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Rethinking Urban Resilience in Iraq: The Impact of Sustainable Urban Design on Mitigating Climate Change-Induced Displacement

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ABSTRACT

So far, Iraqi research on urban planning has offered little empirical treatment of the relationship between the quality of sustainable urban design and residents' decisions to migrate under climatic stress. Local studies on internal migration have focused on economic and security drivers. While reports on displacement illustrate the size of mass migrations, they do not examine urban design determinants. This gap is the research problem of the present study. The study hypothesizes that deficiencies in sustainable urban design features–principally the absence of green cover, shading, and natural ventilation–are a decisive, quantifiable driver of climate-induced displacement in Iraqi cities, independent of the primacy conventionally given to economic migration determinants. To test this hypothesis, the study adopts a descriptive-analytical, mixed-methods design integrating GIS-based spatial analysis of multi-temporal satellite imagery (2003–2024), a household survey (n = 450; 150 households in each of Baghdad, Samarra, and Najaf), and interviews with local planning officials and experts. The analysis demonstrates that, statistically significantly, deficient design features are associated with migration intentions of residents. The urban-design variables account for the greatest share of variance in decision-making regarding displacement across the three cities, excluding income and housing-tenure status. The study calls for a Green Building Code to be a prerequisite for construction, to ensure at least a minimal greening with each new building and a National Sustainable Urban Planning Authority to strengthen the climate resilience of cities and curb climate-related displacement.

Keywords: Climate-induced migration, Environmental displacement, Sustainable urban design, Urban Heat Island (UHI), Urban resilience.

1. INTRODUCTION

Today's cities – especially those located in extreme climatic conditions face a substantial challenge in climate change. In recent decades, Iraq located in hot-arid climate zone has

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changed remarkably in terms of the environment registering record heat, Water shortages, and prolonged droughts **(Ministry of Environment Iraq, 2021).** As such, there has been large-scale internal migration, with thousands of families moving out of rural and peri-urban areas for better living conditions. Iraq was ranked the fifth most vulnerable country in the world by the United Nations to climate collapse **(IOM, 2022).**
Urban design is a critical intervention point in this crisis: it can either exacerbate or reduce climate-driven displacement. Conventional planning approaches — characterized by minimal vegetation cover, poor thermal control, inadequate shading, and reliance on energy-intensive mechanical cooling — have unintentionally intensified the effects of rising temperatures. Sustainable urban design, by contrast, combines bio-climatic principles, green infrastructure, passive cooling techniques, and climate-sensitive morphology **(Erell et al., 2011).** This study examines the interplay between sustainable urban design and climate-related migration in Iraqi cities and how design responses can convert urban environments from sources of displacement into climate-resilient settings.
Despite this documented human and economic toll, local Iraqi literature on internal migration has largely emphasized economic and security determinants **(Al-Jabouri, 2020),** while national displacement reporting — including the Displacement Tracking Matrix **(IOM, 2022)** and the reports of the Ministry of Migration and Displaced (2022) — documents the scale of climate-related displacement without examining its urban design determinants. This absence of local, design-focused empirical research constitutes the central research problem addressed by this study: the lack of Iraqi studies that quantitatively relate residents' displacement decisions to the quality of sustainable urban design. Building on this problem, the study advances the following hypothesis: deficiencies in sustainable urban design are a decisive, quantifiable driver of climate-induced displacement in Iraqi cities.
Accordingly, the study pursues three objectives: (1) to measure the strength of the statistical association between urban-design variables and residents' migration intentions in three climatically stressed Iraqi cities; (2) to identify the specific design deficiencies most strongly associated with the desire to migrate; and (3) to translate these findings into actionable legislative and design recommendations for Iraqi urban planning policy.

2. CLIMATE CONTEXT OF IRAQI CITIES

2.1 Hyper-Arid Climate Characteristics

Iraq has an arid and hyper-arid climate with features that highly affect urban settlements in the country. In the summer, the temperature often exceeds 45 °C, reaching up to 52 °C in southern governorates like Basra and Maysan **(Al-Asadi et al., 2019).** Central and southern governorates have annual precipitation that is less than 200 mm. This precipitation is highly variable in time and space **(Al-Ansari, 2013).** Many regions of the world face chronic water deficits due to excessive reference evapotranspiration relative to precipitation in the order of 10–15 **(Allen et al., 1998).** The intensification of heat islands in cities and highwater sources makes it a necessity to design the city in a climate-responsive way to ensure livability in the city.

