University of Kent

Kent Academic Repository

Torai, Kenza, Bouzaher, Soumia, Caputo, Silvio, Manente, Valentina and Khelili, Mohammed (2026) *Suitability analysis for urban oasis gardens: mapping potential sites in Biskra, Algeria*. Ecological Modelling, 515 . ISSN 0304-3800.

Downloaded from
https://kar.kent.ac.uk/114299/ The University of Kent's Academic Repository KAR

The version of record is available from
https://doi.org/10.1016/j.ecolmodel.2026.111514

This document version
Author's Accepted Manuscript

DOI for this version

Licence for this version
CC BY (Attribution)

Additional information
For the purpose of open access, the author(s) has applied a Creative Commons Attribution (CC BY) licence to any Author Accepted Manuscript version arising.

Versions of research works

Versions of Record
If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts
If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in ***Title of Journal*** , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries
If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies).

Title: Suitability Analysis for Urban Oasis Gardens: Mapping Potential Sites in Biskra, Algeria

Kenza Torai [a, c], Soumia Bouzaher [b], Silvio Caputo [c], Valentina Manente [d] and Mohammed Khelili [e]

[a] LACOMOFA laboratory, Department of Architecture, University of Mohamed Khider, Biskra 07000, Algeria

[b] BERLab, Department of Architecture, University of Mohamed Khider, Biskra 07000, Algeria

[c] Kent School of Architecture and Planning, University of Kent, Canterbury CT2 7NR, UK

[d] University of Parma, 43121 Parma, Italy

[e] LRNAT Laboratory, Geography and Territory Planning Department, University of Batna2, Algeria.

Corresponding author

Name : Kenza TORAI

Email : kenza.torai@univ-biskra.dz; kenzatorai@hotmail.com

Address : BP 145 RP, Biskra 07000, Algeria

Abstract:

The rapid urbanisation of Biskra, a Saharan city whose environmental balance historically depended on its oasis gardens, has accelerated agricultural land loss and driven a sustained decline in vegetation cover. These changes have intensified local heat exposure and weakened ecological and cultural systems that once shaped the city's identity. Although green infrastructure is increasingly recognised for mitigating heat stress, limited research has examined how oasis-based landscapes can be translated into spatial tools for planning decisions in arid environments. Existing studies largely document environmental change without providing operational support for planning tools in Algeria, leaving a clear gap in guidance for prioritising green infrastructure interventions. In response, this study applies a GIS-based multi-criteria analysis to develop a spatial tool for planning support. The Analytic Hierarchy Process guides the weighting of fourteen temporally and spatially relevant indicators, including land surface temperature, population density, green space availability and land-use patterns, which are integrated to assess suitability for reintroducing oasis gardens within the city's expanding urban fabric. The framework provides a practical baseline for current planning needs and can be updated as urban conditions evolve. The analysis indicates that approximately 41% of the study area offers moderate to high potential for oasis garden reintroduction. These zones align with areas showing elevated land surface temperatures and limited vegetation cover, indicating where interventions could most effectively improve local environmental conditions. The findings offer actionable support for planning decisions in Biskra while establishing a transferable spatial approach for other arid cities facing similar pressures.

Key words:

Oasis gardens; Urban agriculture; Multi-criteria analysis; Suitability analysis; AHP; Nature-based solutions.

List of abbreviations:

AHP, Analytical Hierarchy Process; LSA, Land Suitability Analysis; LST, Land Surface Temperature; LULC, Land Use/Land Cover; MCA, Multi-Criteria Analysis; MCDM, Multi-Criteria Decision Making; NDVI, Normalized Difference Vegetation Index; PDAU, Plan Directeur d'Aménagement et d'Urbanisme (Master Plan for Development and Urban Planning in Algeria)

1. Introduction

The accelerating pace of urbanization is exerting immense pressure on cities worldwide. Unregulated expansion often produces urban sprawl, posing major challenges to sustainable development (Yasin, 2020). In regions lacking proper planning or oversight, such growth fosters informal settlements deprived of essential infrastructure and services (Jarah et al., 2019). A key deficiency in these settings is the scarcity of green spaces, which intensifies air pollution, heat island effects, and stormwater runoff, while also heightening public health concerns by reducing opportunities for recreation and social interaction (Jabbar et al., 2022; Anderson et al., 2021). In Algeria, since independence, rapid urbanization has outpaced the capacity for sustainable planning, with land expansion progressing faster than demographic growth and producing inefficient land consumption patterns (Bounoua et al., 2023). Current planning frameworks and tools have proven inadequate, with key weaknesses in land management, poor diagnostic capacity, and a persistent gap between legislation and implementation (Saharaoui and Bada, 2021; Sidi Boumedine, 2013). These challenges are particularly acute in southern Algeria, where harsh environmental conditions of Saharan regions amplify the impacts of unregulated development. Rapid urbanization has disrupted traditional oasis-based structures, reshaped population distribution, and produced new urban centres, progressing faster than existing planning systems can manage, further stretching already limited capacities, while reflecting a shift away from vernacular architecture and cultural values (Kouzmine and Fontaine, 2018; Cote, 2014). Among transforming Saharan cities, Biskra, often referred to as the 'Gate of the Sahara', offers a striking example of urban change. Historically renowned for its oasis agriculture and strategic location, Biskra has transitioned from an oasis to a large Saharan city, where urban growth has altered the physical landscape and strained its ecological and social systems (Farhi, 2002). Urban sprawl in Biskra has extensively encroached on agricultural land, especially palm groves, which have lost most of their area over the past four decades (Fig. 1). This decline threatens local food production and undermines the region's agricultural identity and long-standing ecological functions (Dechaicha and Alkama, 2020).

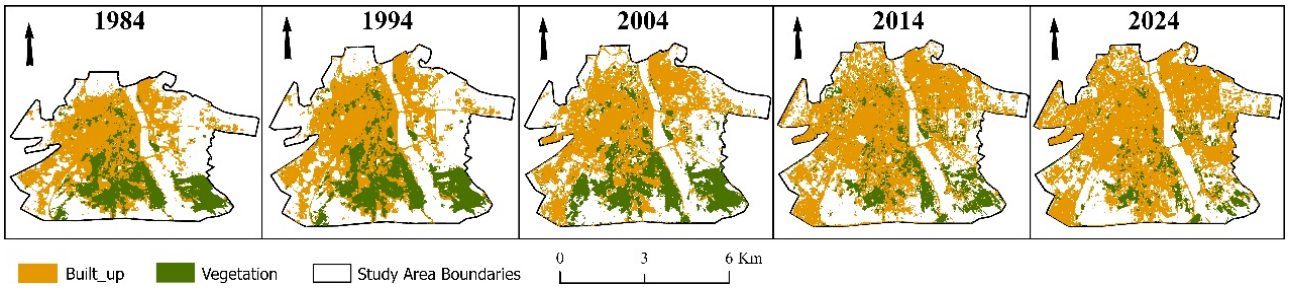


Fig. 1. Land cover changes maps of Biskra between 1984-2024

In arid urban environments like Biskra, where oasis ecosystems are highly sensitive, extreme climatic conditions, combined with the spread of impervious surfaces and vegetative loss, have intensified thermal stress and environmental degradation (Matallah et al., 2021). Despite these urgent concerns, there remains a notable gap in the application of integrated spatial tools for guiding the reintegration of green infrastructure in oasis cities. While previous studies have highlighted the environmental and spatial consequences of unplanned urban growth in Biskra, particularly the fragmentation of traditional gardens and degradation of irrigation networks (Hadji & Petrisor, 2024; Abdou & Djamel, 2022; Hadagha, 2022), there is limited research that translate these findings into practical planning solutions. In Algerian cities, particularly in oasis regions, underdeveloped planning support tools restrict the effective use of land for sustainable development, and oasis garden restoration as a planning intervention has not been systematically studied. Integrating natural systems into urban planning is crucial for addressing these challenges. Oasis gardens in Biskra serve as vital green infrastructure, deeply embedded in the region's natural heritage and cultural identity, while delivering essential ecological and social functions (Bouzaher and Alkama, 2013). These gardens have long been multifunctional, supporting agriculture, microclimate regulation, social interaction, and local economies; today, as the city's urban fabric transforms, they could serve as nature-based solutions for mitigating heat, managing water scarcity, and enhancing biodiversity (Ahriz et al., 2019; Hadagha et al., 2018). Their typical structure, comprising date palms, fruit trees, and ground crops, reflects adaptation to arid conditions, offering a model for sustainable land use (Amrani, 2023). Multifunctional and productive green infrastructure has become a key strategy in promoting sustainable practices within urban environments and is increasingly embraced worldwide (Giudice et al., 2023). In the MENA region, such infrastructures represent a continuity with traditional gardens that historically fulfilled essential functions beyond aesthetics, serving as sources of food, medicinal plants, and environmental stability in arid climates, while maintaining cultural continuity and historical identity (Jardins d'Orient, 2016). Addressing contemporary urban challenges requires blending traditional agricultural practices with modern techniques to create resilient systems that balance productivity with social and environmental needs (Hamamouche et al., 2018).!Using these multifunctional green spaces as a planning tool within modern urban contexts allows reconciliation of traditional agricultural practices with contemporary sustainability goals, supporting a resilient and adaptable urban landscape (Amani-Beni et al., 2022). In recent years, nature-based solutions and green infrastructure strategies have emerged as promising approaches for revitalising cities, offering ecological and social benefits while mitigating the negative impacts of urban sprawl (Vargas-Hernández and Zdunek-Wielgołaska, 2021; Albert et al., 2019; Czechowski et al., 2014). !Urban agricultural productive projects are regarded as a significant aspect of green infrastructure due to their

multiple benefits (Lin et al., 2017). A wide range of planning strategies has been employed globally to identify land suitable for implementing greening interventions within urban contexts. This involves addressing constraints in dense areas and engaging with institutional, regulatory, and socio-political factors that influence the feasibility and long-term integration of such initiatives (Muñoz and Duarte, 2025). Estimating the entire area that can be used for urban agriculture is a crucial first step in planning local productive networks (Saha and Eckelman, 2017). At a foundational level of this process, land inventories have been widely adopted to systematically locate and catalogue vacant or unoccupied sites in cities (Rogers and Hiner, 2016). When focused on vacant or underutilized urban land, such inventories not only reveal patterns of spatial availability but also support planning efforts that frame vacancy as an opportunity for creating productive green spaces (Drake et al., 2016; Eanes and Ventura, 2015; Taylor and Lovell, 2012). However, while some land inventories focus mainly on quantitatively assessing availability or productivity potential as an initial step toward a comprehensive vision, additional data and analysis are required to effectively prioritize sites for such operations (McClintock et al., 2013). More advanced approaches consider the suitability of spaces to host specific activities by analysing their unique characteristics and adaptability to the local context through defined qualitative criteria (Mohamad Selamat et al., 2023). Selecting areas based on their specific qualities will ensure their usability and improve their functionality (Ustaoglu and Aydınoglu, 2020). To evaluate each site's potential, suitability analyses often employ spatial multi-criteria decision-making processes supported by Geographic Information Systems (GIS) which efficiently visualize and manage numerous alternatives (Murayama and Thapa, 2011). There is increasing recognition of land suitability evaluation as a comprehensive decision-making approach for addressing challenging issues. It has been applied across various domains, including landfill development (Chabuk et al., 2017; Beskese et al., 2015), urban growth and development (Aliani et al., 2021; Raddad, 2016), agricultural use (Binte Mostafiz et al., 2021; Akıncı et al., 2013), and water resources management involving irrigation, groundwater, and flood risks (Waleed et al., 2020). This integrated approach enables urban planners to make informed decisions and customize solutions for targeted problems (Malczewski, 2004). Frameworks combining GIS and multiple criteria analysis (MCA) help navigate various physical, socio-economic and environmental factors influencing the needed implementation (Muhsin et al., 2022; Purnamasari et al., 2022). In rapidly urbanizing cities, reintegrating green spaces faces challenges such as limited land availability, competition with essential infrastructure, weak coordination among responsible agencies, and poor planning (Bressane et al., 2024). In Biskra, as in other fast-growing cities, planning new gardens is further constrained by land speculation, limited land availability, and the deterioration of traditional irrigation systems. However, the application of GIS-based MCA in green infrastructure planning remains rare in

Algerian oasis cities. GIS-supported MCA can assist planners in balancing competing spatial demands and identifying priority sites for green infrastructure. Among MCDM methods, the Analytic Hierarchy Process (AHP) is widely used in land suitability and site selection studies, providing a clear and structured way to compare factors (Leal, 2020). AHP has proven effective in prioritizing criteria and combining expert judgment with systematic analysis, making it well-suited for addressing complex problems, particularly when factors are difficult to compare objectively (Russo and Camanho, 2015) and (Table 2). In response to this gap in both the literature and planning practice, the aim of this study is to develop a spatial decision-support framework for identifying suitable locations for reintegrating oasis gardens in the city of Biskra. The framework builds on the established methods using AHP and GIS-based MCA but adapts them to the specific challenges of Biskra's urban and environmental context. It focuses on evaluating underutilized or vacant land that could support the revitalization of oasis functions, by considering ecological, infrastructural, and social criteria. The study contributes by offering a context-sensitive GIS-based framework for land suitability analysis, a practical tool to guide the spatial integration of traditional agricultural functions into contemporary urban development. The broader objective is to inform planning strategies that reconnect the city with its historical green identity while addressing contemporary challenges such as environmental degradation, biodiversity loss, and limited access to green spaces, offering recommendations for reintroducing oasis gardens as multifunctional green infrastructure that links the city's ecological and cultural heritage with sustainable and inclusive urban planning strategies.

2. Materials and methods

!"#$%&' ()$*+,*$

Biskra province, located in the Ziban territory, is known for its highly productive oases in Algeria and North Africa, with small settlements surrounded by palm groves that are deeply connected to their local context (Matallah et al., 2023). The municipality of Biskra lies at the centre of this territory and serves as its capital, playing a key role in administrative and economic activities. Biskra's history dates back beyond Roman times, with advanced irrigation systems introduced during the Roman era to support agriculture in the arid landscape, leaving a legacy of water management practices that influenced later developments in the region (Mattingly et al., 2020; Meouak, 2017). Biskra, situated in southeastern Algeria, occupies a strategic geographic position at the southern foothills of the Saharan Atlas, serving as a transitioning area towards the vast Saharan lands. This location marks its importance as one of the gateways to the Algerian Desert (Cote, 1991). Historian (Zerdoum, 2003) characterizes Biskra as an intermediate zone, shaped by the interplay of climatic influences from both the north and the south. This dynamic positioning contributes to the development of a unique and

diverse landscape, enhancing its touristic potential (Rais and Bouzaher, 2021), while also reflecting its historical significance as a hub for trade and cultural exchange which has supported agriculture and commerce for centuries (Bouzaher, 2015). It is well-connected by major roads that link it to key urban centres across Algeria, including the capital, Algiers to the north, which is approximately 430 km away. The city covers an area of 127.55 km², at an elevation of approximately 120 m above sea level. Biskra's climate, defined by its hot desertic conditions, reflects the arid environment of its location on the edge of the Sahara. Biskra experiences cold, dry winters and hot, dry summers, it is classified in zone BWh according to the Köppen climate classification (Semahi et al., 2019). From 1943 to 2023, the average annual temperature in the studied area was 22.05°C, with a relative humidity of 42.28%. The maximum recorded air temperature reached 46°C (CBE, 2023). The study area is between latitudes 34.873 north and 34.816 south and longitudes 5.782 east and 5.687 west, as presented in Fig. 2.

