Original scientific paper

Comparative Spatio-Temporal Dynamics of Urban Sprawl in Algerian Cities Skikda and Tébessa (1985-2024) Using GIS and Landsat Imagery

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ABSTRACT

This study analyzes urban sprawl in the Algerian cities of Skikda and Tébessa from 1985 to 2024, utilizing supervised classification of Landsat satellite imagery and GIS analysis. Skikda, a coastal city, experienced a 68% increase in built-up areas due to industrial growth and coastal geography, whereas Tébessa, an inland city, saw a 45% increase, with growth moderated by its topography and economic structure. The findings illustrate how socio-economic factors, land-use policies, and geographical characteristics influence urban expansion patterns. Skikda's rapid, scattered growth contrasts with Tébessa's controlled expansion. This study highlights the need for customized urban planning strategies that consider local contexts to manage urban sprawl effectively. By comparing the dynamics of coastal and inland cities, the research provides valuable insights for sustainable urban development in medium-sized Algerian cities, offering a framework for similar studies nationwide.

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Highlights:	Contribution to the field statement:
- Population density and land use changes are key indicators of urban sprawl - This study examines the spatial and temporal trends of urban growth in Skikda and Tébessa from 1985 to 2024. - Skikda experienced more rapid and extensive urban sprawl compared to Tébessa. - Factors influencing urban sprawl include socio-economic drivers, planning and policy impact, and topographical features.	This study contributes to urban planning research by providing a novel comparative analysis of urban sprawl patterns in two medium-sized Algerian cities - one coastal and one inland - over a 40-year period, revealing distinct growth trajectories shaped by local socio-economic, policy, and topographical factors, and demonstrating the need for tailored, context-specific urban management strategies.

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1. Introduction

The early decades of the twenty-first century marked a significant milestone in global urbanization, characterized by an unprecedented rate of urban growth. During this period, nearly half of the world's population resided in urban areas, reflecting a rapid increase in urbanization (Birch & Wachter, 2011; Kookana et al., 2020). This accelerating urbanization has resulted in complex transformations in land use and land cover across different geographical scales, contributing to phenomena such as urban sprawl (Asabere et al., 2020; Nuissl & Siedentop, 2021; Sharma et al., 2024). Urban sprawl, often characterized by uncontrolled city expansion, low-density development, dispersed housing, car dependency, and extensive land use, has been a central theme in planning literature and discussions (Hu & Yang, 2018; Fuladlu, 2019; Siyavuş & Aydın, 2022). It commonly occurs in a radial pattern around city centers or along major transportation corridors (He et al., 2019; Oyesiji, 2023). While extensive research has explored urban sprawl in large cities, there remains a significant gap in understanding its patterns and dynamics in medium-sized cities (Jain & Sharma, 2019; Chettry, 2022), especially in developing nations where urbanization is occurring at a faster pace than in developed countries (Getu & Bhat, 2021; Auwalu & Bello, 2023).

Algeria exemplifies these trends. The United Nations (2019) and the World Bank (2015) report that Algeria's urbanization rate increased from 31.4% in 1966 to 73.7% by 2020. The phenomenon of urban sprawl in Algeria began in the 1970s, driven primarily by rural-to-urban migration and a rapid population increase following independence (DECHAICHA, 2020; Abdelhakim, 2023). This growth has resulted in the proliferation of small and medium-sized towns and unregulated urban expansion (CNES, 2002; ONS, 2011). The impacts of urban sprawl vary widely across different regions, with each city experiencing distinct challenges based on its unique geographical and socio-economic context (Salvati, 2016). Previous studies on urban sprawl in Algeria have primarily focused on large cities like Algiers, Constantine, and Oran, leaving a substantial gap in knowledge about medium-sized cities (Nemouchi, 2023).

Moreover, comparative research examining the patterns and spatio-temporal dynamics of urban sprawl across diverse urban regions of Algeria, particularly in terms of varying climatic and geographical characteristics, remains scarce. This research gap limits our understanding of how urban expansion occurs in these often-overlooked medium-sized cities and how it should be managed.

This study addresses this gap by examining the spatial and temporal trends of urban growth in two Algerian cities, Skikda and Tébessa, from 1985 to 2024. We hypothesize that these cities, with their contrasting characteristics, exhibit significantly different urban sprawl patterns shaped by varying socio-economic drivers, land-use policies, and natural topographic factors.

