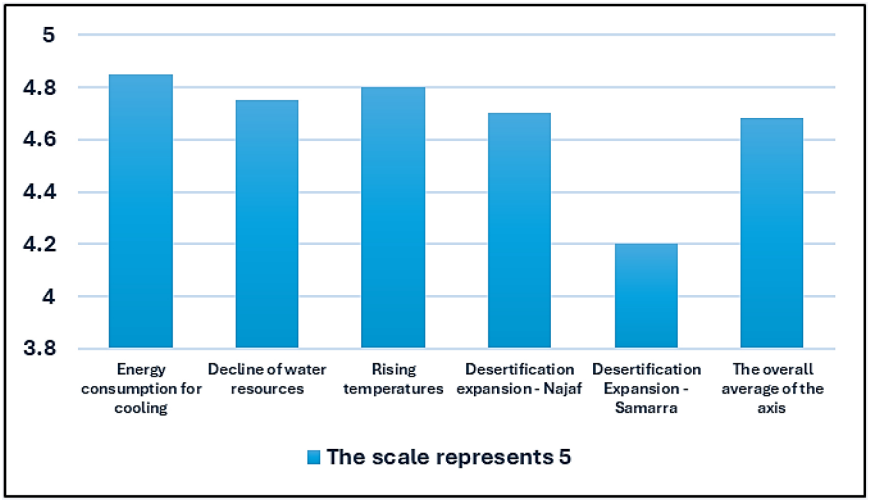

Fig. 4. Mean values of the magnitude of climate change (scale 5).

contributed to uncoordinated urban expansion, placing strain on its infrastructure and increasing its susceptibility to heat stress. Samarra boasts a more stable population based on its long-standing historical and cultural heritage. Despite their diverging demographic trajectories, both cities face significant environmental challenges such as water scarcity, desertification and the need for responsive architectural solutions to extreme heat [25]. In this regard, the building typologies in Old Al-Najaf are an example of traditional reactions to the harsh climate in the form of dense interwoven urban fabrics, solid masses with few openings to the outside, and basements to decrease heat transfer and increase humidity [26].

5. Discussion and results

This section presents the results of the comparative analysis of the two cities of Samarra and Najaf in terms of the effectiveness of various sustainable design strategies in reducing the thermal discomfort and increasing the urban resilience. The study examined the local climate variations around streets and buildings, and the effect of the cities' layout and the change of the building material on heat accumulation in the urban environment and outdoor comfort level in each city. This paper explores the impact of city design, street enclosure ratios and the location of plazas or parks on the weather conditions of the surrounding areas such as ambient heat levels, the flow of breezes and the comfort level of residents outdoors. Analysis indicated that Samarra's multidirectional street network generated lower temperatures than the narrow and treeless deep streets in parts of Najaf, where the limited space and slow cooling overnight trapped heat.

5.1. Environmental indicator comparison

Data on air temperature, surface temperature and humidity in the two cities gave concrete evidence of these regional climate changes and showed how certain urban planning measures can alleviate the urban heat island effect. More specifically, while the narrow and barren gorges of Najaf enhanced the heat accumulation over the entire city, the street orientations of Samarra had a much lower average radiant heat and cooled down much stronger during night. Results reveal that districts with roadways in all directions have significantly cooler air temperatures than narrow, desolate gorges that trap heat and prevent cooling at night. This helps to reduce the urban heat island effect typical in arid areas.

5.2. Assessment of urban resilience

Examples of sustainable design techniques that have been shown to improve urban microclimates include higher canyon ratios and North-South Street orientations, which can reduce the Universal Thermal Climate Index by up to 5 °C and improve the overall thermal comfort of hot, arid regions [27]. Additionally, in urban canyons with an aspect ratio (H/W) of 0.5, a uniform albedo of 0.2 is ideal for reducing thermal stress; however, with H/W = 1, an albedo gradient from high at the bottom to low at the top of vertical walls is ideal [28]. The results highlight the role of urban design and material choice in creating the urban microclimate and show that