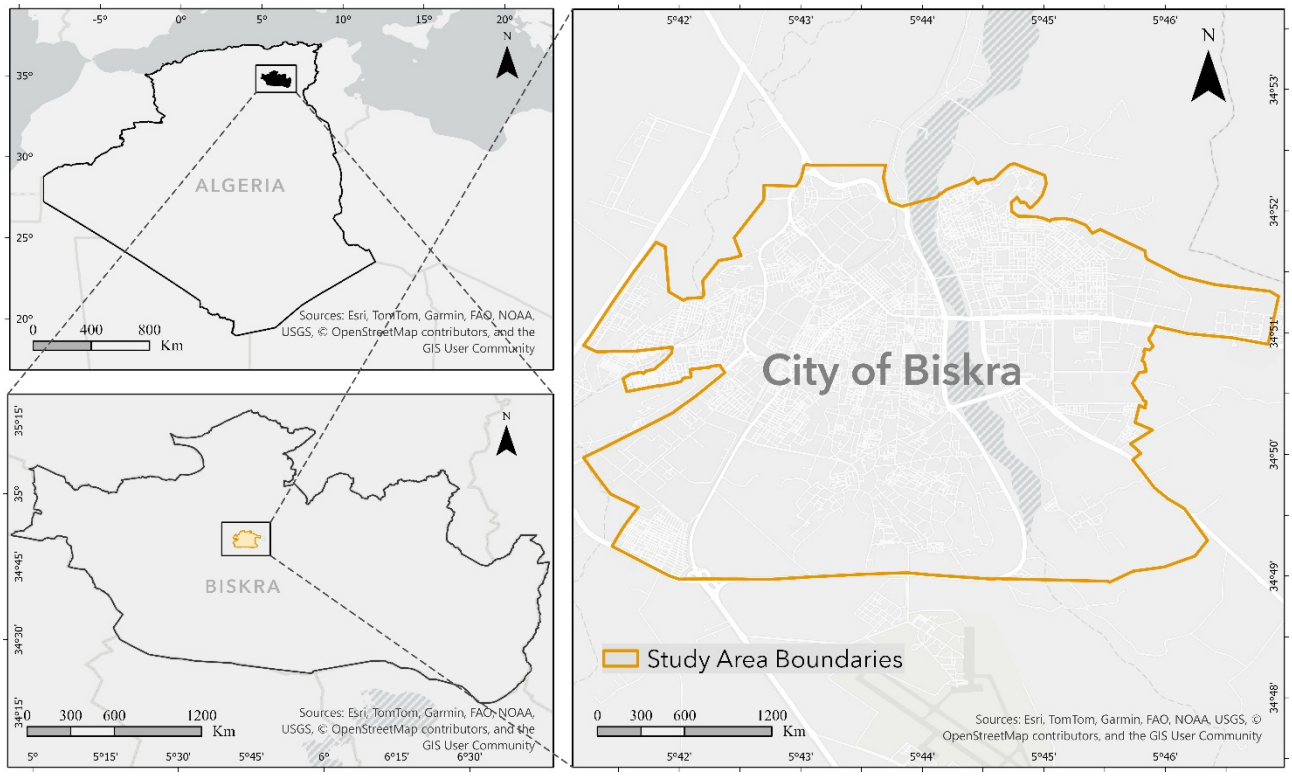


Fig. 2. Location of the study area: Biskra, Algeria. *! "#$%& ' ()&*+,$-&.$*+,$(#$&-#/.0&(1$(-&(,.&."&,"#&,2--(1+*0&.$)+2#& (22$)#$.&,(#+",(*&3"/,.(1+$-4&*

!"!$-*&*$%.'+/,0$

This study is carried out in several steps (Fig. 3), aimed at identifying potential suitable sites for urban agricultural gardens in Biskra. Each step contributes to building a practical framework for a spatial decision-making tool.

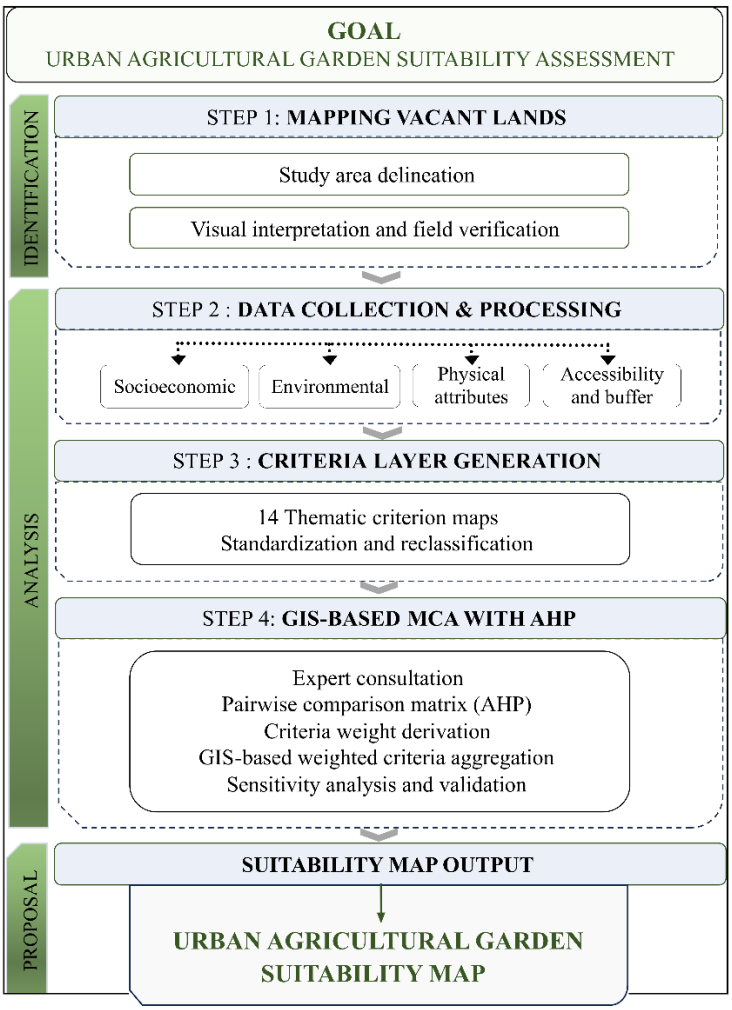


Fig. 3. Methodological workflow for urban agricultural garden suitability

Step 1: Mapping vacant lands

The first step involved mapping vacant parcels within Biskra (Fig. 4). Using aerial imagery from Google Earth Pro, a virtual interpretation was conducted to identify potential sites. This process was complemented by comprehensive ground-truthing to verify and exclude parcels that did not meet the initial selection criteria. These criteria included planned but undeveloped green spaces, parcels without permanent structures, non-impervious or unpaved surfaces, and residual green areas such as linear and nodal parcels adjacent to roadways. Sites already used for agriculture, densely vegetated areas, and parcels within institutional boundaries were omitted. The remaining candidate sites were digitized to create a baseline dataset of vacant or underutilized parcels for further analysis. It should be noted that the identification of vacant land based on visual interpretation of Google Earth imagery is subject to limitations related to image acquisition dates, spatial resolution variability, and a degree of interpretative subjectivity. While ground-truthing helped to reduce misclassification, it cannot fully capture recent land-use changes, subsurface conditions, or legal and ownership constraints.

Accordingly, the vacant land inventory represents a preliminary spatial screening rather than a definitive site feasibility assessment.

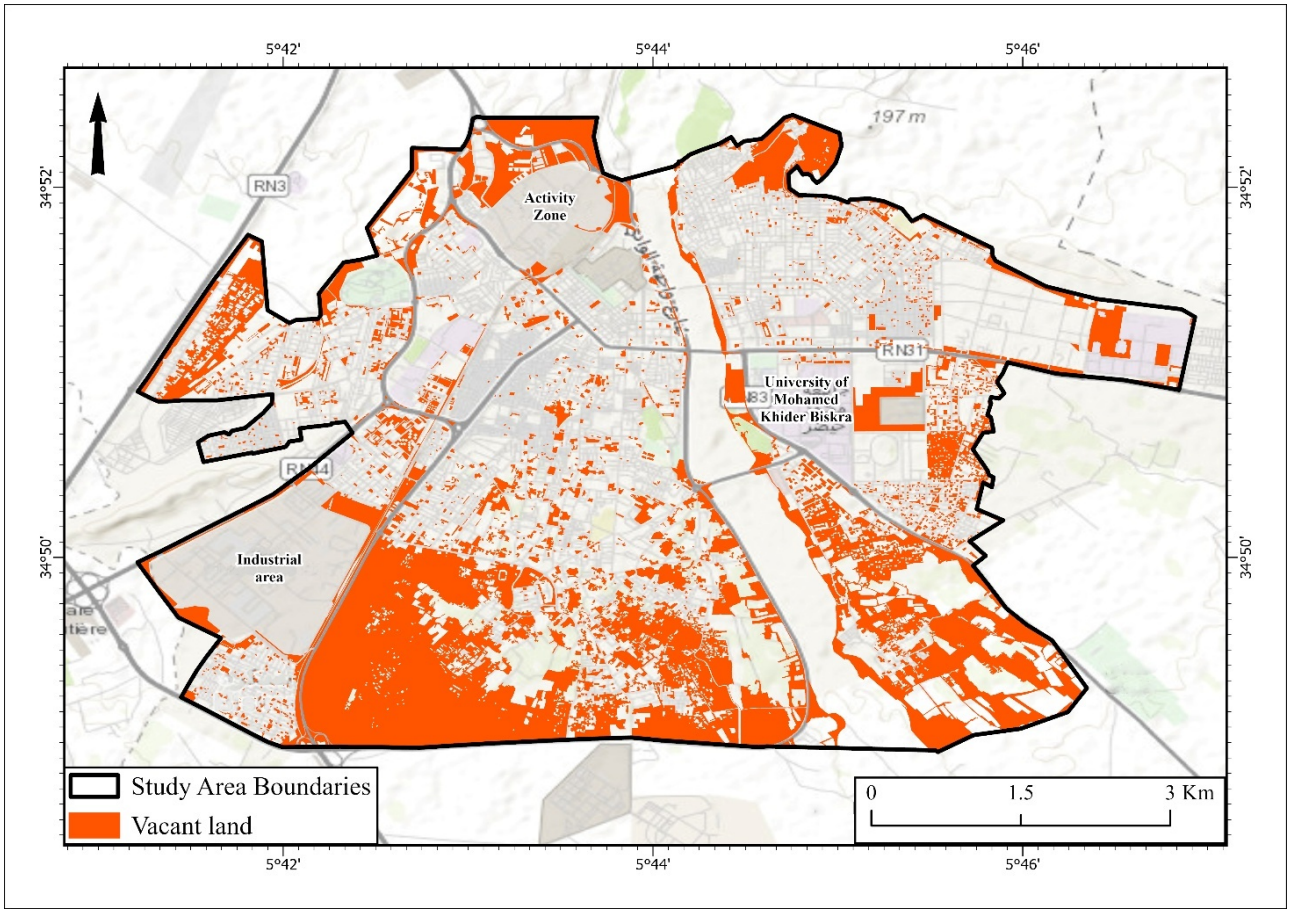


Fig. 4. Map of vacant parcels identified for urban oasis garden development in Biskra

Step 2: Data acquisition and processing

This study relied on a variety of spatial and non-spatial data, collected from various sources (Table 1). Some data were obtained from local or municipal planning offices. Other spatial data were sourced from open-source databases.

Table 1

Summary of data sources and types used in the study

Data	Source	Type	Year
Slope and Water bodies	ALOS Global Digital Surface Model (AW3D30) https://opentopography.org/	Raster/Vector	Publication 2016
LULC, NDVI and LST	Google earth pro Landsat https://earthexplorer.usgs.gov/	Raster/Vector	January 2024
Administrative boundaries Building footprints Public green spaces	PDAU AutoCAD file Municipality of Biskra www.openstreetmap.org	Vector	2016 2024

Road networks Industrial Zone and Railways			
Population density	Local statistics authority and Municipality of Biskra	Excel	2023
Soil data Groundwater data	(CRSTRA) Biskra and local water management agencies	Raster	2011
Bus stops	Public transport authority of Biskra (EtusBiskra)	Vector	2025
GPS data	Field surveys	Vector	2025

Step 3: Preparation of thematic maps and possible scenarios

The collected datasets were processed using GIS techniques and standard spatial preprocessing procedures. ArcGIS Pro 3.2.0 software was employed to generate the thematic layers. A geodatabase was first established to organize and manage all spatial data, with all layers projected to a unified coordinate system, WGS 1984 UTM Zone 31N, to ensure spatial consistency and accuracy. Both vector and raster data were pre-processed using tools such as Clip, Merge, Dissolve, and Union to extract and focus on the extent of the study area. Basic data cleaning and validation were conducted to check data completeness and correct geometric inconsistencies, particularly in datasets obtained from OpenStreetMap, to ensure the reliability of the spatial datasets. Land Use/Land Cover (LULC) mapping was carried out through visual interpretation and digitization in ArcGIS using high-resolution imagery from Google Earth and Landsat data. Land-use classes were delineated based on spatial characteristics and contextual information. The resulting LULC map was verified through field survey observations and further validated by comparison with the PDAU of the Municipality of Biskra, ensuring consistency with official land-use planning documents. Topographic characteristics were obtained from the ALOS Global Digital Surface Model; water bodies and slope maps were derived from the digital elevation model. Raster datasets representing vegetation cover and surface temperature were also processed. The Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) maps were generated using the Raster Calculator, applying standard index-based formulas to derive spatial representations of vegetation density and surface thermal conditions. NDVI was calculated from Landsat imagery using the standard equation (1):

$$!"\#\$\%\&!\$'(')*+-\&!\$',')*+! \quad (1)$$

Where $"\#\$$ represents the near-infrared band and $\$\%\&$ represents the red band of the Landsat sensor. LST was derived from Landsat-8 OLI/TIRS imagery acquired in 2024 following a standard and widely adopted procedure (Waleed and Sajjad, 2022) and calculated using the following equation (2):

$$./0\ \% \frac{10_!}{2\ ,\ 3\frac{4\ 5\ 0_!}{6}7\ 5\ 89:}\ (\ ;<\Rightarrow 2?! \qquad (2)$$

Where $'(\ )$ represents land surface temperature in (@), $10_!$ is the at-satellite brightness temperature (K), 4 is the wavelength of emitted radiance, 6 is a constant (1.438×10^{-2} mK), and : denotes land surface emissivity. The resulting LST map was reclassified into suitability classes and used as one of the environmental criteria in the site suitability analysis. Proximity distances to key features, including residential areas, bus stops, roads, cultural and educational institutions, water bodies, railways, and industrial zones, were generated using spatial analysis tools (Euclidean distance) to represent accessibility and environmental constraints. Vector layers, including roads, buildings, and administrative boundaries, were converted to raster format and standardized to a common spatial resolution to ensure compatibility. In total, fourteen thematic maps were produced, each representing one of the selected suitability criteria.