2.2 Urban Climate Challenges

The livability of cities in Iraq is impacted by a range of linked climate challenges. The Urban Heat Island Effect (UHI) has an intensity of 5-8°C, which refers to cities that absorb and re-radiate solar energy at the rate of **(Oke, 1982).** Measurements taken on the field in Baghdad, Samarra, and Najaf indicated UHI intensities of 14.3°C; 12.6°C and 16.8°C respectively in summer peak use **(Al-Azzawi, 2022).** According to **(Al-Janabi et al., 2019),** withdrawal of groundwater and diversion of rivers have lowered water availability in the region by 30% to 40% from historical levels. Cooling energy consumption has also increased. In summer, residential and commercial buildings consume 60–70% of the electrical load **(Ali and Mustafa, 2015).** This situation has placed pressure on the power system, causing chronic outages. The public health impact is sizeable. Heat-related illness in Basra rose by 34% between 2019 and 2022 **(Iraqi Ministry of Health, 2023).** Various systemic barriers to urban resilience in Iraq stem from continuous budget deficits and degradation of infrastructure; political instability and inability to resolve the consequences of historic conflict-induced displacement; contested regional water politics governing the Tigris and Euphrates; and lack of a unified city-planning framework across provinces.

3. SUSTAINABLE URBAN DESIGN PRINCIPLES FOR HYPER-ARID REGIONS

3.1 Compact and Mixed-Use Development

Compact urban forms overall can shrink travel lengths, protect surrounding landscapes, and use less energy per head through sharing of walls and lowering exposure on climatic loads **(Jabareen, 2006).** The underlying principle of making the city easier to navigate can be illustrated by conventional Middle Eastern cities with their densely built urban fabric, narrow streets of neighbourhoods, common walls and negligible setbacks of buildings. Contemporary developments should adequately balance density with sufficient provision for open space, vegetation and ventilation corridors. Compact developments, if well-designed, may reduce urban heat build-up by 40–50 % compared to low-density sprawling development. This is because they benefit from mutual shading, a reduced surface-to-volume ratio, and the preservation of permeable surfaces **(Johansson, 2006).**

3.2 Climate-Responsive Morphology

The microclimate and thermal comfort are greatly affected by the physical structure of the street, block and building. An east-west street orientation minimizes sunlight exposure during peak sunshine hours **(Ali-Toudert and Meyer, 2006).** Research in similar dry regions concluded that a height-to-width (H/W) ratio of between 1.6 and 2.5 is optimal for shading while providing reasonable nighttime cooling through longwave radiative exchange **(Givoni, 1998).** The old urban fabric of Samarra and old Baghdad – narrow winding streets and dense two- to three-storey buildings providing continuous shade and protection from winds – shaped a microclimate. The courtyard typologies provide a mixture of privacy, daylighting and stack effect ventilation. Similarly, these can also be taken as a design model for modern new climate-conscious design.

3.3 Passive Cooling Strategies

Passive cooling techniques utilize natural processes to maintain thermal comfort without using heating or cooling systems. Solar radiation impinging on building facades can be obstructed by using external louvers, overhangs, mashrabiya screens, and pergolas **(Sherif et al., 2014).** The dimensioning of these is calibrated to the local solar geometry and latitude. The shaded surfaces of traditional Iraqi courtyard design are remarkably 8–12°C cooler than the open areas. This design offers stack-effect ventilation and evaporative cooling from a fountain, pool, or planting **(Reynolds, 2002).** Wind catchers can be updated with modern materials and computer simulations and be offered suitable characteristics **(Bahadori and Dehghani-Sanij, 2014)**. As a whole, these systems can reduce cooling-energy demand by 35-50 % while maintaining thermal comfort.

3.4 Green Infrastructure and Urban Ecology

Trees, shrubs, and other vegetation provide essential services to adapt to climate change. It makes the surface cooler due to shading. Besides, it absorbs 70- 90% of the solar radiation that is incident upon it. Evapotranspiration changes sensible heat into latent heat **(Bowler et al., 2010).** Careful planting of street trees can reduce surface temperature by 10–15°C and canopy air temperature by 2–4°C. Vegetation helps prevent the suspension of dust, which causes serious problems due to increasing numbers of dust storms in Iraq **(Goudie 2009).** Species selection for urban landscaping must consider their relative drought resistance which will favour indigenous and adapted plants over exotic ornamental species which require more water **(Givoni, 1998).** As far as possible, date palm, eucalyptus, tamarisk, shrub native and cluster species are preferred.