Skikda and Tébessa were selected for this comparative analysis due to their unique characteristics. Skikda, a significant coastal city on the Mediterranean coast with a population of nearly 210,000 (2008 census), serves as a crucial port with an economy primarily based on the petrochemical industry, port operations, and tourism (Hadef & Hadef, 2022). In contrast, Tébessa, an inland city located in northeastern Algeria near the Tunisian border, has a population of approximately 190,000 (2008 census) and an economy traditionally centered on phosphate mining and agriculture (Hadjela & Menacer, 2023). The differing geographical and socio-economic contexts of these cities provide a valuable opportunity to analyze and compare urban sprawl patterns in various regions of Algeria, essential for developing urban planning strategies tailored to each context for sustainable development. This study seeks to answer the following research questions:

1. How do the spatio-temporal dynamics of urban sprawl differ between Skikda and Tébessa from 1985 to 2024?
2. What are the primary drivers influencing the variations in urban sprawl patterns observed in Skikda and Tébessa over the study period?

The research methodology involves a comprehensive analysis using Landsat satellite imagery from 1985, 2005, and 2024, applying supervised classification techniques and Geographic Information System (GIS) analysis to accurately delineate and measure urban sprawl's spatial expansion patterns.

This methodology enables a detailed assessment and comparison of urban sprawl patterns in Skikda and Tébessa, considering factors such as expansion rate, growth direction, and land use changes. Socio-economic data, policy documents, and historical information are also analyzed to provide a comprehensive understanding of the observed patterns.

The study aims to:

1. Classify and map the spatial extent and temporal changes in urban sprawl in Skikda and Tébessa across three periods (1985, 2005, and 2024) using satellite imagery and GIS techniques.
2. Assess and compare the rates of built-up area expansion between the two cities over the nearly 40-year study period.
3. Evaluate how topographical, policy, economic, and demographic factors interact to shape divergent urbanization patterns.
4. Discuss the sustainability implications of unmanaged expansion, such as loss of farmland, congestion, infrastructure deficits, and ecosystem disruption.
5. Suggest tailored policy responses and growth management strategies for secondary cities, building on context-specific drivers and impacts.

To the best of our knowledge, this is the first comprehensive study comparing two medium-sized cities—one coastal and one inland—in Algeria. It provides valuable insights into strategically planning sustainable development in growing urban areas. By employing a comparative approach, we can better understand how coastal and inland environments uniquely affect urban sprawl, contributing to developing more customized and efficient urban planning strategies for similar cities nationwide.

The paper is organized into five sections. The first section presents the current situation, outlines the research problem, and defines the study's scope and approach. The second section details the materials and methods used in the analysis. The third section examines and interprets the results, establishing the cognitive and data foundation for the study. The fourth section summarizes the study's key contributions, and the final section discusses the findings, limitations, and suggestions for future research.

2. Material and Methods

2.1 Case studies

Two distinct Algerian cities, Skikda (a coastal city and economic center) and Tébessa (an intermediate and border city) were chosen to study the forms of urban expansion and spatiotemporal dynamic evolutions between 1985 and 2024.

Figure 1 illustrates the location of the two case studies in Algeria. Skikda (37°52'00" North, 7°54'00" East), situated on the Mediterranean coast in north-eastern Algeria, covers 55.4 km² and is the country's most efficient manufacturing center. Tébessa (35°40'06" North, 8°12'12" East), located in the far east of Algeria, has a surface area of 184 km². It is a border town with Tunisia and the desert, serving as a crossing point between the interior and exterior of the country and between the Tell and the SaharaThe selection of these cities is based on various geographical, economic, and socio-political criteria, allowing for analysis of urban dynamics in diverse contexts. Skikda, with its varied industries and active port infrastructure, exemplifies urban expansion dynamics influenced by economic activities and maritime trade. In contrast, Tébessa, despite its strategic location at the crossroads of major traffic routes, has a weaker economic base and lags in social development. Studying Tébessa provides insight into urban dynamics in a context of limited development, illustrating how economic constraints and social challenges influence urban expansion. These case studies demonstrate how different factors affect urban development and can serve as references for other cities with similar characteristics.
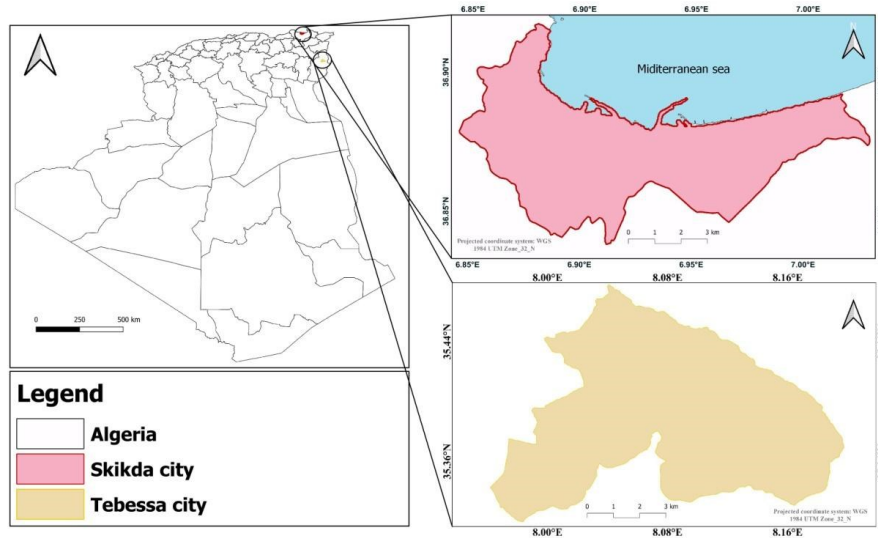
Figure 1: Location map.