!"1$%,2,/&345$6*/&.+0$3462',4/345$'+7*4$*5+3/'2&'+*2$5*+(,40$0'3&*7323&)$

Identifying the factors influencing land suitability for urban agricultural gardens is a fundamental step in the planning process. Considering a wide range of contextual factors makes planning approaches more inclusive, allowing for a more equitable distribution of green infrastructure across the city (Wolch et al., 2014). However, planning for urban greenery lacks a universally standardized set of criteria since local cultural, environmental, and socio-economic contexts significantly influence the priorities and practices of their development (Gelan, 2021; James et al., 2009). This variation is driven not only by the different purposes of those spaces, such as supporting biodiversity, improving climate resilience, or providing recreational areas, but also by variations in how they are defined and managed, which are shaped by each city's unique history and urban structure (Hansen and Pauleit, 2014; Kabisch and Haase, 2013). Global organizations recognize the challenges in planning urban green amenities, emphasizing the need for adaptable, context-specific guidelines that address diverse environmental and socio-economic conditions through nature-based systems. Such flexibility is essential for balancing the competing demands of communities and ecosystems (UN-Habitat, 2023; WHO, 2021). The absence of universally agreed-upon criteria for urban green space planning highlights the varied factors that shape their management. This complexity increases when considering the productive function of these spaces, such as urban agricultural gardens, which face additional challenges. These spaces must fulfil environmental and aesthetic goals while also supporting agricultural needs like water access. In this study, we reviewed existing literature to identify the factors used to map potential agricultural activities particularly within urban contexts. This review provided insight into the criteria and methods applied to assess land suitability for urban

agricultural gardens in Biskra. Relevant studies were sourced from databases including Science Direct, Web of Science, and Scopus, supplemented by targeted searches through Google Scholar and ResearchGate. Articles were selected using keywords related to urban garden land suitability and the analysis of land for new urban agricultural gardens, ensuring alignment with the research focus. The main findings are summarized in Table 2.

Table 2

Review of Case Studies on Urban Productive and Green Spaces: Factors, Methods, and Applications

References	Methods and Techniques	Siting variables	Area of application	Case study
(Kanosvamhira et al., 2025)	GIS-based suitability analysis; AHP	Soil type, slope, temperature, precipitation, distance from streams and road.	Urban agriculture	Cape Town (South Africa)
(Joy et al., 2024)	GIS-based suitability analysis; AHP	NDVI, LULC, population distribution, PM 2.5, UHI, distance from water bodies/bus stops/roads/rivers/railway stations, elevation, slope, temperature, rainfall	Urban green parks	Ranchi city (India)
(Al-Johari and Sharaf, 2024)	GIS and Remote Sensing; MCA with Boolean-overlap	Land use, slopes, soil type, and vegetation.	Urban agriculture	Amman City (Jordan)
(Aiymeku et al., 2024)	GIS-based MCDA; AHP	Soil type, LULC, slope, LST, population density, NDVI, proximity to river, roads, existing green spaces, protected areas and major institutions.	Green spaces	Jimma city, Oromia (Ethiopia)
(Li, 2023)	GIS-based LSA; AHP and TOPSIS; Prospect theory	Land elevation, slope, precipitation, population density, GDP, land rent, accessibility.	Urban agriculture	Fuzhou (China)
(Ahmad Zaki et al., 2023)	GIS-based LSA; AHP	Slope, elevation, land use, distance from settlement area, proximity to road accessibility, proximity to water access.	Urban gardening	Shah Alam (Malaysia)
(Türker and Akten, 2023)	GIS-based vacant land inventory, suitability analysis; Expert scoring	Slope, aspect, land use, erosion, soil depth, drainage problem, environmental sensitivity, spatial location, proximity to industrial sites and roads, water and vehicle access.	Urban agriculture	Usak (Turkey)
(Li et al., 2022)	Fuzzy AHP and GIS for suitability mapping	Elevation, slope, aspect, precipitation, temperature, NDVI, heat-island effect, air pollution, carbon storage, distance to metro and bus stations, road accessibility, population density.	Urban parks	Nanjing (China)
(Nkosi et al., 2022)	GIS-MCDA (suitability analysis) using (WLC); Group AHP	Land cover, NDVI, soil texture, agricultural potential, proximity to water sources, annual rainfall, slope, environment sensitive areas, groundwater quality, temperature (min & max), proximity to strategic infrastructure, informal settlements, and public transport.	Urban agriculture	Johannesburg (South Africa)
(Sonneveld et al., 2021)	GIS-MCDA; Ordered logistic regression	Soil types, road accessibility, land use, groundwater depth, women's safety (proxied by distance to built-up areas), geological	Urban allotment gardens	Three Cities in (Benin)

		suitability, distance to markets (proxied by population density).		
(Gelan, 2021)	GIS-MCDA; AHP	Existing land use, vegetation cover, road type, proximity to: settlement area/road /water sources, population density, land ownership, slope, elevation, flood-prone area, scenic attractiveness.	Urban green spaces	Sululta town (Ethiopia)
(Smith et al., 2021)	GIS-MCDA; Stakeholder-based weighting	Food deserts, community health, low-income and minority neighbourhoods, park-poor neighbourhoods, community space proximity, heat vulnerability, residential and commercial proximity, population density, extreme temperature, stormwater runoff, bikeability, mass transit accessibility, groundcover (bare, scrub, mesic).	Urban community gardens	Phoenix metropolitan area (USA)
(Ustaoglu and Aydınoglu, 2020)	GIS-MCDA; AHP; Fuzzy modelling	Slope, elevation, aspect, distance from: highways/roads/bus stops/metro stops, distance from: reservoirs /watercourses /coastline / urban recreation, distance from industry/commerce and residential centres, existing land use, agricultural land suitability, erosion risk, land capability.	Green space development	Pendik district (Turkey)
(Li et al., 2018)	GIS-based LSA; AHP and coefficient of variation	Existing land use, pollution source, significant infrastructure, road traffic, ancient and famous trees, tourism resources, heritage sites, water area, slope, elevation, heat island effect, geological disasters, NDVI and ecological patches.	Urban green spaces	Fuping County (China)
(Parece and Campbell, 2017)	GIS-based suitability analysis; Demographic analysis	Open land, impervious surfaces, tree canopy, water bodies. zoning, parcel ownership, schoolyards, pollution sites, brownfields, flood zones. poverty rates.	Urban agriculture	Roanoke, Virginia (USA)
(Yousefi, 2016)	GIS-based LSA (WLC/genetic algorithms); FRAGSTATS	Slope, water supply, road access, residential proximity, cultural/educational proximity, population density, land price, class area proportion, number of patches, mean patch size, mean nearest neighbour.	Urban green spaces	Birjand city (Iran)
(Rogers and Hiner, 2016)	GIS-based suitability analysis; HAS delineation (land inventory)	Land use/cover, slope, topographic index, impervious surfaces, runoff risk, zoning, public vs. private land, soil depth, hydraulic conductivity.	Urban agriculture	Austin, TX (USA)
(Eanes and Ventura, 2015)	-GIS-based suitability analysis (land inventory)	Water access, solar access, size, vehicular accessibility, land-use conflicts, pervious surface, shrub coverage, development potential and geophysical context, slope.	Community gardens	Madison, Wisconsin (USA)
(Weerakoon, 2014)	GIS-based MCE with AHP; Regression analysis	Land use, slope, water table depth, flood retention areas, land value, environmental sensitive areas, population and housing density.	Urban agriculture	Colombo District (Sri Lanka)
(Chandio et al., 2011)	GIS-based LSA with AHP; Expert Choice 11.5	Land availability (vacant land, existing parks), land price/value, accessibility (roads), population density, income group/level.	Public parks	Larkana City (Pakistan)

(Mahmoud and El-Sayed, 2011)	GIS-based LSA; AHP; Ecological threshold method	Elevation, slope, climate, soil types, vegetation coverage, water availability, land use, road access, railways, power lines.	Sustainable urban green network	El-Sadat City (Egypt)
(Kêdowidé, 2010)	GIS-based LSA; MCE with WLC in IDRISI	Land use/cover, slope, soil fertility, proximity to water, road networks, market proximity, zoning regulations, SDAGO 2025 projections.	Urban agriculture	Burkina Faso (Ouagadougou)
(Uy and Nakagoshi, 2008)	GIS-based LSA; AHP; Ecological threshold method	Air quality, water bodies, existing land use, historical and cultural landscapes, industrial zone.	Urban green spaces	Hanoi (Vietnam)

Numerous studies have utilized integrated approaches combining GIS with advanced decision-making techniques, like the AHP, due to its flexibility and simplicity in assigning weights to various criteria. This technique enables the integration of ecological, social, and economic considerations, facilitating informed decision-making in complex scenarios. Previous research offers significant contributions to understanding the critical factors influencing land suitability for urban gardening initiatives. For this study, the factors chosen were derived from the review of the literature (Table 2) and filtered according to the availability and quality of local data. This ensures that the chosen factors are both theoretically grounded and practical. A framework was then developed to evaluate the suitability of potential sites for new oasis gardens in Biskra, focusing on ecological sustainability, urban resilience, and agricultural viability. The chosen criteria were refined to reflect the specific environmental, social, and infrastructural conditions of Biskra and were organized into thematic categories representing the key elements influencing land suitability. The evaluation framework comprises four main criteria and fourteen sub-criteria (Fig. 5), collectively addressing a comprehensive range of factors. These include population density, land cover, water availability, proximity to infrastructure, and environmental conditions, providing a structured basis for assessing the suitability of land for urban oasis gardens.

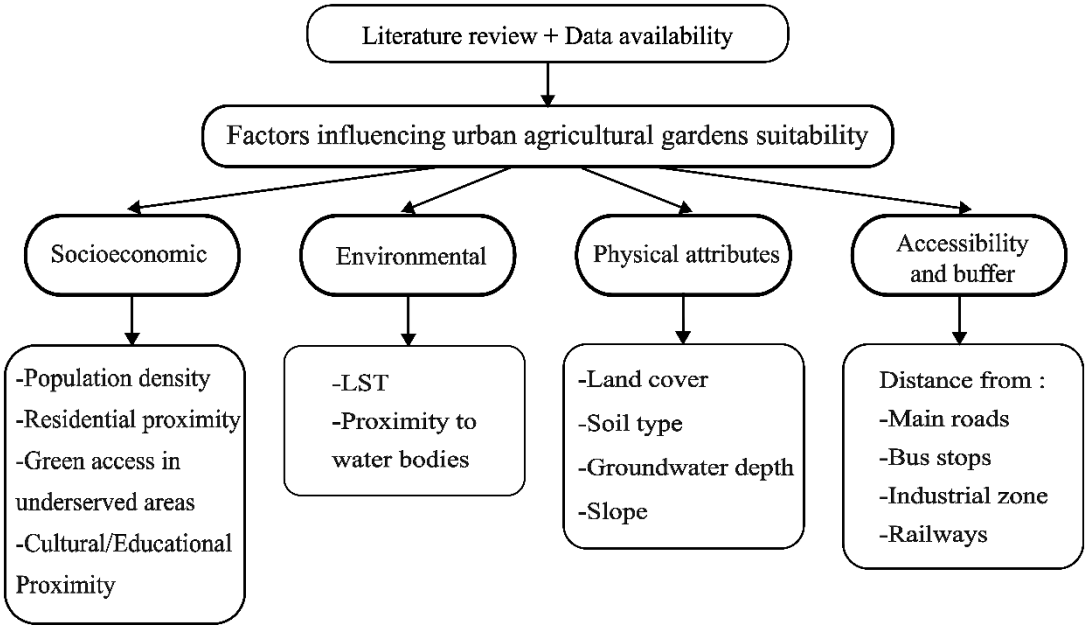


Fig. 5. Simplified Decision Criteria Hierarchy for Site Selection

Population density

Because of its effects on community involvement, urban population density is an important consideration when deciding where to provide new urban gardens. It is widely used in urban agriculture planning as both a socio-economic factor and a guide for siting productive spaces in diverse urban contexts (Kil et al., 2023; Yang et al., 2020). Areas with higher population densities are often considered more suitable, as they can maximize the number of people who benefit from and engage with such spaces. Accordingly, several researchers recommend locating new urban gardens near areas with high population concentration (Smith et al., 2021). However, densely populated areas are often associated with spatial limitations that can restrict gardening activities (Akaeze and Nandwani, 2020). Given their need for greenery to enhance recreation and quality of life, this study prioritizes sites closer to densely populated neighbourhoods when identifying suitable locations.

Residential proximity

Proximity of gardens to residential areas is a key factor, as it directly affects physical accessibility and encourages residents to utilize these spaces (Gelan, 2021). Locating gardens within neighbourhoods engages residents in their planning, design, and management, fostering a sense of ownership and investment, ensuring that these spaces are maintained and protected by the community. Closer residential proximity enhances security; for instance, a study on allotment gardens in Benin (Sonneveld et al., 2021) used residential proximity as a proxy for women's safety, reinforcing the idea that closeness fosters safer environments for female gardeners. Furthermore, historically, gardens and

agricultural activities in the study area were closely integrated with the built environment, where proximity to dwellings provided social, spatial, and environmental benefits, forming a key pillar of spatial organization in arid and semi-arid regions (Bouzaher and Alkama, 2012). Accordingly, sites located closer to residential areas are considered more suitable.

Green Access in Underserved Areas

Accessibility to green areas is not confined to a specific distance or metric. Instead, it involves considering different factors like personal preferences, cultural influences, and the unique character of each neighbourhood. Several studies have examined the ideal proximity to green spaces and walking distances to access nature, but no universal standard exists. People visit green spaces more frequently the closer they are to their residences. Research indicates that proximity is important and walking willingness declines over distances longer than 300 m (Grahn and Stigsdotter, 2003). Many sources highlight the importance of strategic distribution of gardens to maximize community benefits, for example, the English Nature's Accessible Natural Greenspace Standards (ANGSt) model for the provision of natural greenspaces states that the closest natural greenspace area, measuring at least 2 ha, shall be no more than 300 m away from any given residence (English Nature, 2003). Mapping potential new sites helps stakeholders identify areas lacking green spaces, especially in regions affected by poverty, food insecurity, or public health issues (Eanes and Ventura, 2015; Taylor and Lovell, 2012). Areas with limited existing green access are thus prioritised, as introducing gardens in these contexts yields greater social and health benefits.

Cultural and Educational Proximity (Schools and Mosques)

Proximity to cultural and educational institutions is frequently highlighted in urban planning and sustainability literature as a critical parameter in evaluating land suitability for green infrastructure and urban agriculture (Smith et al., 2021; Yousefi, 2016). In this study, particular emphasis is placed on schools and mosques, which serve as community anchors and enhance access for diverse population groups. Their inclusion in the land suitability analysis is based on several considerations. Schools are increasingly seen as catalysts for educational and community gardening initiatives, offering opportunities for environmental education and promoting sustainable practices among youth (Newell et al., 2022). Both schools and mosques function as established gathering spaces embedded in the social and spatial fabric of neighbourhoods. Their centrality and visibility make them strategic sites for integrating multifunctional green spaces that promote community participation. Gardening in and around these institutions forms part of the cultural identity, and locating gardens nearby strengthens this connection by enhancing cultural ecosystem services such as environmental education, spiritual enrichment, and communal interaction (Tafliha, 2020; Omar et al., 2018). Their

proximity not only improves physical accessibility but also supports the socio-cultural integration of new gardens into the everyday lives of residents. Consequently, sites in closer proximity to schools and mosques receive higher suitability scores.

Land surface temperature

In determining priority locations for urban greening intervention, land surface temperature can serve as a valuable indicator. LST is commonly used as a proxy to assess the impact of land cover and spatial patterns changes on urban temperature and climate conditions (Tiwari and Kanchan, 2024; Bekele et al., 2022; Masoudi and Tan, 2019). Studies on the linkage between both of the vegetation and the urbanisation on the surface temperature show that areas with high vegetations have a lower LSTs than urbanized areas (Yang et al., 2017; Di Leo et al., 2016). Mapping LST can therefore identify surfaces with elevated temperatures that would benefit most from gardens implementation to help regulate local climate. There are many factors that can affects the LST changes, and vegetation is one of the most important ones (Taripanah and Ranjbar, 2021) . Studies indicate an inverse relationship between the abundance of urban green spaces and surface temperature. While opting for LST as an indicator is beneficial due to the availability of geospatial data, ground-based measurements are recommended for higher accuracy. Summer LST maps of Biskra show significantly higher temperatures over bare soil surfaces surrounding the city. Similar patterns were also observed in studies done in other hot and arid regions (Abulibdeh, 2021), where the shading of building affect the temperature in the urban centre appearing cooler than its surroundings. In contrast, winter LST reveals clearer spatial thermal variations within the built-up fabric, highlighting areas that retain elevated temperatures even during cooler months. Accordingly, winter LST was used and areas with higher LST values are prioritised, as they indicate sustained thermal stress and limited vegetation cover.