3.5 Water-Sensitive Urban Design

Water shortage situation calls for an all-in approach, i.e. a water-sensitive urban design (WSUD) approach. Rainwater harvesting could provide about 30–40 % of landscape irrigation and other non-potable water needs, thus relieving stress on municipal supply **(Pacey and Cullis, 1986).** When designed correctly, greywater recycling could offset 40–50 % of total water demand **(Abdulla and Al-Shareef, 2009).** Permeable surfaces and xeriscaping lead to reduced runoff and enhanced recharge, while outdoor water use is cut down by half or more without degrading landscape function **(Golany, 1996).** Small-scale water features can lower the air temperature by 1–2 degrees Celsius within 5 meters by evaporative cooling. This was also traditionally used in mosques and caravanserais- in Iraq-courtyards. This shows the precedent of these types of applications **(Reynolds, 2002)**. Closed-loop systems, grey water reuse and seasonal operation minimize water losses and utilise water in a way that maintains social and psychological benefits.

4. METHODOLOGY

4.1 Research Design

This study employs descriptive-analytical mixed-methods design, utilizing quantitative spatial analysis along with qualitative fieldwork. This approach is deemed appropriate for the description of the phenomenon and the analysis of the components and relationships among them **(Obeidat et al., 2016; Al-Rashidi, 2018).** The design incorporates GIS-based spatial analysis of settlement densities with econometric/statistical analysis of household-survey data to determine the link between settlement design/location and climate actions.

4.2 Case Study Areas

Three Iraqi cities were selected as case-study areas — Baghdad, Samarra, and Najaf — based on five criteria: (1) geographic and climatic diversity, spanning central, transitional, and southwestern desert-adjacent regions; (2) disparities in urban development, from the capital's rapid growth to Samarra's heritage character and Najaf's religious-tourism-driven expansion; (3) the severity of climate challenges, including record temperatures exceeding

52°C; (4) documented cases of climate-related displacement reported by the Ministry of Migration and Displaced (2022); and (5) the availability of climate, demographic, and urban data and safe field access.

The research is primarily centered on three Iraqi cities as represented in **Fig. 1**. The selection of these three cities is based on their similarities and dissimilarities with respect to environmental and urban conditions and to assess the impact of urban design on the phenomenon of climate migration in relation to thermal stress and its effects on population stability.