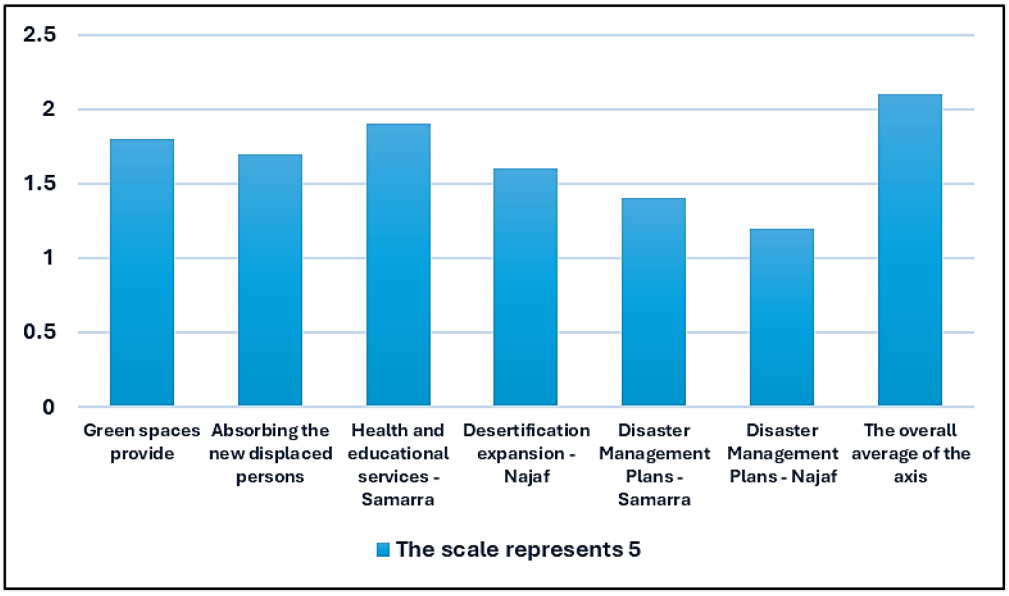

Fig. 5. The arithmetic averages of the cities' response capabilities (scale of 5) are shown.

significant reductions in heat stress may be attained in desert cities by carefully altering the surface albedo and street canyon geometry. There are more ways to enhance local climates besides material and design. It is possible to install parks and appropriate vegetation. These plants may give shade and release more moisture from their leaves. Shade may make people feel more at ease while they are outside by cooling the surrounding air.

The empirical data shows that there is an alarming deficit in the "Urban Resilience" in both research sites with an overall mean score of 2.1 out of 5. According to the scale of interpretation in the study, this value is in the "Very Weak" resilience group. This result suggests that the urban environments of Samarra and Najaf are structurally vulnerable and do not have the adaptive mechanisms to mitigate the negative impacts of climate change-induced pressures.

- Infrastructure and Essential Services: In Samarra, the "Availability of health and educational services" was only 1.9, and in Najaf, 1.6. This indicates a systemic infrastructure problem that leaves the population vulnerable as the current services are not enough to meet current requirements let alone future expectations.
- Inward Migration capacity: The indicator with the most concerning outcome was the one of the City to absorb new displaced persons and the average overall score was the lowest (1.7). That is, these communities can no longer be a safe haven, as there is a high likelihood that with another increase in population, there will be a total disintegration of public services.
- Green Infrastructure and Climate Buffers: The average score for "Green space availability" was 1.8, consistent with the NDVI satellite data indicating that the plant cover in Najaf is less than 4.3% of the city. This shortfall removes the natural thermal buffers needed for climate adaptation in urban areas.

Najaf and Samarra exhibited a high level of "thermal dissonance" which was directly correlated with a low urban resilience index (2.1/5). This disparity in the built environment renders residential communities as sites of environmental repulsion, as inhabitants are forced to move in search of more sustainable alternatives, because of the loss of biological insulation caused by the deterioration of the NDVI cover.

5.3. Talking about design approaches

Studies show that characteristics of urban canyons, such as height-to-width ratios, have a significant impact on external weather patterns and pedestrian comfort since higher buildings and skinnier roads reduce sunlight penetration and reduce overheating pressures. In contrast, careful adjustments to these proportions via thoughtful urban planning can promote cooler city conditions, especially overnight, by promoting better heat dissipation after sunset and curbing daytime solar absorption. Therefore, the urban heat island effect may be reduced by well-designed urban canyons with suitable aspect ratios and orientations, resulting in more pleasant and energy-efficient urban settings [29, 30].

6. Suggestions for improving Iraq's urban resilience

This research makes a specific set of suggestions based on the empirical results and the comparison of Samarra and Najaf. These are intended as vital "survival tools" to improve the built environment's habitability and lessen the push factors of relocation brought on by climate change, rather than only as aesthetic enhancements.

6.1. Law reform: Development of an Arid zone "Green Building Code"

Iraqi planning authorities such as local municipalities and the Ministry of Construction and Housing need to go beyond conventional zoning and develop a specific "Green Building Code". This new code must require, unlike existing standards which only cover plot ratios and setbacks:

- Thermal Performance Standards – Maximum Window-to-Wall Ratio (WWR) to minimize solar heat gain.
- Self-Shading Requirements: To encourage urban designs that use building mass to shade adjacent buildings and public walkways. When embedded in institutions, urban resilience becomes a legal requirement for all new projects.