Proximity to Water Bodies / Groundwater Depth

The proximity to water bodies represents a critical criterion in identifying suitable locations for new urban gardens. Access to a reliable water source is essential for the sustainability, maintenance, and productivity of green spaces, particularly in arid and semi-arid regions like Biskra. Green spaces are often planned near water bodies to benefit from their cooling effects and ecological services. Water bodies regulate temperatures, improve humidity, and support biodiversity, enhancing the resilience and multifunctionality of urban green infrastructures (Jandaghian and Colombo, 2024). The historical development of cities reveals a strong link between water bodies and land use, where rivers and irrigation networks traditionally guided the placement of green spaces and shaped urban form (Kurochkina, 2020). In oasis cities, the historical association between green spaces and traditional

irrigation systems reinforces the relevance of this factor. The case study is served by natural watercourses or wadis, which have long structured land use patterns and supported oasis agriculture. A wadi is an Arabic term for a dry valley or streambed in arid regions and is shaped by seasonal or intermittent flows that can recharge groundwater and enable flood-based irrigation (Shahin, 2007). In Biskra, for example, the Wadi-Biskra was a key source of irrigation for the city's oasis gardens, reflecting the enduring link between water and land use. Historical accounts also describe the use of subsurface water flows, locally known as Bahar-that-el-erd (underground rivers), and note that the French undertook the development of artesian wells to access these hidden resources (Meouak, 2017; Morell, 1854). Thus, proximity to water addresses practical irrigation needs while aligning with historical land use patterns and the region's ecological dynamics. Sites located closer to water sources are therefore considered more suitable.

Land use and land cover

LULC is a fundamental factor in determining suitable sites for new urban gardens, as both the type and condition of land cover directly affect feasibility and development costs. In the initial selection phase, heavily urbanized or impervious surfaces such as paved areas, were excluded when mapping vacant land (Fig. 4). The analysis prioritized open spaces and land with bare soil or sparse vegetation. Built-up areas generally receive the lowest suitability scores due to their limited potential for green space development (Moisa et al., 2023) , as they often require extensive modifications before repurposing. This approach is supported by several studies. For instance, (Smith et al., 2021, 2017) demonstrate that vacant parcels with cultivable groundcover are more cost-effective and practical to develop into green spaces than sites obstructed by buildings or impermeable surfaces. Consequently, vacant lands were rated most suitable for cultivation, while built-up areas were least suitable.

Soil Type

Soil type is a key factor in determining land suitability for urban green spaces. Physical properties (e.g., texture, bulk density) and chemical properties (e.g., nutrients, organic matter) impact plant growth and water retention (Saeedavi et al., 2017). In this study, soils were classified into two types based on available data: sandy clay and gravelly soils. While this classification provides a basic understanding of soil structure and drainage, it is a preliminary assessment. According to the FAO Digital Soil Map of the World (DSMW), the dominant soil texture in the study area is loam, which closely corresponds to the sandy clay category identified here. Loamy and sandy clay soils are generally more suitable for urban agriculture due to their moderate fertility and water retention, whereas gravelly soils, which are typically coarse, low in nutrients, and gypsiferous, present more

constraints. Further, detailed soil analysis will be needed in future phases to refine suitability assessments.

Slope

Flatter terrain is generally preferred for urban agriculture as it facilitates easier cultivation and improves accessibility. High slopes, on the other hand, can increase soil erosion, making the land less suitable for agricultural use (Li, 2023). With a relatively low presence of steep slopes in the area, it is well-suited for new garden development, ensuring both practicality and sustainability.

Proximity to Main Roads

Proximity to main roads is often considered in LSA for urban agriculture, due to its role in accessibility and integration within the urban fabric. Enhanced accessibility improves reachability for gardeners, suppliers, and consumers, facilitates movement of materials and produce and strengthens the garden's connection to the city, supporting functional connectivity and social engagement (Kanosvamhira et al., 2025). However, sites adjacent to high-traffic roads may be less suitable due to associated environmental and public health concerns, such as air and noise pollution (Türker and Akten, 2023). In this study, areas within 10 m of major roads were excluded to reduce risks. Beyond this buffer, sites closer to roads were considered more suitable due to better accessibility, while suitability gradually decreased with greater distance.

Proximity to Bus Stops

The location of urban gardens near public transport stops, such as bus and metro station, greatly improves their accessibility. When these areas are easy to reach by public transport, they become available to a larger and more diverse population, including people without private cars, the elderly, and those with limited mobility (Zhang et al., 2023). In this study, a walking distance of less than 300 m from bus stops was considered the optimal threshold, as spaces within this range are the most accessible. As the distance exceeds this threshold, the suitability of the location decreases.

Distance from Industrial Zone and Railways

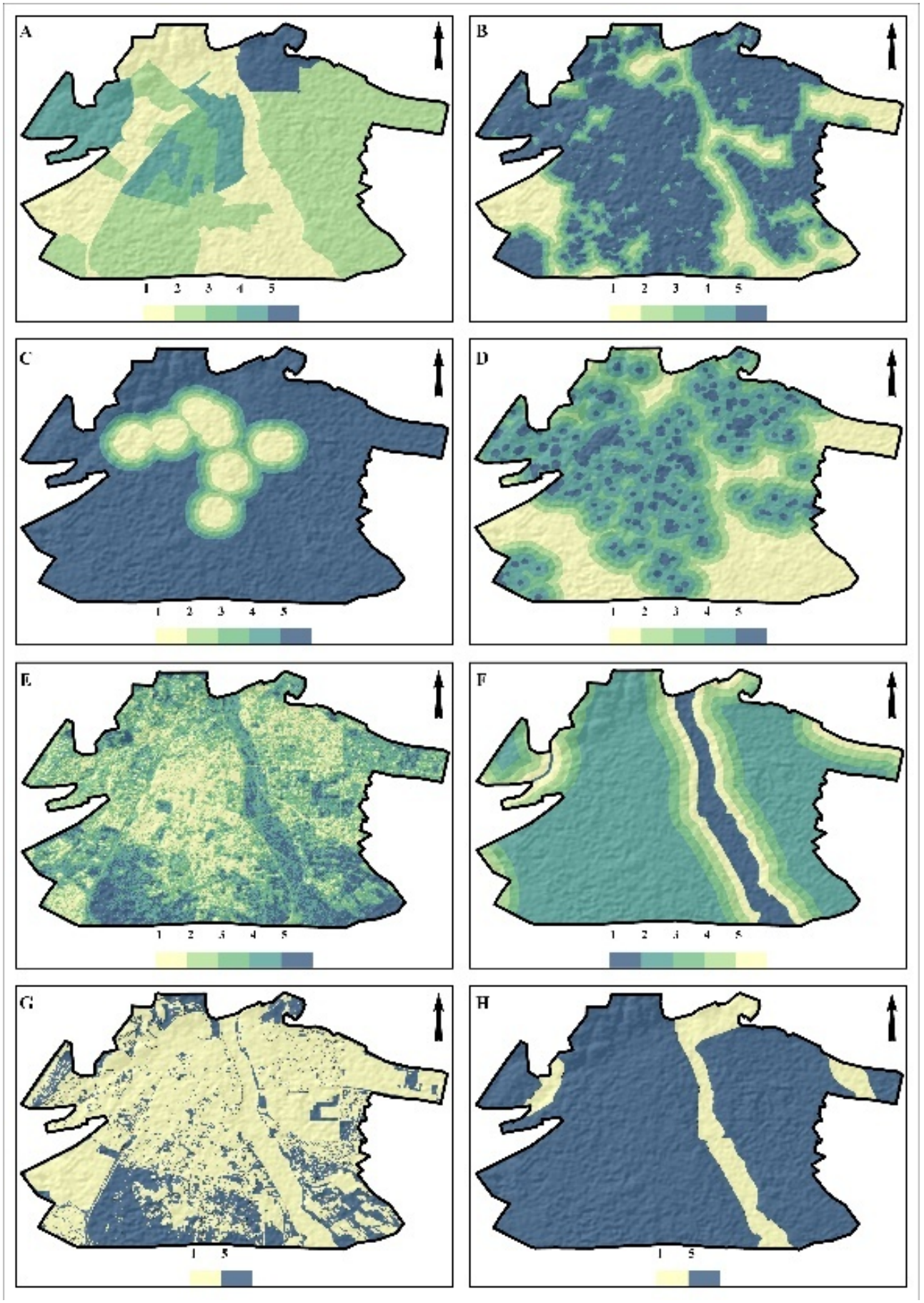
A greater distance from industrial or waste sites is typically preferred for urban agriculture and green spaces to ensure a healthier environment (Ustaoglu and Aydınoglu, 2020). Similarly, railways can contribute to pollution through emissions and noise, which may negatively affect the surrounding environment. Therefore, greater distances from these sites are generally preferred to ensure a safer and healthier environment for cultivation. This study used buffer zones around industrial sites and railways to exclude high-risk areas and guide the selection of suitable land.

Table 3

Siting Criteria for the suitability analysis

Siting Criterion	Level of suitability / Ranking					References
	5	4	3	2	1	
Population density (pop/ha)	120-170	90-120	60-90	30-60	0-30	(Li et al., 2022)
Residential proximity	< 50 m	50–100 m	100–200 m	200–300 m	> 300 m	(Smith et al., 2021; Sonneveld et al., 2021)
Green access in underserved areas	> 500 m	400–500 m	300–400 m	200–300 m	< 200 m	(Smith et al., 2021)
Cultural/Educational Proximity	< 50 m	50–200 m	200–350 m	350–500 m	> 500 m	(Smith et al., 2021; Yousefi et al., 2016)
LST	20-22 °C	19-20 °C	18-19 °C	17-18 °C	16-17 °C	(Aiymeku et al., 2024; Joy et al., 2024)
Proximity to water bodies	25–200m	200–400m	400–600 m	> 600 m	<25m	(Li et al., 2018)
Land cover	Vacant	-	-	-	Built-up	(Rogers and Hiner, 2016)
Soil type	Sandy clay	-	-	-	Gravelly	(CRSTRA, 2022)
Groundwater depth	< 5 m	5-10 m	10-25 m	25-50 m	-	(CRSTRA, 2022)
Slope	< 3%	3–6 %	6–9 %	9–12 %	> 12 %	(Gelan, 2021)
Proximity to main roads	10–100m	100–200m	200–300m	> 300 m	< 10m	(Türker and Akten, 2023)
Proximity to bus stops	< 300 m	300–600 m	600–900 m	900–1200 m	> 1200 m	(Ustaoglu and Aydınoglu, 2020)
Distance from industrial zone	> 500 m	50-500 m	-	-	< 50 m	(Ustaoglu and Aydınoglu, 2020)
Distance from railways	> 50 m	-	25–50m	-	< 25m	(Khelili et al., 2025)

After identifying the relevant criteria and preparing the corresponding thematic maps (Fig. 6), each criterion was reclassified to reflect its degree of suitability for the intended land use. To assign suitability scores for each criterion and sub-criterion, the study relied on a combination of literature review and expert consultation. Previous studies were examined to understand how each parameter influences land suitability. Each factor was reclassified into five suitability levels: Highly Suitable, Suitable, Moderately Suitable, Less Suitable, and Unsuitable, with corresponding values from 5 to 1 (Table 3). This system is based on the land evaluation framework proposed by the Food and Agriculture Organization (FAO, 2007), which has been widely used in similar studies (Gelan, 2021; Li et al., 2018). By converting continuous data into these discrete classes, the analysis becomes more consistent and allows for easier integration within the GIS-based decision-making model.


A
1 2 3 4 5
B
1 2 3 4 5
C
1 2 3 4 5
D
1 2 3 4 5
E
1 2 3 4 5
F
1 2 3 4 5
G
1 5
H
1 5

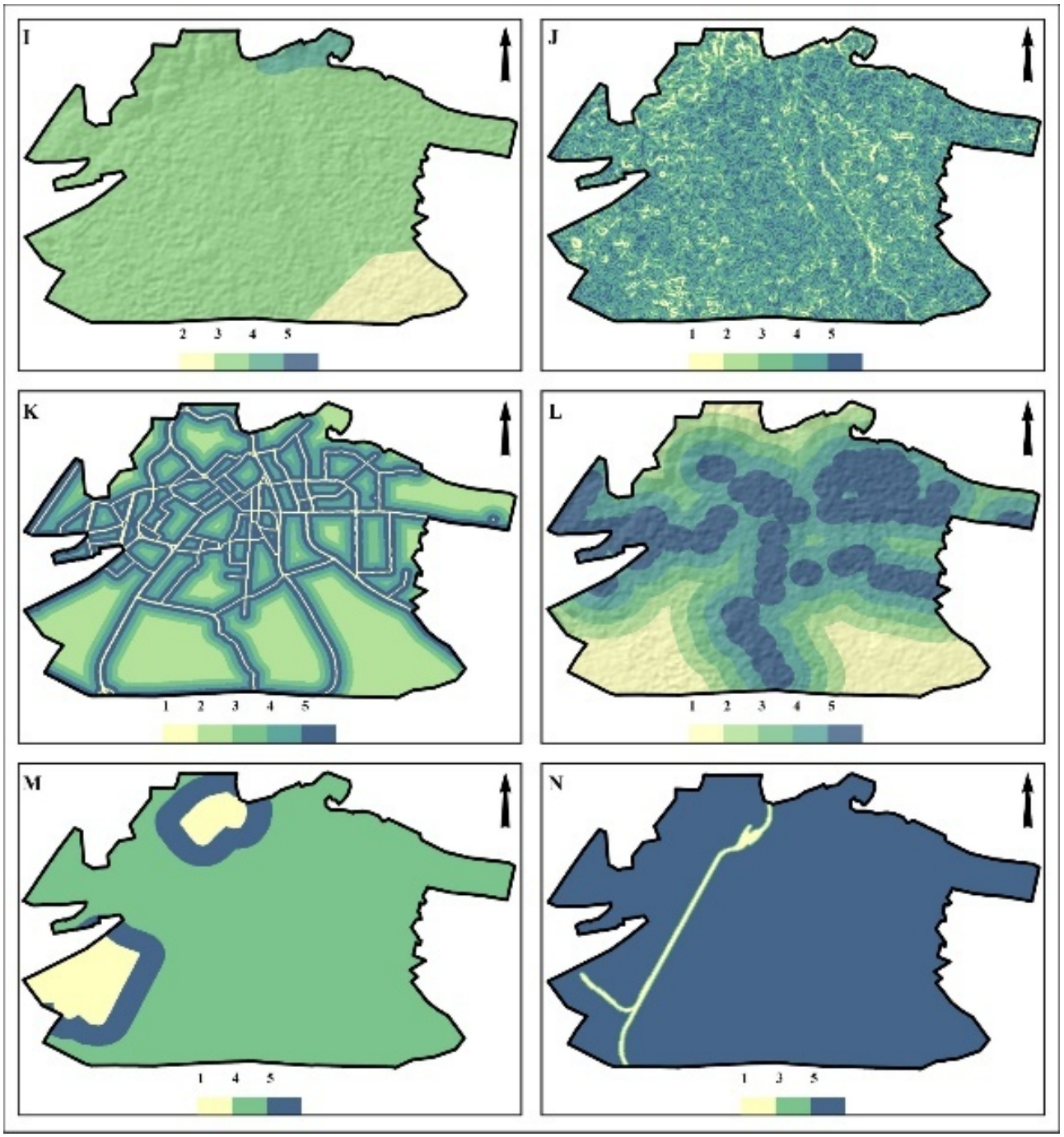


Fig. 6. Suitability Evaluation Maps by Criterion: (A) Population Density, (B) Residential Proximity, (C) Green Access in Underserved Areas, (D) Cultural/Educational Proximity, (E) Land Surface Temperature (LST), (F) Proximity to Water Bodies, (G) Land Cover, (H) Soil Type, (I) Groundwater Depth, (J) Slope, (K) Proximity to Main Roads, (L) Proximity to Bus Stops, (M) Distance from Industrial Zone, (N) Distance from Railways

!"8$9 : ;$*4($%’3&*7323&)$94*2)030$

To determine the relative importance of each criterion in the site suitability analysis, the Analytic Hierarchy Process (AHP) was used. AHP, introduced by Saaty (1980), structures complex decision problems involving multiple criteria into a hierarchical framework composed of an overall objective, main criteria, and sub-criteria (Figure 4), where each criterion is systematically compared with the

others in pairs using a standardized scale to assign relative importance values (Kumar and Pant, 2023). In this study, the key step of ranking the selected criteria through pairwise comparison was carried out by consulting a group of 10 experts, including urban planners, architects, local farmers, agronomists, and researchers.