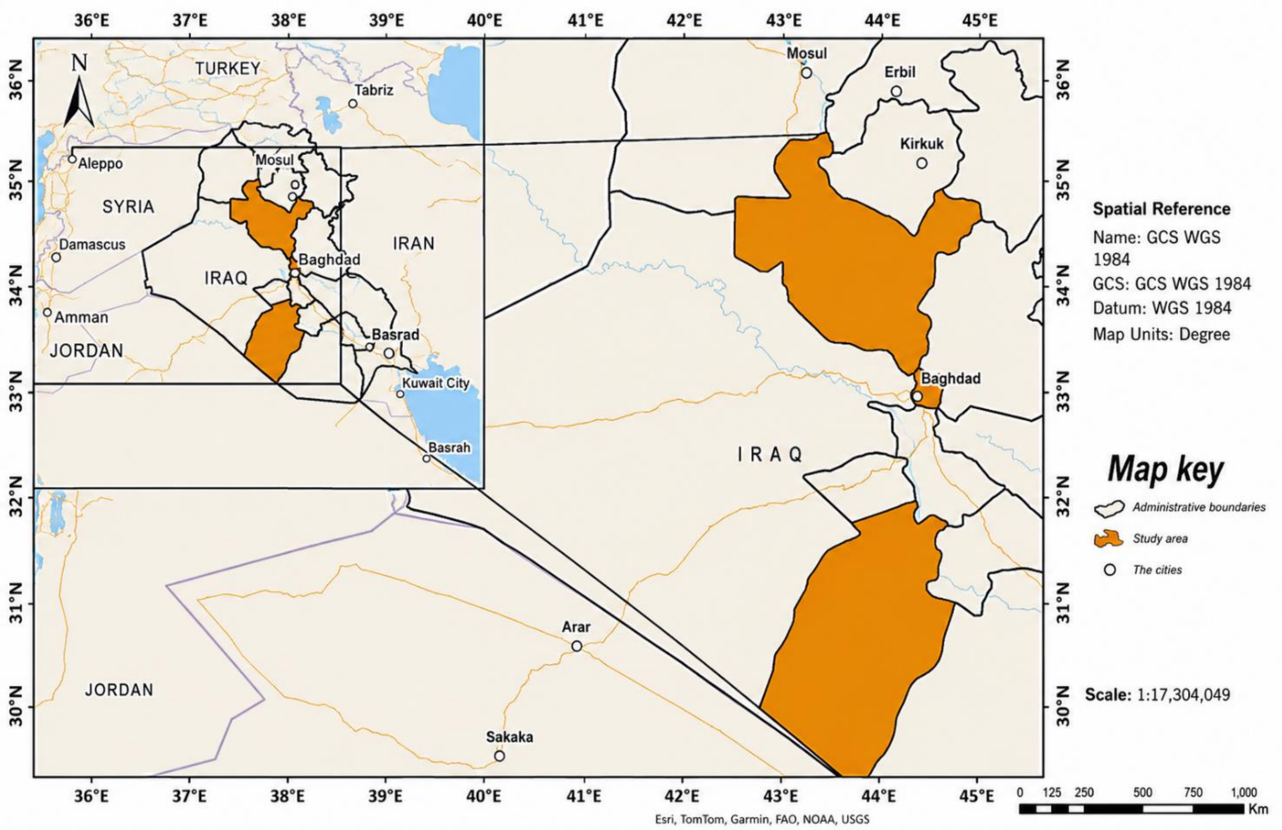

Figure 1. Location of the study cities (Baghdad, Samarra, and Najaf) in the map of Iraqi cities.

4.3 Data Collection Tools

The data collection was done using five tools. First, high-resolution multi-temporal satellite imagery (Landsat 8 and Sentinel-2, 2015–2024) was obtained from the USGS Earth Explorer database to track changes in vegetation cover, urban expansion, and surface temperature **(Jensen, 2015).** Second, ArcGIS Pro 3.0 was used to process spatial data and produce thematic maps of population density, solar radiation and urban heat islands, vegetation cover (NDVI), and land-use change **(Longley et al., 2015).** Third, SketchUp Pro 2023 with V-Ray was used to build three-dimensional before/after models of selected urban areas to visualize the potential impact of proposed design interventions **(Seipel, 2013).** Fourth, a structured household questionnaire was administered to 450 households (150 per city), using stratified random sampling to capture residents' perceptions of climatic challenges, thermal comfort, and migration intentions; this was complemented by semi-structured interviews with 24 officials from municipal planning departments and local experts in urban design and environmental management **(Creswell, 2014).** Fifth, climate records (temperature, precipitation, wind, and humidity, 2000–2023) were obtained from the Iraqi General Authority for Meteorology, and demographic data from the Central Statistical Organization **(Ministry of Planning, 2021).**

4.4 Data Analysis

Thermal-stress hotspots and vulnerable populations were detected using GIS layers. Analyses of the survey responses using correlation and regression were applied to indicate which design deficiencies were most affected by migration intentions while controlling for income and housing tenure. The ENVI-met microclimate simulation programme manages Scenario modelling to measure thermal impact from the proposed design interventions **(Al-Samarrai, 2022).**

5. RESULTS AND DISCUSSION

5.1 Urban Microclimates, Thermal Stress, and Morphological Performance

The thermal remote sensing analysis across Baghdad, Samarra, and Najaf demonstrates a direct, spatially explicit relationship between land-surface temperatures and urban morphological features. Urban Areas with more tree cover and developed spaces featuring reflective materials frequently posted cooler surface temperatures than those associated with all other forms of development. The historical core of Baghdad, which is high-density traditional courtyard typologies and narrow shaded alleys, was shown to achieve peak daytime surface temperatures of 48 ◦C. In contrast, contemporary developments facing the periphery were calculated as high as 62 ◦C with wide paved rights-of-way and little street-level shading. The utmost heat penalty occurred in an informal settlement created after 2003. These locations utilize unshaded asphalt with dark roofing materials that push peak afternoon surface temperatures over 70 °C.