2.3 Methodological Framework

Remote sensing and GIS-based Land Use/Land Cover Change (LULC) detection methods are often employed due to their cost-effectiveness and high Temporal Resolution (Abdelkebir et al., 2023; Leulmi et al., 2023; Wu et al., 2023). The main objective of this study was to examine the effect of land use/land cover change on urban sprawl using LULC spatial analysis in a GIS environment.

The methodological framework consisted of two parts. The first step was to predict the spatial-temporal patterns of land use (LULC) for the two case studies (the city of Skikda and the city of Tébessa) using a quantitative supervised classification method and RS remote sensing data at a spatial resolution of 30 for the three time periods of 1985, 2005 and 2024. The second part involved comparing the extent of urban land use change for the two case studies over the study period (1985-2024) for representing urban expansion, in which the influential factors of natural topography and demographic change are highlighted. A flow chart describing the study approach is shown in Figure 2.
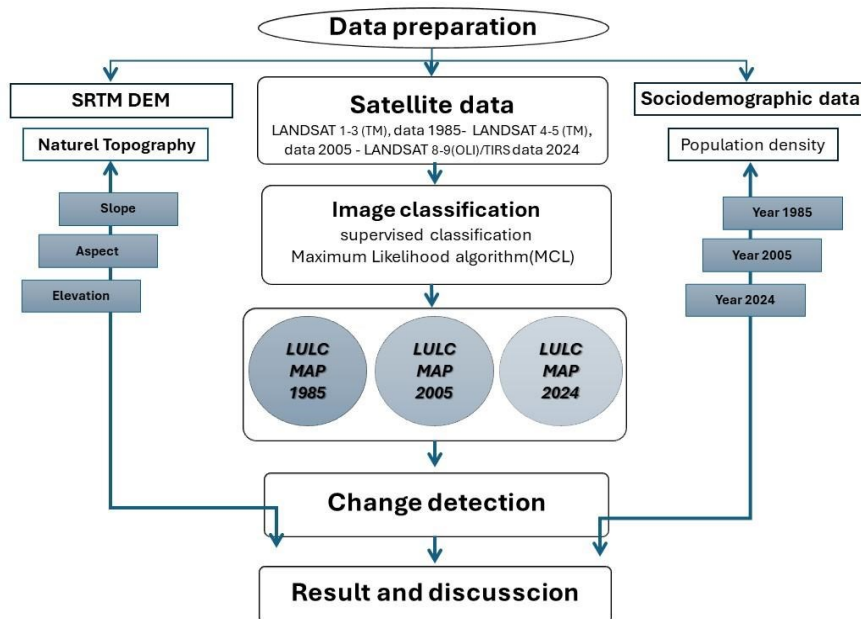

Figure 2: Structure of the study.

2.4 Data Acquisition and Pre-processing

This study used a range of data (Table 1). The baseline information was remote sensing data from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/). The data were analyzed using Landsat 1-3 TM (1985), Landsat 4-5 TM (2005), and Landsat 8-9 OLI/TIRS (2024) satellite images to obtain land use information (Idowu & Zhou, 2021). Table 2 provides information on the satellite images. Other auxiliary data related to natural topography (elevation, slope, and aspect) were used in the study, obtained from the Shuttle Radar Topographic Mission (SRTM) 1 arc-second digital elevation model (DEM) in raster format on the official United States Geological Survey (USGS) web portal: https://www.usgs.gov/. In addition, population census data was collected from government reports for the years 1985, 2005, and 2024 to compare population change and land use/cover change in the two urban areas. All data was resampled to a spatial resolution of 30 meters. The data management steps were carried out using the (internationally recognized) actions integrated into the Quantum GIS open-source software (QGIS 3.18).