Table 4

Composition of Experts for Criteria Ranking

Field / Expertise	Experts Included	Affiliation / Sector
Urban Planning	E1, E6	University / Municipality
Architecture	E2, E7	University / Private Practice
Agronomy	E3, E8	Agricultural Research Centre
Research	E4, E9	University
Local Farming	E5, E10	Private Sector

This diverse group (**Error! Reference source not found.**) was selected to ensure that the evaluation process reflected both academic knowledge and local experience. Establishing the relative importance was done using Saaty's (1980) 1–9 scale, where a score of 1 represents equal importance and 9 indicates extreme importance of one factor over another. Intermediate values (2, 4, 6, 8) were used to express compromise between the main levels. Expert assessments were organized into a pairwise comparison matrix, with values from the scale reflecting relative importance, reciprocals for inverse comparisons, and 1s along the diagonal. Criterion weights were then derived by calculating the matrix's principal eigenvector. The final weights and rankings of each criterion derived from this process are presented in Table 5. To validate the reliability of expert input in the pairwise comparison matrix, a consistency check was conducted. This involved calculating the Consistency Ratio $*\$$ using the standard AHP formula (3):

$$A' \% A\$ - '\$! \quad (3)$$

The consistency index $*\#$ is determined from the maximum eigenvalue of the comparison matrix $4_{\#\$}$ and the matrix order $+$:

$$A\$ \% \&4_{\#\$} (B+ - \&B (2+ \quad (4)$$

The random index $\$\#$ is obtained from standard reference values provided by Saaty for matrices of size $+$. A ($*\$$) value lower than 0.10 is generally regarded as acceptable, indicating that the judgments are consistent and the resulting weight allocations are meaningful. In this study, the calculated $*\$$ was 0.040 (i.e., 4.0%), which falls within the acceptable threshold, confirming that the pairwise comparison matrix is considered consistent and the results acceptable.

Table 5

Results from the pairwise comparison: weightage and ranking

Criteria	Weight	Rank
Population density	0.139	4
Residential proximity	0.175	2
Green access in underserved areas	0.034	9
Cultural/Educational Proximity	0.044	7
LST	0.073	5
Proximity to water bodies	0.191	1
Land cover	0.166	3
Soil type	0.013	14
Groundwater depth	0.013	13
Slope	0.017	12
Proximity to main roads	0.040	8
Proximity to bus stops	0.051	6
Distance from industrial zone	0.025	10
Distance from railways	0.020	11

The results show that proximity to water bodies (0.191), residential proximity (0.175), and land cover (0.166) hold the highest weights, while soil type (0.013), groundwater depth (0.013), and slope (0.017) are the least important criteria. The final suitability map was produced using Raster Calculator in ArcGIS by integrating reclassified raster criteria with weights derived from the AHP, according to (5):

$$CDEFGHE8EFI\ \%\ \ J\ \&K_{\%}\ 5\ A_{\%}+ \quad (5)$$

Where $K_{\%}$ is the AHP-derived weight for criterion L, $A_{\%}$ is the reclassified raster for criterion L, and M is the total number of criteria.

3. Results

1"#"$<=,+=3,>$.6$%'3&*7323&)$?2*00363/*&3.4$

The LSA for urban oasis gardens in Biskra, using a GIS-based MCA with AHP, has generated a spatial inventory of potential sites classified into five suitability classes: highly suitable, suitable, moderately suitable, less suitable, and unsuitable. The resulting suitability map (Fig. 7) shows diverse land potential across the city. Of the total evaluated area (3,743.92 ha),13.47% (504.62 ha) was classified as highly suitable. These areas cluster in the northern and western peripheries, mainly near wadis, dense populations, underserved communities, and vacant lots adjoining residential or institutional land. They combine environmental suitability with high social value, reflecting factors such as water proximity, population density, and limited green space access. Another 27.83% (1,042

ha) was identified as suitable, representing another substantial area that could support urban agriculture in the short to medium term. These areas generally exhibit favourable conditions, though some may require targeted interventions, such as improved water management, to fully unlock their potential. Moderately suitable areas, constituting 35.59% (1,332.09 ha), are spread across the city, often in locations with intermediate slopes or mixed land uses. While not meeting all optimal criteria, they remain viable for interventions. Strategic enhancements in infrastructure and land management could transform these areas into productive urban gardens. The remaining 6.07% (227.25 ha) is considered less suitable, while 17.04% (637.96 ha) is unsuitable, mainly concentrated in the southern and eastern parts. Less suitable areas often coincide with fragmented or transitional urban zones suffering from infrastructure limitations, as well as densely built-up districts with limited space, dominant impermeable surfaces, and adverse environmental conditions. The unsuitable areas primarily include industrial zones where pollution, ecological degradation constrain potential and sites with topographical limitations (e.g., high slopes).

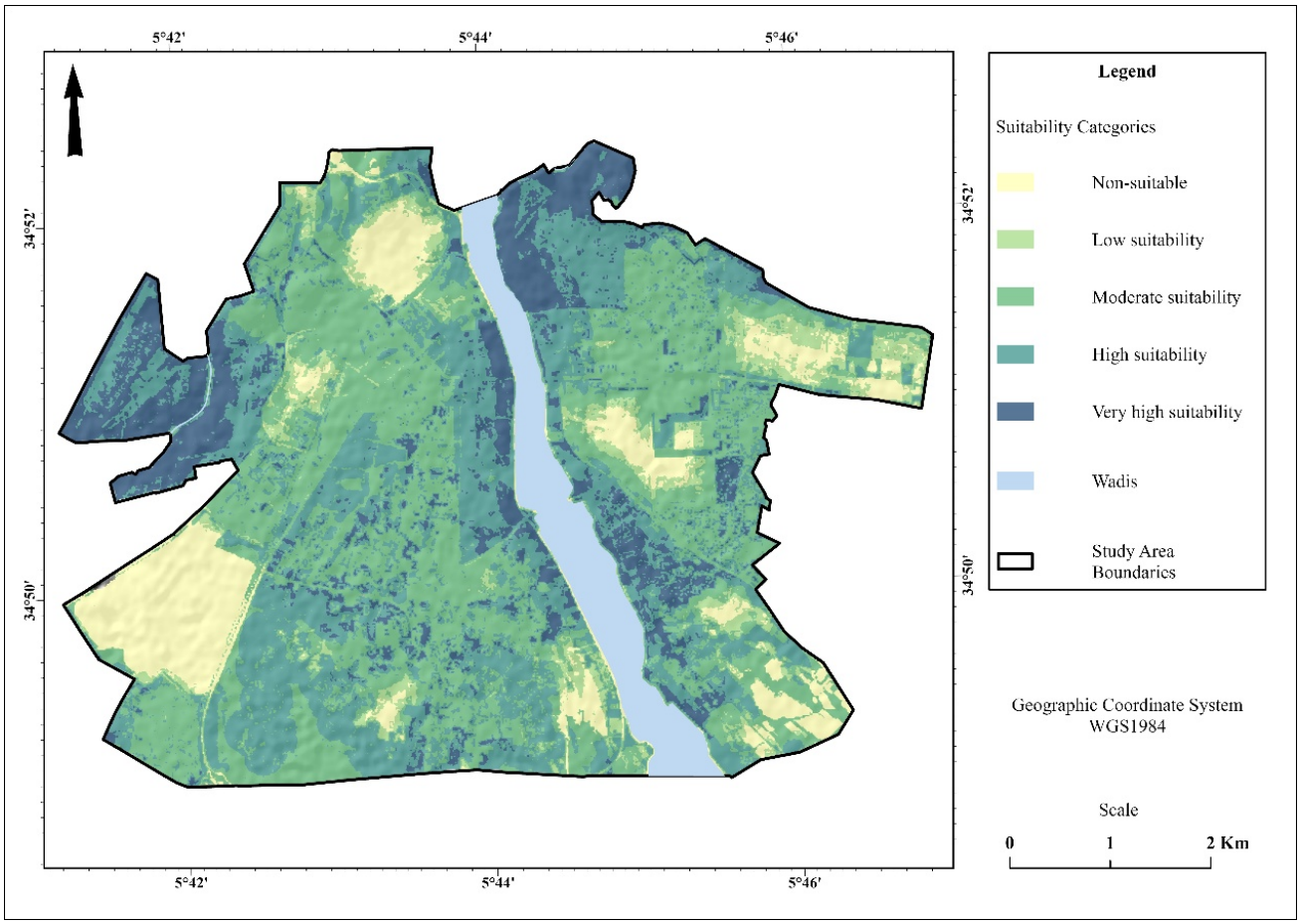


Fig. 7. Urban agricultural gardens suitability map in Biskra

The study area, covering 3,743.92 ha, was assessed for land availability by overlaying the suitability map with the vacant land inventory. Of this, 1,033.09 ha (27.6 %) were classified as vacant or

underutilised. Vacant land was concentrated in higher suitability classes: 288.88 ha (27.97 %) highly suitable, 490.31 ha (47.46 %) suitable, and 230.46 ha (22.31 %) moderately suitable, with only 11.48 ha (1.11 %) and 11.96 ha (1.16 %) in the less suitable and unsuitable classes. Combined, highly suitable and suitable land accounted for 779.19 ha (75.43 %). Spatially, highly suitable vacant parcels are primarily located in peripheral and transitional zones, often in proximity to wadis or areas of recent urban expansion. In contrast, vacant land within central and older neighbourhoods is more fragmented and limited in extent.

1"!"$%,403&3=3&)$94*2)030$*4($@.(,2$A*23(*&3.4$

A sensitivity analysis was conducted to examine the stability of the criteria ranking. Using the single-factor variation approach, each criterion weight was individually increased or decreased while the remaining weights were proportionally rescaled to maintain a total sum of one (Malinić et al., 2025). This procedure isolates the influence of each criterion and identifies the threshold at which a lower-ranked criterion surpasses its immediate neighbour in the ranking. These thresholds reveal the model's sensitivity to weight perturbations, distinguishing robust from flexible rankings. Fig. 8 shows percentage increases for lower-weighted criteria to surpass higher ones, and decreases for reversal. The results indicate differences in robustness across the hierarchy of criteria. The pair population density versus LST requires +78.61% or −43.77% to change order, indicating high stability, while LST versus bus stops is moderately stable (+40.06% / −28.57%). In contrast, water bodies versus residential proximity (+7.41% / −6.84%) and residential proximity versus land cover (+4.48% / −4.28%) are highly sensitive. Lower-ranked pairs generally show moderate stability, whereas groundwater depth versus soil type exhibits 0% thresholds, reflecting equal weights and an indifferent ranking. Overall, although some adjacent criteria are sensitive to weight changes, the majority of the ranking remains stable. Combined with a consistency ratio of 4% (CR < 10%), these results support the reliability of the derived weighting scheme.

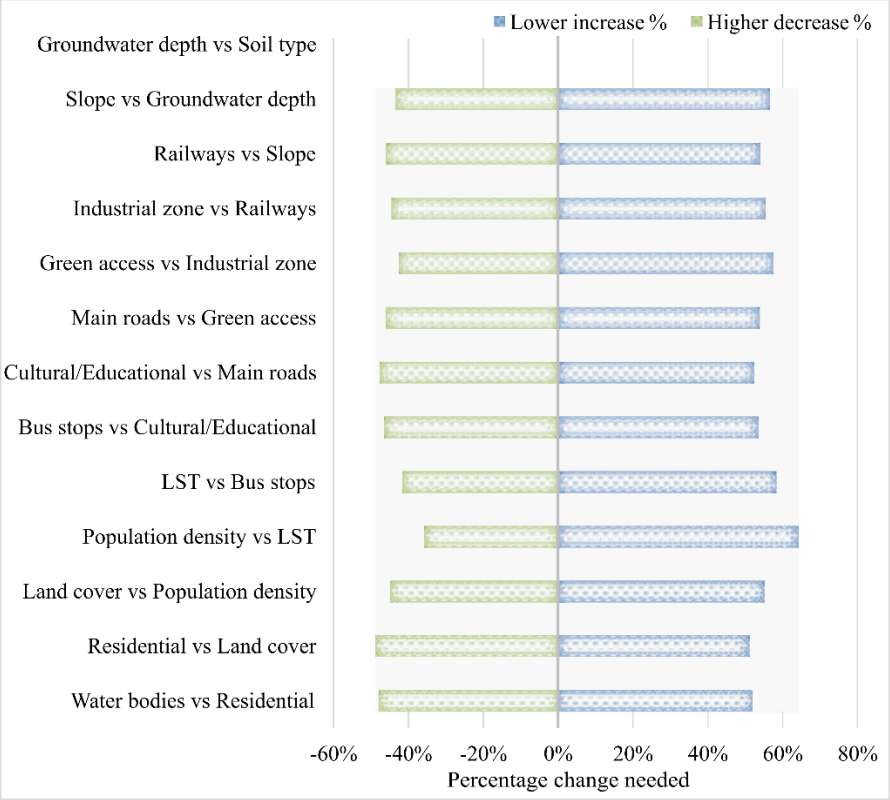


Fig. 8. Thresholds for Changes in Criteria Ranking from Sensitivity Analysis

Model validation was conducted using a random sampling and agreement-based approach. A set of 68 points was randomly generated in ArcGIS within the study area. Each point was examined using high-resolution Google Earth imagery, supported by field verification, and classified based on directly observable site conditions (e.g., land vacancy, accessibility, and presence of built structures). Observed site classes were compared with the GIS–AHP model-predicted suitability classes using a confusion matrix (Table 6). The comparison shows that 58 of 68 samples were correctly classified, resulting in an overall agreement of 0.8529. Agreement beyond chance was assessed using Cohen's kappa ($\kappa = 0.8071$), indicating substantial agreement.