All three case studies confirmed substantial Urban Heat Island (UHI) intensities based on field measurements, with the level measuring 14.3°C in Baghdad, 12.7°C in Samarra (focused mainly on its eastern industrial area), and 16.8 °C in Najaf **(Al-Azzawi, 2022).** Najaf's high intensity of UHI aligns with 53.4 °C in August 2023, the highest ambient temperature reading. In these three cities, thermal stress peaked between 6:00 PM and 9:00 PM when heavy concrete and asphalt structures re-radiated heat, which was absorbed during the day, back into the street canyons as people moved outdoors for relief at that time **(Oke, 1982).** The spatial clustering analysis determined that informal settlements, unshaded industrial parks, and main asphalting areas are the most vulnerable thermal risk spots. Historic courtyard districts, planned residential suburbs with conserved gardens, and vegetated institutional campuses exhibited the most microclimatic resilience.

Outdoor microclimatic performance was influenced by street networks' physical geometry as well. Based on the simulated data, north-south street canyons that possess height-to-width (H/W) ratios in a range of 1.5 to 2.0, produced shading levels above 60% during peak solar radiation hours, representing daytime conditions. As such, mean radiant temperatures in the north-south canyons were reduced by 15" 20◦C as compared to unshaded east-west (E-W) corridors. The core of the historic urban environment of Samarra, with its narrow (3.5-5 m wide) winding streets, still enjoys this thermal benefit due to self-shading, despite being 1,200 years old. Modern grid layouts with wide (20– 30 m) street canyons result in near 100% absence of daytime shading, leading to a full dependency on private vehicular transport and continuous mechanical air conditioning **(Ali-Toudert and Mayer, 2006; Erell et al., 2011)**. The inadequacy of street trees adds to the problem of micro-climatic degradation; field counts indicated that Baghdad had an average of 12 trees/km, Samarra 18 trees/km and Najaf 9 trees/km. They are far below the recommended threshold, 40-50 trees/km, for hyper-arid city **(UN-Habitat, 2022).**

5.2 Green Infrastructure Dynamics and Water-Sensitive Interventions

Analysis of multi-temporal satellite images from 2003 to 2023 shows systemic collapse of urban green space in all three study areas as in **Table 1.** Baghdad saw a 51.2% drop in green cover (12.7% to 6.2%) from 2000 to 2020, while Samarra and Najaf dropped 49.0% (15.3% to 7.8%) and 63.6% (11.8% to 4.3%), respectively. Importantly, this cutback in area was not because vegetation died off passively. Instead, land was actively converted where open green space and peri-urban agricultural lands were paved for low-density residential infill and commercial uses.

Table 1. Less Urban Green Space from 2003 through 2023.

City	Green Space % (2003)	Green Space % (2023)	Percentage of Loss (%)
Baghdad	12.7%	6.2%	- 51.2%
Samarra	15.3%	7.8%	- 49.0%
Najaf	11.8%	4.3%	- 63.6%

Temperatures measured during the day were 2–4°C lower in the nearby built-up areas where urban parks and mature street canopy trees were retained than in the residential buildings close to those parks and trees where the energy requirement for cooling was lower by 25–35% Research matching two similar neighborhoods show that urban greening can offset between 40 percent and 60 percent of the temperature increase in the local area due to urbanization. Nevertheless, Iraq's extreme water crisis makes flood irrigation (150- 200 L/m^2/year) environmentally unsustainable for conventional municipal landscaping practices. Switching to native drought-resistant plants (for example, Phoenix dactylifera, Eucalyptus, and Tamarix) with subsurface drip irrigation reduces water-use by 60% - 70% while maintaining full cooling efficiency **(Givoni, 1998).**

Field measurements of localized water-sensitive urban design interventions specifically small courtyard water features (1-2 m^2) yielded ambient air temperature reductions (1–2 °C) within a 5m radius via evaporative cooling, as well as significant reductions in airborne pollutants. The city of Najaf has installed low-volume evaporative cooling systems in a number of public spaces. These systems cool the air by 3-4 degrees Celsius while consuming less than 10 L/m^2/day. The active water features can be used without further burdening the city's water supplies **(Reynolds, 2002).**

5.3 Empirical Quantification of the Urban Design–Migration Nexus

The household survey data (n=450) provided strong empirical support for the central hypothesis of the study, which attests to the fact that deficits in sustainable urban design serve as the main quantifiable driver of internal displacement in Iraqi cities. Multiple linear regression analysis found that urban design variables account for 73% of the variance in residents' reported intentions to migrate (R^2=0.73, p<0.001), better than standard demographics and socio-economics.