Table 1: Data used in the study.

Data used	Resolution scale	Format	Acquisition date	Source	Usage
Shuttle Radar Topography Mission (SRTM) – DEM	30 × 30 m	Raster/Spatial resolution (30 m)	2024	www.usgs.gov /	Calculation of elevation, slope, and aspect.
LANDSAT: ▪ Landsat 1-3 (TM) ▪ Landsat 4-5 (TM) ▪ LANDSAT 8-9(OLI)	30 × 30 m	Satellite image	2024	https://earthexplorer.usgs.gov/	LULC simulation
Administrative boundary	Commune /Ville	Shapefile (Polygon)	2024	DUCH	Administrative divisions.
Census	1985-2024	Text - District	2024	Office of Statistics (ONS)	Density of population

Table 2: The main characteristics of the Landsat satellite data.

site	Scene ID	Satellite & Sensor	WRS (Path/Row)	Spatial Resolution (m)	Acquisition date	Producer
Skikda city City	LM04_L1TP_193034_19851109_20210917_02_T2	Landsat 1-3 TM	137/43	30 × 30	1985-11-09	USGS
	LT05_L2SP_193034_20051108_20200901_02_T1	Landsat 4-5TM	137/43	30 × 30	2005-11-08	USGS
	LC08_L2SP_193034_20240214_20240223_02_T1	Landsat 8-9 OLI/TIRS	137/43	30 × 30	2024-02-14	USGS
Tebessa City	LT05_L1TP_192035_19851110_20200918_02_T1	Landsat 1-3TM	137/43	30 × 30	1985-11-10	USGS
	LT05_L1TP_192036_20050930_20200901_02_T1	Landsat 4-5TM	137/43	30 × 30	2005-09-30	USGS
	LC09_L1TP_192035_20240213_20240213_02_T1	Landsat 8-9 OLI/TIRS	137/43	30 × 30	2024-02-13	USGS

2.5 Image classification

Quantitative supervised classification by maximum likelihood was used in this study, allowing the grouping of LULCs detected from satellite images ((Idowu & Zhou, 2021; Xu et al., 2021). The UTM WGS 1984 Zone_32_N projection system was used for image processing. Pixels were trained according to their colour tone based on land use classes (built-up land, green space, and other lands), collected from ground truth value observation via Google Earth and field observation. Land use/land cover was categorized using the Maximum Likelihood Classification (MLC) algorithm. The assessment calculated the extent of changes in each land use and land cover category (LULC) over the designated study periods. The entire classification process was implemented in Q-GIS software (version 3.18). In accordance with the study's objective, the study area was classified into three classes, as shown in Table 3.

Table 3: Description of land use/cover classes.

Type LULC	Description	References
Built up area	Urban areas (buildings and concrete structures, gray infrastructure).	(Ahmadpour & Shahraki, 2019)
Green space	Agricultural lands, plantations, pastures, forests, etc.	(Aswal et al., 2018; Manikandan, 2019; J. Wu et al., 2023)
Other	Water bodies and uncultivated lands; lands with barren rocks and sandy sections.	(Ahmadpour & Shahraki, 2019; Lawrence F. & Mildred E., 2020)