Table 6:

Confusion matrix comparing Google Earth ground truth classes (rows) and AHP-predicted suitability classes (columns). (1 = Very Low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very High)

True \ Pred	1	2	3	4	5	Total
1	11	1	2	0	0	14
2	1	1	0	0	1	3
3	0	1	18	0	1	20
4	0	0	1	16	0	17
5	0	0	0	2	12	14
Total	12	3	21	18	14	68

4. Discussion

8"#"$%&+*&,53/$%3&,$%,2,/&3.4$6.+$B+7*4$<*030$C*+(,40$

The use of a GIS-based MCA, with AHP for criteria weighting, is consistent with established methods frequently employed in LSA for urban green space and agriculture planning in various urban contexts (Table 2). These studies affirm the robustness of this structured approach for weighting diverse criteria through the combination of quantitative spatial analysis and qualitative expert judgment (Kanosvamhira et al., 2025; Li et al., 2018). The AHP enabled integration of environmental indicators (e.g., LST, water proximity), socio-infrastructural factors (e.g., road access, residential proximity), and spatial justice variables (e.g., underserved areas, population density). Similar to studies conducted across Africa, Asia, and the Middle East (Kanosvamhira et al., 2025; Aiymeku et al., 2024; Ahmad Zaki et al., 2023; Türker & Akten, 2023; Nkosi et al., 2022; Gelan, 2021; Yousefi, 2016), This study applies framework that integrates key criteria including land availability, infrastructure, accessibility, and environmental conditions. However, while these studies share a similar analytical structure, the relative importance assigned to specific criteria varies according to local environmental and climatic conditions. In Biskra, environmental indicators such as LST and proximity to water, alongside infrastructural factors including road access and residential proximity, were central in determining suitability. This weighting pattern aligns with findings from studies conducted in arid and semi-arid contexts, where proximity to irrigation sources and water availability are prioritised due to climatic constraints (Yousefi et al., 2016; Mahmoud and El-Sayed, 2011). A key feature of this study is the inclusion of the LST as a suitability criterion. Although widely used in studies addressing urban heat, LULC and vegetation loss (Waleed and Sajjad, 2022), LST remains largely absent from urban agriculture suitability models. Its integration here supports site selection in areas vulnerable to urban heat, thereby introducing an environmental justice dimension. Similar observations were reported by (Jha et al., 2024), who highlighted the relevance of temperature-related indicators in guiding equitable green infrastructure planning. A comparable approach was adopted by (Aiymeku et al., 2024) in Jimma, Ethiopia, to assess urban greening suitability. Using LST, they identified urban heat hotspots in need of greening, demonstrating its value as a critical indicator for directing green infrastructure planning, particularly in rapidly urbanizing cities. The findings suggest that LST deserves further consideration in urban agriculture planning, especially in arid and heat-stressed environments where temperature regulation is essential. In Biskra, this approach is particularly relevant, as it guides the siting of urban oasis gardens where they contribute to cooling the urban environment while sustaining agriculture and enhancing well-being.

8" ! "$D*4($9=*32*7323&)$*4($;2*44345$?.40&+*34&0$$

When combined, the highly suitable and suitable areas cover about 41% of the study area, highlighting notable spatial opportunities for integrating urban oasis gardens into Biskra's urban fabric. Although urban agriculture has been successfully implemented in dense cities globally, spatial limitations remain a common challenge, particularly in rapidly urbanizing contexts. In the case of Biskra, the findings of this study reveal that land availability may not be the principal barrier, as significant spatial opportunities exist for developing productive green spaces. Nonetheless, the suitability analysis did not include data on land tenure, specifically whether the identified plots are publicly or privately owned, which limits the assessment of implementation feasibility. In the initial phase of the study, which involved mapping vacant land across neighbourhoods, priority was given to identifying publicly owned parcels. Yet, in the southern districts, particularly within the old core of Biskra, much of the vacant land corresponds to remnants of the traditional oasis system and remains under private ownership. Therefore, although some areas appear physically suitable, their legal status and institutional accessibility remain uncertain, underscoring the need to integrate cadastral and governance data to support practical planning decisions. While suitability mapping identifies a broad range of potential areas for urban oasis gardens, intersecting the results with the vacant land map shows that only about 27.6% of the study area is vacant or unbuilt. This suggests that a significant share of suitable land is already developed, occupied, or under planning constraints. In this context, suitability reflects spatial opportunity rather than immediate feasibility. Comparable challenges have been reported in other contexts. In Cape Town, for example, large areas deemed suitable were already developed or allocated for other purposes, limiting availability for urban agriculture (Kanosvamhira et al., 2025). In Boston, a study on rooftop and ground-level farming identified substantial available space, but noted that challenges related to ownership, site conditions, and urban development pressures may limit its use (Saha and Eckelman, 2017). These cases show that spatial suitability, while necessary, is insufficient; successful implementation requires aligning physical availability with legal frameworks, property rights, and planning regulations. In Algeria, the integration of urban oasis gardens faces several regulatory and institutional constraints. For example, Law 7/6 of 2007 provides the general legal framework for the management, protection, and development of green spaces, assigning responsibility to local authorities. However, the law mainly addresses ornamental and recreational functions and does not explicitly cover productive uses such as urban agriculture. Accordingly, although agriculture in green spaces is not formally prohibited, it is also not clearly recognised, creating a legal grey area that limits institutional support. As highlighted by (Makhloufi and Ghanemi, 2024) in their study of Biskra, the legal texts remain vague and difficult to apply locally. They point to the lack of technical tools, limited coordination between institutions, and

absence of clear planning instruments as major challenges. These issues create a gap between national frameworks and their practical application, particularly for multifunctional green infrastructure. Urban planning tools such as the PDAU and POS rarely designate land for agricultural use within green spaces. Reinterpreting existing laws and regulations to include productive functions would be significant. Provisions like those in Executive Decree 09-67 of 2009, which mandate classifying plant types in green spaces, could be extended to include productive species. Unlocking this spatial potential ultimately requires clarifying legal ambiguity, strengthening institutional coordination, and formally integrating productive land uses into urban planning.

8"1"$E,/.4/32345$F+*(3&3.4$>3&G$H44.=*&3.4I$E,&G34J345$B+7*4$95+3/’2&’+,$34$

?.4&,KL.+*+)$M30J+*$

Drawing on the spatial structure of the results, key insights emerge. The proximity of highly suitable areas to wadis highlights water access as a primary determinant of feasibility, an observation consistent with studies in arid and semi-arid environments (Abdelkader et al., 2023). These zones are particularly attractive for urban agriculture due to their historical association with oasis-based cultivation. The analysis identifies a pattern of linear features near wadis intersecting suitable and moderately suitable areas. These corridors could support ribbon-like oasis gardens or greenways that enhance ecological connectivity, passive cooling, and stormwater management. This spatial logic points to multifunctional design potential, echoing (Moosavi et al., 2020) on urban wadis in Muscat and (İnançoğlu et al., 2020) on green corridors for biodiversity and resilience. Another notable spatial feature is the proximity of high- and medium-suitability sites in compact urban areas to public institutions, including schools and hospitals, making them especially promising for multifunctional uses such as demonstration gardens, educational farms, or therapeutic green spaces. This vision recognises these agricultural interventions as sites of broader socio-ecological significance. As proposed by (Li et al., 2018; Mahmoud and El-Sayed, 2011), integrating such spaces enhances connectivity and sustains essential environmental and social functions. The Biskra model for siting oasis gardens on underutilised land meets global urban agriculture planning trends, as studies by (Türker and Akten, 2023; Eanes and Ventura, 2015) show the potential of such spaces for food production and community gardens. Future research could expand beyond oasis gardens to include other forms of urban agriculture, such as rooftop farming and other innovative cultivation methods, broadening sustainable food systems in Biskra. Additionally, integrating peri-urban areas into future analyses through green belts or buffer zones may enhance ecological connectivity and resilience, offering opportunities to reconcile urban growth with environmental sustainability.

Biskra's rapid and often unplanned urbanisation has eroded its traditional oasis system, with the loss of palm groves and irrigation channels (,%-./0,) contributing to increased urban heat and growing social dissatisfaction with environmental decline (Makhloufi and Ghanemi, 2024). This study does not advocate a return to historical agricultural systems as they once existed. Rather, it proposes a reinterpretation of traditional oasis principles such as water efficiency, microclimatic regulation, and multifunctional land use through contemporary planning tools and adaptive infrastructure.!These principles remain relevant but must be adapted to the spatial, environmental, and socio-demographic shifts shaping Biskra today. The socio-economic role of agriculture in Biskra has also changed significantly. Once central to daily life and economic activity, it now holds a marginal position within an increasingly service-oriented and informal urban context. Yet this transition does not diminish its potential. Instead, the proposed interventions seek to reposition agriculture in Biskra's present context as a supplementary practice with environmental and social roles, helping to move its emphasis from production to function, in line with contemporary practices where gardens are valued for more than purely economic purposes (Lin et al., 2017). In sum, reconciling tradition with innovation in Biskra involves adapting historical knowledge to contemporary challenges. Urban oasis gardens can serve as strategic nodes within a broader green infrastructure network, integrated into institutional, residential, and infrastructural settings. They offer a means to restore ecological balance and reconnect communities with their heritage. This is not a nostalgic return to the past, but a forward-looking strategy grounded in local realities and informed by global principles of sustainability, justice, and resilience.

Limitations and future work

It is important to acknowledge several limitations that affect the scope and interpretation of this study. First and foremost, the analysis is constrained by the availability, quality, and spatial resolution of input data. Several datasets, particularly those related to socio-economic conditions such as household income, employment rates, and demographic indicators, were either unavailable or insufficiently spatialized, and thus excluded from the model. Their inclusion could significantly deepen the social feasibility and equity in future analyses of urban oasis garden integration. Recent studies underscore the importance of integrating social dimensions into urban agriculture planning (Caputo et al., 2021). For example, (Li, 2023) noted that urban agriculture differs from traditional farming, requiring a distinct framework that considers not only ecological suitability but also social demand and investment conditions. His model provides valuable insights for more context-sensitive and inclusive land assessments. In addition, some criteria initially considered such as the distribution and the type of plant species within existing oasis gardens or the height of surrounding buildings, were excluded

due to the difficulty of representing them spatially at scale. These variables are relevant to microclimate regulation and aesthetic integration but require finer-resolution data. Soil data were classified into only two broad types, which limits the precision of the agricultural suitability assessment. Future studies should incorporate more detailed soil information to improve accuracy.

A second methodological limitation arises from the use of the AHP as the sole technique for weighting the relative importance of the criteria. While AHP offers a transparent and systematic structure for decision-making and facilitates the integration of expert knowledge, it is also influenced by inherent subjectivity, particularly in the pairwise comparison process. Expert judgments may carry individual biases, especially when qualitative factors are involved or consensus is difficult to establish. Suitability outcomes are strongly influenced by the selection and weighting of criteria, and changing weights significantly reshape the spatial distribution of suitable land (Ustaoglu and Aydınoglu, 2020; Abebe and Megento, 2017). Recent studies have addressed this limitation by combining AHP with other techniques, such as fuzzy logic, entropy weighting, or statistical normalization, to increase objectivity and robustness (Sonneveld et al., 2021; Ustaoglu & Aydınoglu, 2020; Z. Li et al., 2018). Due to time constraints and the exploratory scope of this study, these hybrid methods were not employed. In Biskra, this subjectivity may affect the prioritisation of environmental versus socio-infrastructural criteria, influencing the distribution of highly suitable areas. Small variations in expert judgment can change the importance of indicators such as LST or population density, linked to equity outcomes. Although sensitivity analysis suggests overall robustness, results should be seen as decision-support tools rather than definitive prescriptions. Expanding the number and diversity of experts and refining or adding criteria would enhance the robustness and accuracy of the evaluation. Beyond methodological constraints, institutional and governance limitations affect the study. The analysis did not include formal land tenure records, ownership databases, or municipal development plans, restricting the assessment of legal feasibility and stakeholder agency. The absence of engagement with municipal authorities and local communities means the model could not account for land use conflicts, political priorities, or community preferences. Finally, the study focuses on identifying suitable sites but does not explicitly model the ecological outcomes of establishing urban oasis gardens, such as temperature reduction, biodiversity enhancement, or water-use efficiency.

Future research should pursue three main directions. First, methodological refinement through hybrid weighting techniques and systematic sensitivity analyses would assess alternative scenarios and reduce subjectivity. Second, the integration of spatially explicit socio-economic and governance data, including land tenure, household income, and local regulatory frameworks, would strengthen social equity and implementation feasibility assessments. Third, coupling suitability analysis with

ecological and ecosystem service modelling would quantify potential environmental outcomes. Incorporating participatory GIS and stakeholder engagement would further ensure that model outputs align with community knowledge and local governance realities. Together, these advances would transform the methodology from a technical site selection tool into a comprehensive socio-ecological planning framework capable of guiding equitable and resilient urban oasis interventions.

5. Conclusions

This study demonstrates that a GIS-based MCA framework, integrated with AHP, provides a robust approach for assessing land suitability for urban oasis gardens in Biskra. Spatial analysis reveals that over 41% of the study area is highly suitable or suitable for oasis garden development. However, a significant portion of this suitable land is already developed or under existing land use constraints, underscoring the critical importance of integrating spatial opportunity assessments with governance frameworks and land tenure considerations in urban planning practice. Highly suitable areas cluster along wadis, urban peripheries, and underserved neighborhoods, indicating opportunities for multifunctional green spaces that can mitigate urban heat, support local food production, and improve access to green infrastructure. The inclusion of land surface temperature (LST) as a criterion illustrates how urban oasis gardens can contribute to microclimatic regulation, extending their relevance beyond food production to broader environmental and social functions. The results also highlight the potential contribution of urban oasis gardens to the food-energy-water (FEW) nexus. Proximity to water sources and integration with infrastructure corridors enable efficient water use, provide opportunities for local food production, and enhance passive cooling, demonstrating the multifunctionality of urban agriculture in arid contexts. Linear features along wadis or infrastructure corridors offer the possibility to create connected green networks that improve ecological connectivity, stormwater management, and urban resilience.

While spatial suitability identifies opportunity, translating it into actionable interventions requires coordinated policies, governance, and community involvement that align biophysical potential with institutional and social realities.

Planning Implications

#+,1/1.1/2+03! 0+&! $%-.301245! $%247,8 Update urban green space laws to formally recognize productive urban agriculture and integrate it into local planning instruments. Incorporate cadastral and land tenure data into suitability assessments and establish a municipal urban agriculture coordination unit to facilitate cross-sector collaboration and technical support.

’0+&!)%+.4%!0+&!9%4/10-%!:421%;1/2+8 Designate traditional oasis remnants in southern districts as cultural and ecological heritage sites. Enable controlled, multifunctional use through public-private partnerships, temporary agreements, or incentives for private owners. Integrate these sites into the urban green network to enhance connectivity, ecosystem services, and preserve Biskra’s agricultural identity.

**277.+/15!<+-0-%7%+1!0+&!(2;/03!#+;3.,/2+8* Engage residents in participatory mapping and site design to improve spatial equity and incorporate local knowledge. Promote co-management through community land organizations, cooperatives, or garden associations. Develop educational and therapeutic gardens in underserved neighbourhoods to foster social inclusion, environmental literacy, and public health benefits.

(1401%-/;!=4>0+!:30++/+-!0+&!:?0,%&!#7@3%7%+101/2+8 Prioritize highly suitable areas for immediate development while targeting moderately suitable zones for intervention. Establish linear corridors along wadis as connected greenways to reduce urban heat, support biodiversity, manage stormwater, and accommodate multifunctional urban agriculture. Sequence implementation according to site readiness, institutional capacity, and community demand to enable adaptive, iterative planning.

By linking spatial analysis with socio-institutional and legal realities, this study shows that urban oasis gardens are not only technically feasible but also socially and environmentally meaningful. They offer a means to reconcile Biskra’s traditional oasis heritage with contemporary sustainability needs, providing multifunctional green spaces that serve ecological, social, and climatic functions. This research contributes to sustainable urbanism by offering a replicable framework for integrating productive green infrastructure into rapidly urbanizing arid cities. It demonstrates how underutilized urban land can enhance ecological resilience, support the (FEW) nexus, and ensure equitable access to multifunctional green spaces, bridging technical spatial analysis with socio-institutional realities to guide inclusive and context-sensitive urban development.

Acknowledgements

Acknowledgement is made to the University of Kent for hosting the main author as a visiting student and for facilitating this research collaboration.