As given in **Table 2**, deficiencies in design of strongest correlation with migration intent were interruptions of water supply (r=0.72), deficiency of green space (r=0.68), deficiency of natural shading (r=0.64) and deficiency of urban ventilation and outdoor air quality (r=0.61). Neighborhoods characterized by severe design defects saw 67% higher displacement rates compared to sound neighborhoods adapted to local climate conditions after controlling for household income levels and housing tenure status. Unlike the emphasis in Iraqi migration literature on economic or security-related causes, a large majority of respondents from Baghdad (68%), Samarra (71%) and Najaf (76%) cited chronic thermal discomfort, deterioration of the environment, and urban heat as their main reason for wanting to migrate.

Table 2. Primary Drivers of Migration Intentions Based on Household Surveys.

Migration Driver / Deficiencies	Correlation Coefficient (r)	Baghdad (%)	Samarra (%)	Najaf (%)
Climatic Discomfort & Poor Design (Overall)	0.73	68%	71%	76%
Lack of Green Areas	0.68	-	-	-
Lack of Natural Shading	0.64	82% (Specifically, Shade)	-	-
Poor Ventilation & Air Quality	0.61	-	-	-
Water Supply Shortages	0.72	-	-	-

The qualitative responses of the survey referred to specific tipping points: regular summer sleep deprivation owing to urban heat retention overnight, heat-induced sickness among children, unaffordable electricity bills due to constantly running air conditioners, and chronic psychophysical stress due to unlivable outdoor surroundings. 82% of respondents in Baghdad flagged the total absence of street shading and green areas in their neighborhood as the reason for not being satisfied with their home.

5.4 Institutional Barriers and the Need for Proactive Spatial Governance

Results show that simple climate-based design measures such as high-density shading, reflective pavements, optimized street orientation, and native vegetation networks can lower air temperature at micro-climatic level by 5°- 8°C which can transform hazardous micro-climatic conditions into resilient and livable spaces **(Erell et al., 2011).** However, these technical possibilities are hindered by deep structural bottlenecks in Iraq's spatial planning system.

In the first instance, public capital expenditure devoted to urban environmental quality and microclimatic adaptation is still less than 4% of national reconstruction budgets, indicating the persisting tendency towards grey infrastructure rather than environmental resilience **(Ministry of Planning Iraq, 2022).** Urban governance happens in different competing ministries and municipal authorities, and without an overall coordination mechanism, there is a wide variation of standards and overlapping of jurisdictions. The foundations of Iraq's legal framework for urban planning were set in 1981, which is outdated. The legislation does not include any statutory obligations in regard to thermal performance, building envelope insulation, passive cooling, or minimum urban green space allocation. The technical capacity of local municipal engineers and building contractors is limited, which, coupled with a growing culture of stand-alone detached villas and spatial privacy, beyond microclimatic compactness and thermal performance, is exacerbating these regulatory gaps. To reverse climate-driven urban displacement in Iraq, its municipal planning ought to shift from reactive disaster response to proactive spatial governance **(Rigaud et al., 2018).** The shift requires anticipating climate migration routes, pre-planning resilient reception neighborhoods with passive cooling infrastructure, and embedding community-driven, participatory design processes in local government urban development programmes. By blending inexpensive passive design approaches such as cross flow, thermal massing and solar shading with localized greening strategies, a systematic broadening of opportunity arises for the stabilization of urban communities, reduction of household energy costs, and climate-driven displacement mitigation across hyper-arid cities in Iraq.

6. POLICY IMPLICATIONS AND DESIGN FRAMEWORK

6.1 Policy Recommendations

A multi-level approach is needed to tackle climate displacement through urban design. National-level development projects over a certain threshold must mandatorily undergo climate impact assessments for thermal performance, water demand, energy needs, and displacement risk. Modern urban planning law, which replaces the law of 1981 must have climate-adaptation and green-infrastructure prescriptions. Also, a National Sustainable Urban Planning Authority empowered to issue directions across ministerial jurisdictions, set technical standards and enforce compliance. Accompanying this model must be dedicated climate-adaptation funding, incentives for the private sector for sustainable development, and penalties for defaults **(Ministry of Environment Iraq, 2022).**
A new public space by-law will ensure that all new developments respect the municipal requirement of 15 % green space; and neighborhoods already established will be provided with 9 m^2 per capita. The setting of the above requirements will be enforced through zoning and a development approval process. The building standard should impose the use of high solar-reflectance materials (albedo ≥ 0.60 on roofs, ≥ 0.45 on walls), adequate thermal insulation, and inclusion of passive cooling provisions. Street design regulations should establish maximum widths for streets, as well as minimum height-to-width ratios for shading and continuous tree planting, with a focus on pedestrian comfort rather than vehicle throughput. Water-sensitive design requirements should require rainwater harvesting for all buildings above 500m^2, reuse of greywater in new residential developments and pervious surfaces in parking and walking areas. Programmes aimed at upgrading informal settlements must pay special attention since they host so many vulnerable people. Programmes should make use of incremental approaches, including street tree planting, shaded gathering space planting, use of reflective surfaces and provision of basic water and waste infrastructure upgrades **(UN-Habitat, 2021).**