6.2. Material engineering: Use of high Albedo surfaces for mitigating urban heat islands (UHI)

The LST mapping of the study found that traditional dark-colored materials such as asphalt act as "thermal reservoirs" and intensify the UHI effect. To lessen this:

- Use of reflective surfaces: Replace traditional pavement with cool pavement technologies or light-colored local materials (e.g., treated limestone) with a solar reflectance (Albedo) of at least 0.2.
- Impact: The change prevents the city's surfaces from absorbing 90% of solar radiation, reducing the ambient temperature at pedestrian level and preventing the "nocturnal heating" that makes urban canyons intolerable at night.

6.3. Reenergized passive design

High Thermal Mass and Courtyards To combat the vulnerability of ongoing energy shortages in Iraq, traditional "passive survival" elements need to be brought back into modern home architecture:

- The Internal Courtyard (Al-Hosh): It produces a thermally stable microclimate without the need for artificial cooling. It also helps in natural vertical ventilation at night by acting as a "cold air sink".
- Thermal Mass: The structure might act as a thermal buffer, accumulating heat throughout the day and slowly releasing it at night, through the use of thick walls built with materials of high thermal capacity.
- Strategic Resilience: The architectural interventions ensure that the house is able to be occupied even if power is not available by eliminating the underlying 'push factors' that make the residents move to safer areas.

7. Conclusion

The findings of this research underscore a critical reality: addressing climate-induced displacement in Iraqi cities, specifically Samarra and Najaf, necessitates a fundamental paradigm shift in urban design. We must transition from "passive urban forms" to "active resilient models." Through the integrated use of remote sensing technologies—specifically the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST)—this study has quantitatively demonstrated a significant resilience deficit in both cities. The calculated resilience index reached a critical low of 2.1 out of 5, characterizing these urban environments as "thermal expulsion zones" that inadvertently force inhabitants toward migration in search of more livable conditions. Key Analytical Insights:

- The Superiority of Vernacular Morphologies: A comparative analysis reveals that the traditional urban fabric of Samarra, with its multi-directional street orientations, facilitates superior nocturnal cooling and thermal comfort. This stands in stark contrast to modern expansions in Najaf, where deep, unshaded street canyons lead to severe heat entrapment.
- Vegetation as a Survival Determinant: The data identifies a direct correlation between the depletion of green cover (where NDVI falls below 4.3%) and the intensification of surface temperatures. This confirms that the loss of "environmental buffers" is a primary, yet silent, driver of climate displacement in these arid regions.
- Infrastructural Limits: The study highlights that the carrying capacity of these cities to absorb new displaced populations has plummeted to 1.7 out of 5, signaling a potential collapse of public

services if current planning trends continue without strategic intervention.

To mitigate these risks, the study advocates for the immediate adoption of a "Green Building Code" specifically tailored for arid climates. This code should mandate strict standards for thermal performance and Window-to-Wall Ratios (WWR) to minimize solar heat gain. Furthermore, there is an urgent need to revive "passive survival" elements, such as internal courtyards and high thermal mass construction, to ensure habitability during power instabilities. Ultimately, integrating these technical design solutions with robust legislative reforms is the only viable pathway to transforming Iraqi cities into resilient urban sanctuaries capable of withstanding the environmental challenges of the 21st century.

Funding

The authors acknowledge that this research work is part of the Master's degree requirements for the first author at the University of Samarra, College of Engineering. The authors received no financial support or research grants from any governmental, commercial, or non-profit sectors for the conduct of this study. All costs associated with data acquisition and digital analysis were self-funded by the authors.

Competing interests

Conflict of interest The authors declare there are no conflicts of interest regarding the publication of this manuscript. The research was conducted for academic purposes and the results are the result of an objective scientific analysis without any external influence.

Ethics approval

This study was performed in accordance with the ethical guidelines of the University of Samarra. The research design and data collection procedures were reviewed and approved by the Ethics Committee of the College of Engineering. All satellite data and urban maps used in the analysis were obtained through official academic channels and are used for research purposes only.

Acknowledgments

The author would like to thank the Dean of the College of Engineering, University of Samarra, for providing the required support and facilities to carry out this research. Special thanks are extended to Assistant Professor Dr. Khalid Hammood Al-Mudhahe for his invaluable guidance, insightful comments and continuous academic support in the development of conceptual framework of this study. The author would like to acknowledge the faculty and colleagues of the Department of Architectural Engineering for their technical advice and professional contribution during the field and analytical phases of the research. Finally, I would like to thank my family for their moral support and the organizations that provided access to the satellite data and urban blue prints of Samarra and Najaf which were important for the empirical results of this study.

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