Declaration of Generative AI

:0@%4@03 was employed during manuscript preparation for grammar and clarity checking. The content was thoroughly reviewed and edited to ensure accuracy and originality, and full responsibility is accepted for the final version.

CRediT authorship contribution statement

Kenza Torai: Writing – original draft, Conceptualization, Methodology, Investigation, Formal analysis, Data curation. **Soumia Bouzaher**: Supervision, Conceptualization, Writing – review & editing. **Silvio Caputo**: Conceptualization, Supervision, Writing – review & editing. **Valentina Manente**: Conceptualization, Writing – review & editing. **Mohammed Khelili**: Methodology, Data curation.

Data availability

Data will be made available on request.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

6. References

Abdelkader, M.M., Mahmoud, U.F., Mobasher, A.M., Reda, M.A., 2023. Multi-criteria decision support system for selecting the rainwater harvesting technique in wadi systems, Sinai, Egypt. Water Pract. Technol. 18, 701–715. https://doi.org/10.2166/wpt.2023.031

Abdou, Y., Djamel, A., 2022. Study of the Spatial Growth Factors by the use of the Fractal Analysis Case Study City of Biskra. International Journal of Innovative Studies in Sociology and Humanities 7, 1–12. https://doi.org/10.20431/2456-4931.0702001

Abebe, M.T., Megento, T.L., 2017. Urban green space development using GIS-based multi-criteria analysis in Addis Ababa metropolis. Applied Geomatics 9, 247–261. https://doi.org/10.1007/s12518-017-0198-7

Abulibdeh, A., 2021. Analysis of urban heat island characteristics and mitigation strategies for eight arid and semi-arid gulf region cities. Environ. Earth Sci. 80, 259. https://doi.org/10.1007/s12665-021-09540-7

Ahmad Zaki, Z., Yusup, M., Che Abdullah, I., Abdullah, Y.A., Abdul Halim Shah, A.S., 2023. Land suitability analysis for urban gardening using GIS-based multi-criteria decision-making approach. Planning Malaysia. https://doi.org/10.21837/pm.v21i29.1379

Ahriz, A., Fezzai, S., Mady AA, M., 2019. Predicting the limits of the oasis effect as a cooling phenomenon in hot deserts. Desert 24, 255–266. https://doi.org/10.22059/jdesert.2019.76384

Aiymeku, T.G., Tabor, K.W., Wedajo, G.D., Roba, Z.R., 2024. Green spaces suitability analysis for urban resilience using geospatial technology: the case of Jimma city, Oromia, Ethiopia. Environ. Dev. Sustain. https://doi.org/10.1007/s10668-023-04365-9

Akaeze, O., Nandwani, D., 2020. Urban agriculture in Asia to meet the food production challenges of urbanization: A review. Urban Agriculture & Regional Food Systems 5, e20002. https://doi.org/10.1002/uar2.20002

Akıncı, H., Özalp, A.Y., Turgut, B., 2013. Agricultural land use suitability analysis using GIS and AHP technique. Comput. Electron. Agric. 97, 71–82. https://doi.org/10.1016/j.compag.2013.07.006

Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., Gottwald, S., Guerrero, P., Nicolas, C., Matzdorf, B., 2019. Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? Landsc. Urban Plan. 182, 12–21. https://doi.org/10.1016/j.landurbplan.2018.10.003

Aliani, Hamide, Ghanbari Motlagh, M., Danesh, G., Aliani, Hamed, 2021. Land suitability analysis for urban development using TOPSIS, WLC and ANP techniques (Eastern cities of Gilan-Iran). Arabian Journal of Geosciences 14, 1276. https://doi.org/10.1007/s12517-021-07606-1

Al-Johari, E., Sharaf, F., 2024. A Land Suitability Model of Urban Agriculture: The Case of Amman City in Jordan. Univers. J. Agric. Res. 12, 211–224. https://doi.org/10.13189/ujar.2024.120201

Amani-Beni, M., Xie, G., Yang, Q., Russo, A., Khalilnezhad, M.R., 2022. Socio-Cultural Appropriateness of the Use of Historic Persian Gardens for Modern Urban Edible Gardens. Land (Basel). 11. https://doi.org/10.3390/land11010038

Amrani, K., 2023. Typologie des oasis algériennes : pour une meilleure considération de ces espaces fertiles dans un milieu aride. Cas de la palmeraie de Ouargla. VertigO 23, 1–20. https://doi.org/10.4000/vertigo.40171

Anderson, V., Gough, W.A., Agic, B., 2021. Nature-Based Equity: An Assessment of the Public Health Impacts of Green Infrastructure in Ontario Canada. Int. J. Environ. Res. Public Health 18. https://doi.org/10.3390/ijerph18115763

Bekele, N.K., Hailu, B.T., Suryabhagavan, K.V., 2022. Spatial patterns of urban blue-green landscapes on land surface temperature: A case of Addis Ababa, Ethiopia. Current Research in Environmental Sustainability 4, 100146. https://doi.org/10.1016/j.crsust.2022.100146

Beskese, A., Demir, H.H., Ozcan, H.K., Okten, H.E., 2015. Landfill site selection using fuzzy AHP and fuzzy TOPSIS: a case study for Istanbul. Environ. Earth Sci. 73, 3513–3521. https://doi.org/10.1007/s12665-014-3635-5

Binte Mostafiz, R., Noguchi, R., Ahamed, T., 2021. Agricultural Land Suitability Assessment Using Satellite Remote Sensing-Derived Soil-Vegetation Indices. Land (Basel). 10. https://doi.org/10.3390/land10020223

Bounoua, L., Bachir, N., Souidi, H., Bahi, H., Lagmiri, S., Khebiza, M.Y., Nigro, J., Thome, K., 2023. Sustainable Development in Algeria's Urban Areas: Population Growth and Land Consumption. Urban Science 7. https://doi.org/10.3390/urbansci7010029

Bouzaher, S., 2015. Un aménagement durable par un projet éco touristique ; Cas des ksour de la micro région des Ziban. Le redressement d'un circuit éco touristique (Thèse de Doctorat d'État). University Mohamed Khider of Biskra.

Bouzaher, S., Alkama, D., 2013. The Requalification of the Palm Trees of Ziban as a Tool for Sustainable Planning. Procedia Soc. Behav. Sci. 102, 508–519. https://doi.org/10.1016/j.sbspro.2013.10.767

Bouzaher, S., Alkama, D., 2012. Palm trees reuses as sustainable element in the Sahara.The case of Ziban, as self-sustainable urban units. Energy Procedia 18, 1076–1085. https://doi.org/10.1016/j.egypro.2012.05.122

Bressane, A., Loureiro, A.I.S., Medeiros, L.C. de C., Negri, R.G., Goulart, A.P.G., 2024. Overcoming Barriers to Managing Urban Green Spaces in Metropolitan Areas: Prospects from a Case Study in an Emerging Economy. Sustainability 16. https://doi.org/10.3390/su16167019

Caputo, S., Schoen, V., Specht, K., Grard, B., Blythe, C., Cohen, N., Fox-Kämper, R., Hawes, J., Newell, J., Poniży, L., 2021. Applying the food-energy-water nexus approach to urban agriculture: From FEW to FEWP (Food-Energy-Water-People). Urban For. Urban Green. 58, 126934. https://doi.org/10.1016/j.ufug.2020.126934

CBE, 2023. Center for the Built Environment (CBE) Clima Tool [WWW Document]. https://clima.cbe.berkeley.edu/.

Chabuk, A.J., Al-Ansari, N., Hussain, H.M., Knutsson, S., Pusch, R., 2017. GIS-based assessment of combined AHP and SAW methods for selecting suitable sites for landfill in Al-Musayiab Qadhaa, Babylon, Iraq. Environ. Earth Sci. 76, 209. https://doi.org/10.1007/s12665-017-6524-x

Chandio, I., Matori, A., Dano, Dr.U.L., Student, L., Sabri, S., Student, P., 2011. GIS-based Land Suitability Analysis Using AHP for Public Parks Planning in Larkana City. Mod. Appl. Sci. 5. https://doi.org/10.5539/mas.v5n4p177

Cote, M., 2014. Le Sahara: barrière ou pont? Méditerranée, Presses universitaires de Provence.

Cote, M., 1991. Biskra. Encyclopédie berbère 1517–1522. https://doi.org/10.4000/encyclopedieberbere.1761

CRSTRA, 2022. Groundwater depth and soil type map [dataset].

Czechowski, D., Hauck, T., Hausladen, G., 2014. Revising green infrastructure: Concepts between nature and design. CRC Press (Taylor & Fransis). https://doi.org/https://doi.org/10.1201/b17639

Dechaicha, A., Alkama, D., 2020. Détection du changement de l'étalement urbain au Bas-Sahara algérien: apport de la télédétection spatiale et des SIG. Cas de la ville de Biskra (Algérie). Revue Française de Photogrammétrie et de Télédétection 43–51. https://doi.org/10.52638/rfpt.2020.486

Di Leo, N., Escobedo, F.J., Dubbeling, M., 2016. The role of urban green infrastructure in mitigating land surface temperature in Bobo-Dioulasso, Burkina Faso. Environ. Dev. Sustain. 18, 373–392. https://doi.org/10.1007/s10668-015-9653-y

Drake, L., Ravit, B., Lawson, L., 2016. Developing a vacant property inventory through productive partnerships: A university, NGO, and municipal planning collaboration in Trenton, New Jersey. Cities Environ. 8, 6. https://doi.org/10.15365/1932-7048.1178

Eanes, F., Ventura, S.J., 2015. Inventorying land availability and suitability for community gardens in Madison, Wisconsin. Cities Environ. 8, 2. https://doi.org/10.15365/1932-7048.1166

English Nature (John Handley et al)., 2003. Accessible Natural Green Space Standards in Towns and Cities: A Review and Toolkit for their Implementation. English Nature Research Reports. Northminster House, Peterborough PE1 1UA.

FAO, 2007. Land evaluation, Towards a revised framework. FAO, Rome, Italy.

Farhi, A., 2002. Biskra : de l'oasis à la ville saharienne. Méditerranée-Le Sahara, cette «autre Méditerranée» (Fernand Braudel) 99, 77–82. https://doi.org/10.3406/medit.2002.3264

Gelan, E., 2021. GIS-based multi-criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia: the case of Sululta town. Environmental Systems Research 10, 13. https://doi.org/10.1186/s40068-021-00220-w

Giudice, B., Novarina, G., Voghera, A., 2023. Framing Green and Blue Infrastructure, in: Giudice, B., Novarina, G., Voghera, A. (Eds.), Green Infrastructure: Planning Strategies and Environmental Design. Springer International Publishing, Cham, pp. 1–11. https://doi.org/10.1007/978-3-031-28772-5_1

Grahn, P., Stigsdotter, U.A., 2003. Landscape planning and stress. Urban For. Urban Green. 2, 1–18. https://doi.org/10.1078/1618-8667-00019

Hadagha, F.Z., 2022. L'écosystème oasien et les enjeux de la programmation environnementale. Cas d'étude ; la ville de Biskra, Algérie. (Doctoral thesis). University Mohamed Khider of Biskra, Algeria, Biskra.

Hadagha, F.Z., Farhi, B., Farhi, A., Petrisor, A.-I., 2018. Multifunctionality of the oasis ecosystem. Case study: Biskra Oasis, Algeria. Journal of Contemporary Urban Affairs 2. https://doi.org/10.25034/ijcua.2018.4716

Hadji, M., Petrisor, A.-I., 2024. From agricultural oasis to urbanization: path of oasis green infrastructures in Biskra, Algeria. Scientific Papers. Series B. Horticulture 621–628.

Hamamouche, M.F., Kuper, M., Amichi, H., Lejars, C., Ghodbani, T., 2018. New reading of Saharan agricultural transformation: Continuities of ancient oases and their extensions (Algeria). World Dev. 107, 210–223. https://doi.org/10.1016/j.worlddev.2018.02.026

Hansen, R., Pauleit, S., 2014. From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas. Ambio 43, 516–529. https://doi.org/10.1007/s13280-014-0510-2

İnançoğlu, S., Özden, Ö., Kara, C., 2020. Green Corridors in Urban Landscapes, Case Study Nicosia Pedieos River. European Journal of Sustainable Development 9, 1. https://doi.org/10.14207/ejsd.2020.v9n1p1

Jabbar, M., Yusoff, M.M., Shafie, A., 2022. Assessing the role of urban green spaces for human well-being: a systematic review. GeoJournal 87, 4405–4423. https://doi.org/10.1007/s10708-021-10474-7

James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste, J., Elmqvist, T., Frith, M., Gordon, C., Greening, K.L., Handley, J., Haworth, S., Kazmierczak, A.E., Johnston, M., Korpela, K., Moretti, M., Niemelä, J., Pauleit, S., Roe, M.H., Sadler, J.P., Ward Thompson, C., 2009. Towards an integrated understanding of green space in the European built environment. Urban For. Urban Green. 8, 65–75. https://doi.org/10.1016/j.ufug.2009.02.001

Jandaghian, Z., Colombo, A., 2024. The Role of Water Bodies in Climate Regulation: Insights from Recent Studies on Urban Heat Island Mitigation. Buildings 14. https://doi.org/10.3390/buildings14092945

Jarah, S.H. Al, Zhou, B., Abdullah, R.J., Lu, Y., Yu, W., 2019. Urbanization and Urban Sprawl Issues in City Structure: A Case of the Sulaymaniah Iraqi Kurdistan Region. Sustainability 11. https://doi.org/10.3390/su11020485

Jardins d'Orient, 2016. Jardins d'Orient - De l'Alhambra au Taj Mahal, SNOECK. ed. SNOECK - l'Institut du monde arabe, Paris.

Jha, P., Joy, M.S., Yadav, P.K., Begam, S., Bansal, T., 2024. Detecting the role of urban green parks in thermal comfort and public health for sustainable urban planning in Delhi. Discover Public Health 21, 236. https://doi.org/10.1186/s12982-024-00368-7

Joy, M.S., Jha, P., Yadav, P.K., Bansal, T., Rawat, P., Begam, S., 2024. Site suitability analysis of urban green parks in Ranchi city using GIS–AHP based multi-criteria decision analysis. Urbanization, Sustainability and Society 1, 169–198. https://doi.org/10.1108/USS-10-2023-0008

Kabisch, N., Haase, D., 2013. Green spaces of European cities revisited for 1990–2006. Landsc. Urban Plan. 110, 113–122. https://doi.org/10.1016/j.landurbplan.2012.10.017

Kanosvamhira, T.P., Tatenda, M., and Mupepi, O., 2025. The potential for urban agriculture (UA) in Cape Town, South Africa: a suitability analysis. Ann. GIS 31, 107–122. https://doi.org/10.1080/19475683.2025.2455430

Kêdowidé, C., 2010. Modélisation géomatique par évaluation multicritère pour la prospection des sites d'agriculture urbaine à Ouagadougou. VertigO 10. https://doi.org/10.4000/vertigo.10368

Khelili, M., Anoune, N., Haoues, C., Khedidja, A., Drifi, N., Chorfi, K., 2025. Multi-Criteria Evaluation of Land Suitability for Urban Extension Areas Identified in the PDAU of Setif City Using GIS and AHP. International Journal of Geoinformatics 21, 78–93. https://doi.org/10.52939/ijg.v21i11.4603

Kil, S.-H., Park, H.-M., Park, M., Kim, Y.I., Lee, E., 2023. Location Selection of Urban Rooftop Greenhouses in Seoul Based on AHP and GIS. Land (Basel). 12. https://doi.org/10.3390/land12122187

Kouzmine, Y., Fontaine, J., 2018. Démographie et urbanisation au Sahara algérien à l'aube du XXIe siècle. Les Cahiers d'EMAM. Études sur le Monde Arabe et la Méditerranée. https://doi.org/10.4000/emam.1426

Kumar, A., Pant, S., 2023. Analytical hierarchy process for sustainable agriculture: An overview. MethodsX 10, 101954. https://doi.org/10.1016/j.mex.2022.101954

Kurochkina, V., 2020. Urban water bodies as the basis for functioning of public spaces, E3S Web of Conferences. https://doi.org/10.1051/e3sconf/202021702005

Law 7/6, 2007. Law 7/6. The Official Gazette No. 31, Algeria.