6.2 Design Framework and Implementation Toolkit

To achieve policy into design implementation processes should be systematic. In this regard, a four-step proposed model viz. climate-data integration (historical records, downscaled projections, thermal-stress thresholds); spatial vulnerability assessment (with GIS) to identify high-stress areas, low-adaptive-capacity populations, and priority intervention zones; strategy alignment (compact-mixed-use on greenfield sites, strategic greening in existing dense neighborhoods, retrofitting in informal settlements, and corridor development along major infrastructure); monitoring and performance assessment (temperature, energy use, water use, migration indicators) to fine-tune interventions over time **(Al-Duleimi, 2023)** are given.

An Iraq-specific toolkit of practical measures should stipulate preferred vegetation (native, low-water species like date palms, eucalyptus, tamarisk and acacia), standardized street cross-sections calibrated to shading requirements, building guidelines on orientation, window-to-wall ratio, shading-device sizing, and courtyard layout adapted to Iraqi climate and culture, and water-system specifications for rainwater harvesting and greywater recycling **(Abd al Rahman and Al Shamari, 2018).** Previous Post Thailand's provinces most in need of development. Next Post Climate change will create both victims and victors

7. CONCLUSIONS

This study set out to address the scarcity of Iraqi empirical research linking the quality of sustainable urban design to climate-induced displacement. Analysis of GIS-based spatial data and a 450-household survey across Baghdad, Samarra, and Najaf confirms the study's hypothesis: deficiencies in sustainable urban design, principally the absence of green cover, shading, and ventilation, are strongly associated with residents' displacement intentions, explaining the majority of the variance in migration decisions independent of income and housing tenure. Vegetation cover across the three cities declined by 49–64 % between 2003 and 2023, intensifying an urban heat island effect that reaches over 16°C above rural baselines in Najaf, while simulation results show that afforestation and passive-cooling interventions can lower ambient temperatures by up to 7.1°C — a margin sufficient to materially shift residents' migration calculus. Realizing these gains requires overcoming entrenched barriers: outdated 1981-era planning legislation, fragmented governance across ministries, and reconstruction budgets that allocate under 4 % to environmental quality. As such, it recommends the mandatory imposition of a Green Building Code, minimum green-space requirements, and a (National) Sustainable Urban Planning Authority to coordinate implementation. Compared to similar contexts in the region, cities in Iraq's hyper-arid areas remain understudied. The findings provide useful lessons for other cities facing similar climate and governance constraints. Later studies must expand this investigation temporally and spatially to other cities to enhance causal inference between design interventions and displacement impacts.

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Credit Authorship Contribution Statement

Ghufran Rassam Hade: Conceptualization, Methodology (Survey design and qualitative interviews), Investigation, Visualization (3D modeling and architectural scenarios), Writing – original draft, Project administration . Khaled. H. Mudhee: Data curation (GIS mapping, multi-temporal satellite imagery, and climate records), Formal analysis (Spatial and statistical analysis), Validation, Writing – review & editing.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX A

Survey Instrument: Household Questionnaire on Climate Change, Urban Resilience, and Sustainable Urban Design (Baghdad, Samarra and Najaf)

The household questionnaire used in this study consists of six thematic sections, each rated on a 5-point scale (1 = very poor to 5 = excellent) unless otherwise noted, plus one open-ended question per section. The instrument was administered to 150 households in Samarra and 150 households in Najaf (300 households total for the household-survey component), complemented by demographic and migration-intention items (Section 5) and a final overall-evaluation section (Section 6). This instrument was supplemented, for the Baghdad case study, by an equivalent 150-household survey documented in the study's underlying field data, and by 24 semi-structured interviews with municipal planning officials, environmental officers, and urban design experts across the three cities, as described in Section 4.3.

Table A1. Structure of the household survey instrument.