Leal, J.E., 2020. AHP-express: A simplified version of the analytical hierarchy process method. MethodsX 7, 100748. https://doi.org/10.1016/j.mex.2019.11.021

Li, C., Zhang, T., Wang, X., Lian, Z., 2022. Site Selection of Urban Parks Based on Fuzzy-Analytic Hierarchy Process (F-AHP): A Case Study of Nanjing, China. Int. J. Environ. Res. Public Health 19. https://doi.org/10.3390/ijerph192013159

Li, J., 2023. Land suitability analysis of urban agriculture for different investment scenarios: Evidence from fuzhou of China. Heliyon 9. https://doi.org/10.1016/j.heliyon.2023.e20817

Li, Z., Fan, Z., Shen, S., 2018. Urban Green Space Suitability Evaluation Based on the AHP-CV Combined Weight Method: A Case Study of Fuping County, China. Sustainability 10. https://doi.org/10.3390/su10082656

Lin, B.B., Philpott, S.M., Jha, S., Liere, H., 2017. Urban Agriculture as a Productive Green Infrastructure for Environmental and Social Well-Being, in: Tan, P.Y., Jim, C.Y. (Eds.), Greening Cities: Forms and Functions. Springer Singapore, Singapore, pp. 155–179. https://doi.org/10.1007/978-981-10-4113-6_8

Mahmoud, A.H.A., El-Sayed, M.A., 2011. Development of sustainable urban green areas in Egyptian new cities: The case of El-Sadat City. Landsc. Urban Plan. 101, 157–170. https://doi.org/10.1016/j.landurbplan.2011.02.008

Makhloufi, S., Ghanemi, F., 2024. Analyzing the regulatory and practical challenges of urban green spaces in arid cities: A Case study of Biskra, Algéria. International Journal of Sustainable Building Technology and Urban Development 15, 563–576. https://doi.org/10.22712/susb.20240039

Malczewski, J., 2004. GIS-based land-use suitability analysis: a critical overview. Prog. Plann. 62, 3–65. https://doi.org/10.1016/j.progress.2003.09.002

Malinić, V., Durlević, U., Brašanac-Bosanac, L., Novković, I., Joksimović, M., Golić, R., Krstić, F., 2025. A Hybrid Fuzzy AHP–MULTIMOORA Approach for Solar Energy Development on Rural Brownfield Sites in Serbia. Sustainability 17. https://doi.org/10.3390/su17177988

Masoudi, M., Tan, P.Y., 2019. Multi-year comparison of the effects of spatial pattern of urban green spaces on urban land surface temperature. Landsc. Urban Plan. 184, 44–58. https://doi.org/10.1016/j.landurbplan.2018.10.023

Matallah, M.E., Ahriz, A., Zitouni, D.C., Arrar, H.F., Ratmia, M.A.E. Ben, Attia, S., 2023. A methodological approach to evaluate the passive cooling effect of Oasis palm groves. Sustain. Cities Soc. 99, 104887. https://doi.org/10.1016/j.scs.2023.104887

Matallah, M.E., Alkama, D., Teller, J., Ahriz, A., Attia, S., 2021. Quantification of the Outdoor Thermal Comfort within Different Oases Urban Fabrics. Sustainability 13. https://doi.org/10.3390/su13063051

Mattingly, D.J., Sterry, M., Al-Haddad, M., Trousset, P., 2020. Pre-Islamic Oasis Settlements in the Northern Sahara, in: Sterry, M., Mattingly, D.J. (Eds.), Urbanisation and State Formation in the Ancient Sahara and Beyond, Trans-Saharan Archaeology. Cambridge University Press, Cambridge, pp. 187–238. https://doi.org/10.1017/9781108637978.006

McClintock, N., Cooper, J., Khandeshi, S., 2013. Assessing the potential contribution of vacant land to urban vegetable production and consumption in Oakland, California. Landsc. Urban Plan. 111, 46–58. https://doi.org/10.1016/j.landurbplan.2012.12.009

Meouak, M., 2017. Les Ziban entre Aurès et Sahara: une géographie historique de Biskra et de ses oasis du Moyen Âge à la fin de l'époque moderne, 2017th ed, Suomalaisen Tiedeakatemian toimituksia: Sarja Humaniora. Academia Scientiarum Fennica.

Mohamad Selamat, I.A., Maruthaveeran, S., Mohd Yusof, M.J., Shahidan, M.F., 2023. Planning Tools to Revitalise Urban Vacant Land from Ecological Perspectives: A Systematic Review. Urban Science 7. https://doi.org/10.3390/urbansci7020058

Moisa, M.B., Biratu Bobo, M., Kiros Tsegay, D., Muleta Ebissa, F., Mengistu Muleta, G., and Gemeda, D.O., 2023. Urban green space suitability analysis using geospatial techniques: a case study of Addis Ababa, Ethiopia. Geocarto Int. 38, 2213674. https://doi.org/10.1080/10106049.2023.2213674

Moosavi, S., Margaret J., G., and Lake, P.S., 2020. Wadis as dryland river parks: challenges and opportunities in designing with hydro-ecological dynamics. Landsc. Res. 45, 193–213. https://doi.org/10.1080/01426397.2019.1592132

Morell, J.R., 1854. Algeria the Topography and History, Political, Social and Natural of French Africa. Nathaniel Cooke Milford House.

Muhsin, N., Noguchi, R., Ahamed, T., 2022. GIS-Based MCA Modeling to Locate Suitable Industrial Sites in Suburb Areas of Bangladesh for Sustainability of Agricultural Lands, in: Ahamed, T. (Ed.), Remote Sensing Application: Regional Perspectives in Agriculture and Forestry. Springer Nature Singapore, Singapore, pp. 185–214. https://doi.org/10.1007/978-981-19-0213-0_7

Muñoz, L.S., Duarte, D.H.S., 2025. Green infrastructure as a planning tool: A comprehensive systematization of urban redesign strategies to increase vegetation within public places. Cities 156, 105551. https://doi.org/10.1016/j.cities.2024.105551

Murayama, Y., Thapa, Rajesh B, 2011. Spatial Analysis: Evolution, Methods, and Applications, in: Murayama, Y., Thapa, Rajesh Bahadur (Eds.), Spatial Analysis and Modeling in Geographical Transformation Process: GIS-Based Applications. Springer Netherlands, Dordrecht, pp. 1–26. https://doi.org/10.1007/978-94-007-0671-2_1

Newell, J.P., Foster, A., Borgman, M., Meerow, S., 2022. Ecosystem services of urban agriculture and prospects for scaling up production: A study of Detroit. Cities 125, 103664. https://doi.org/10.1016/j.cities.2022.103664

Nkosi, D.S., Moyo, T., Musonda, I., 2022. Unlocking Land for Urban Agriculture: Lessons from Marginalised Areas in Johannesburg, South Africa. Land (Basel). 11. https://doi.org/10.3390/land11101713

Omar, S.S., Ilias, N., Teh, M.Z., Borhan, R., 2018. Green Mosque: A Living Nexus. Environment-Behaviour Proceedings Journal 3. https://doi.org/10.21834/e-bpj.v3i7.1281

Parece, T., Campbell, J., 2017. Geospatial Evaluation for Urban Agriculture Land Inventory: Roanoke, Virginia USA. International Journal of Applied Geospatial Research 8, 43–63. https://doi.org/10.4018/IJAGR.2017010103

Purnamasari, R.A., Noguchi, R., Ahamed, T., 2022. Land Suitability Assessment for Cassava Production in Indonesia Using GIS, Remote Sensing, and Multi-Criteria Analysis, in: Ahamed, T. (Ed.), Remote Sensing Application: Regional Perspectives in Agriculture and Forestry. Springer Nature Singapore, Singapore, pp. 99–132. https://doi.org/10.1007/978-981-19-0213-0_4

Raddad, S., 2016. Integrated a GIS and Multi Criteria Evaluation Approach for Suitability Analysis of Urban Expansion in Southeastern Jerusalem Region-Palestine 2016, 24–31. https://doi.org/10.5923/j.ajgis.20160501.03

Rais, S., Bouzaher, S., 2021. Sustainable Touristic Strategies in the Colonial Period in Biskra city: Lessons and Perspectives. Strategy & Development Review 11.

Rogers, C.M., Hiner, C.C., 2016. Siting Urban Agriculture as a Green Infrastructure Strategy for Land Use Planning in Austin, TX. Challenges in Sustainability 4. https://doi.org/10.12924/cis2016.04010039

Russo, R. de F.S.M., Camanho, R., 2015. Criteria in AHP: A Systematic Review of Literature. Procedia Comput. Sci. 55, 1123–1132. https://doi.org/10.1016/j.procs.2015.07.081

Saaty, T.L., 1980. The analytic hierarchy process : planning, priority setting, resource allocation. New York London: McGraw-Hill.

Saeedavi, Z., Khalili Moghadam, B., Bagheri Bodaghabadi, M., Rangzan, N., 2017. Land suitability assessment for urban green space using AHP and GIS: A case study of Ahvaz parks, Iran. Desert 22, 117–133. https://doi.org/10.22059/jdesert.2017.62174

Saha, M., Eckelman, M.J., 2017. Growing fresh fruits and vegetables in an urban landscape: A geospatial assessment of ground level and rooftop urban agriculture potential in Boston, USA. Landsc. Urban Plan. 165, 130–141. https://doi.org/10.1016/j.landurbplan.2017.04.015

Saharaoui, L., Bada, Y., 2021. La planification urbaine et la gestion foncière en Algérie: quelle durabilité? Cas de la ville de Blida. Cybergeo: European Journal Of Geography. https://doi.org/10.4000/cybergeo.36229

Semahi, S., Zemmouri, N., Singh, M.K., Attia, S., 2019. Comparative bioclimatic approach for comfort and passive heating and cooling strategies in Algeria. Build. Environ. 161, 106271. https://doi.org/10.1016/j.buildenv.2019.106271

Shahin, M., 2007. Wadis and Wadi Flow, in: Shahin, M. (Ed.), Water Resources and Hydrometeorology of the Arab Region. Springer Netherlands, Dordrecht, pp. 279–332. https://doi.org/10.1007/1-4020-5414-9_7

Sidi Boumedine, R., 2013. L'urbanisme en Algérie: échec des instruments ou instruments de l'échec ? Alternatives urbaines.

Smith, J.P., Li, X., Turner, B.L., 2017. Lots for greening: Identification of metropolitan vacant land and its potential use for cooling and agriculture in Phoenix, AZ, USA. Applied Geography 85, 139–151. https://doi.org/10.1016/j.apgeog.2017.06.005

Smith, J.P., Meerow, S., Turner, B.L., 2021. Planning urban community gardens strategically through multicriteria decision analysis. Urban For. Urban Green. 58, 126897. https://doi.org/10.1016/j.ufug.2020.126897

Sonneveld, B.G.J.S., Houessou, M.D., van den Boom, G.J.M., Aoudji, A., 2021. Where Do I Allocate My Urban Allotment Gardens? Development of a Site Selection Tool for Three Cities in Benin. Land (Basel). 10. https://doi.org/10.3390/land10030318

Tafliha, I.N., 2020. Landscape Evaluation of Mosque Garden Based on the Concept of Islam. Journal of Islamic Architecture 6. https://doi.org/10.18860/jia.v6i2.8028

Taripanah, F., Ranjbar, A., 2021. Quantitative analysis of spatial distribution of land surface temperature (LST) in relation Ecohydrological, terrain and socio- economic factors based on Landsat data in mountainous area. Advances in Space Research 68, 3622–3640. https://doi.org/10.1016/j.asr.2021.07.008

Taylor, J.R., Lovell, S.T., 2012. Mapping public and private spaces of urban agriculture in Chicago through the analysis of high-resolution aerial images in Google Earth. Landsc. Urban Plan. https://doi.org/10.1016/j.landurbplan.2012.08.001

Tiwari, A.K., Kanchan, R., 2024. Analytical study on the relationship among land surface temperature, land use/land cover and spectral indices using geospatial techniques. Discover Environment 2, 1. https://doi.org/10.1007/s44274-023-00021-1

Türker, H.B., Akten, M., 2023. Harvesting the Hidden Value of Vacant Lands: A GIS-Based Approach to Urban Agriculture. Journal of Architectural Sciences and Applications 8, 422–437. https://doi.org/10.30785/mbud.1292693

UN-Habitat, 2023. Nature-based Solutions to Build Climate Resilience in Informal Areas.

Ustaoglu, E., Aydınoglu, A.C., 2020. Site suitability analysis for green space development of Pendik district (Turkey). Urban For. Urban Green. 47, 126542. https://doi.org/10.1016/j.ufug.2019.126542

Uy, P.D., Nakagoshi, N., 2008. Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. Urban For. Urban Green. 7, 25–40. https://doi.org/10.1016/j.ufug.2007.09.002

Vargas-Hernández, J.G., Zdunek-Wielgołaska, J., 2021. Urban green infrastructure as a tool for controlling the resilience of urban sprawl. Environ. Dev. Sustain. 23, 1335–1354. https://doi.org/10.1007/s10668-020-00623-2

Waleed, M., Ahmad, S.R., Javed, M.A., Samiullah, S., 2020. Identification of irrigation potential areas, using multi-criteria analysis in Khyber District, Pakistan. Environmental Science and Pollution Research 27, 39832–39840. https://doi.org/10.1007/s11356-020-08967-y

Waleed, M., Sajjad, M., 2022. Leveraging cloud-based computing and spatial modeling approaches for land surface temperature disparities in response to land cover change: Evidence from Pakistan. Remote Sens. Appl. 25, 100665. https://doi.org/10.1016/j.rsase.2021.100665

Weerakoon, K., 2014. Suitability Analysis for Urban Agriculture Using GIS and Multi-Criteria Evaluation. International Journal of Agricultural Science and Technology 2. https://doi.org/10.14355/ijast.2014.0302.03

WHO, 2021. Green and blue spaces and mental health: New evidence and perspectives for action.

Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough.' Landsc. Urban Plan. 125, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

Yang, J., Sun, J., Ge, Q., Li, X., 2017. Assessing the impacts of urbanization-associated green space on urban land surface temperature: A case study of Dalian, China. Urban For. Urban Green. 22, 1–10. https://doi.org/10.1016/j.ufug.2017.01.002

Yang, Y., Zhang, Y., Huang, S., 2020. Urban Agriculture Oriented Community Planning and Spatial Modeling in Chinese Cities. Sustainability 12. https://doi.org/10.3390/su12208735

Yasin, M., 2020. Is urban sprawl a threat to sustainable development? A review of characteristics and consequences. Malaysian Journal of Society and Space 16, 56–68. https://doi.org/10.17576/geo-2020-1604-05

Yousefi, E., Salehi, E., Zahiri, S.-H., Yavari, A., 2016. Green Space Suitability Analysis Using Evolutionary Algorithm and Weighted Linear Combination (WLC) Method. Space Ontology International Journal 5, 51–60.

Zerdoum, A., 2003. La carte d'identité de Biskra.

Zhang, R., Huang, L., Wang, H., 2023. Accessibility Improvement and Renewal of Urban Park Green Space for the Elderly and the Disabled. Forests 14. https://doi.org/10.3390/f14091801