Section	Construct measured	Items	Response format
1. Climate Change Indicators	Perceived temperature rise, heatwave frequency, water-resource decline, desertification, rainfall change, dust storms, electricity cost from cooling	7 rated + 1 open-ended	5-point scale (1–5)
2. Urban Resilience Indicators	Infrastructure resilience, green-space availability, water/sanitation network efficiency, housing diversity, disaster-management planning, health/education services, capacity to absorb displaced populations	7 rated + 1 open-ended	5-point scale (1–5)
3. Sustainable Urban Design Indicators	Green-space ratio, building density/street narrowness, building energy efficiency, climate-appropriate materials, street ventilation/shading, open public space, dwelling climate-responsiveness	7 rated + 1 open-ended	5-point scale (1–5)
4. Building Sustainability Indicators	Household electricity consumption, thermal insulation, renewable-energy use, natural	7 rated + 1 open-ended	5-point scale (1–5)

Section	Construct measured	Items	Response format
	daylighting, water-consumption perception, greywater reuse, personal carbon-reduction actions		
5. Climate Migration Indicators	Demographics (gender, age, education, tenure, length of residence); out-migration perception, in-migration/overcrowding, service pressure, unemployment among newcomers, density change, informal-settlement expansion, land-use change; personal migration intention and stated drivers (multi-select)	7 rated + demographic + migration-intention items	5-point scale (1–5); categorical; multi-select
6. Urban Quality of Life Indicators	Public space/recreation adequacy, outdoor thermal comfort, air quality, service accessibility, perceived safety, overall residential satisfaction, overall life satisfaction (1–10), perceived effect of design improvements on migration intention	6 rated + overall satisfaction (1–10) + multi-select	5-point scale (1–5); 1–10 scale; multi-select

For the migration-intention item (Section 5, Part C), respondents indicating an intention to leave their current area were asked to select all applicable drivers from a predefined list: severe heat, water scarcity and interruptions, frequent power outages, absence of green space, recurrent dust storms, air/environmental pollution, weak employment opportunities, shortage of health and education services, rising cost of living, and an open “other” option. These items directly informed the correlation analysis reported in Section 5.5.

إعادة التفكير في المرونة الحضرية في العراق: أثر التصميم الحضري المستدام في التخفيف من النزوح الناجم عن تغير المناخ

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الخلاصة

لم تقدِّم الدراسات العراقية إلى الآن معالجة تجريبية كافية للعلاقة بين جودة التصميم الحضري المستدام وقرارات السكان بالنزوح تحت وطأة الإجهاد المناخي، إذ ركّزت الدراسات المحلية السابقة على المحددات الاقتصادية والأمنية للنزوح، في حين وثّقت التقارير حجم الظاهرة دون فحص محدداتها التصميمية. وتفترض الدراسة أن أوجه القصور في التصميم الحضري المستدام — وخصوصاً غياب الغطاء الأخضر والتظليل الطبيعي والتهوية — تمثّل محرّكاً حاسماً وقابلاً للقياس لنزوح السكان في المدن العراقية، بصرف النظر عن الأولوية التقليدية الممنوحة للمحددات الاقتصادية. ولاختبار هذه الفرضية، اعتمدت الدراسة منهجاً وصفياً تحليلياً ذا أساليب مختلطة، دمج التحليل المكاني بنظم المعلومات الجغرافية (GIS) للصور الفضائية للفترة (2003–2024)، مع استبيان ميداني شمل 450 أسرة (150 أسرة في كل من بغداد وسامراء والنجف)، ومقابلات مع مسؤولي التخطيط المحليين. وتؤكّد النتائج وجود علاقة إحصائية قوية بين ضعف معايير التصميم الحضري ونية السكان في الهجرة، إذ فسّرت متغيرات التصميم الحضري الجزءِ الأكبر من تباين قرارات النزوح في المدن الثلاث. وتختتم الدراسة بمجموعة من التوصيات التشريعية والتصميمية، من بينها إلزامية اعتماد كود بناء أخضر، وتخصيص نسبة دنيا من المساحات الخضراء في المشاريع الجديدة، وإنشاء هيئة وطنية للتخطيط الحضري المستدام لتعزيز المرونة المناخية للمدن العراقية والتخفيف من النزوح الناجم عن تغير المناخ.

الكلمات المفتاحية: الهجرة الناجمة عن المناخ، النزوح البيئي، التصميم الحضري المستدام، جزيرة الحرارة الحضرية (UHI)، الصمود الحضري.