3. Results

3.1 Urban sprawl and spatial pattern from 1985 to 2024

To better understand urban development and its spatiotemporal pattern in the two cities (Skikda and Tebessa), Landsat images from 1985, 2005, and 2024 have been classified into built-up, green spaces, and others. This has resulted in three thematic maps, illustrated in Figure 3 below.
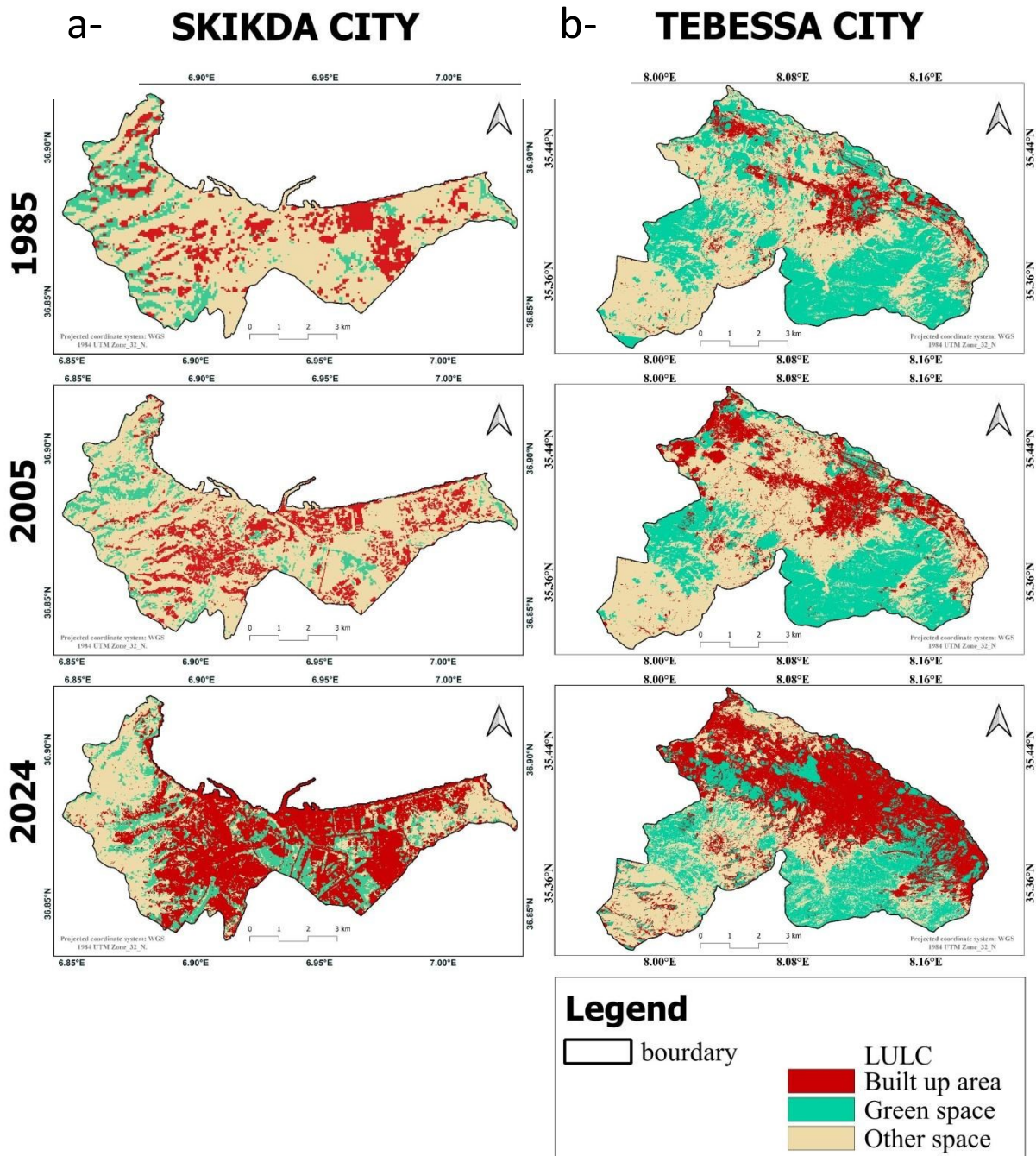
Figure 3: Urban sprawl patterns in Skikda and Tebessa.

3.2 Land use and land cover change analysis

The results indicate that the two studied urban agglomerations underwent substantial urban expansion from 1985 to 2024. On one hand, in Skikda City, the built-up area progressively expanded from the port towards the south-west direction between 1985 and 2005, while slightly decreasing in the eastern region. However, from 2005 to 2024, a significant growth in built-up areas was observed in all directions, encroaching upon other land and green spaces.

The graphs (Fig. 4; a) below depict the urban sprawl trend in Skikda by illustrating changes in built-up areas, green spaces, and other land cover categories from 1985 to 2024. Built-up areas exhibited a significant increase, rising from 14% in 1985 to 37% in 2005 and a projected 47% in 2024, indicating continuous urbanization. Conversely, while green spaces initially expanded from 23% in 1985 to 42% in 2005, they are projected to decrease to 39% by 2024, potentially due to the encroachment of urban

development. The "Others" category, comprising land covers beyond built-up and green areas, decreased from 35% in 2005 to a projected 22% in 2024, suggesting land use conversions to accommodate urban growth. Overall, the data illustrates Skikda's urban sprawl pattern, characterized by the expansion of built-up areas at the expense of green spaces and other land cover types.

On the other hand, from 1985 to 2005 in Tebessa city, the built-up area continued to expand in a northerly and westerly direction, but within a planned and organized framework through the urban development plan (PDAU), which aimed for regular space consumption. This growth was accompanied by the expansion of illegal fabrics to the south, southeast, and north and the deployment of activities, equipment, and housing. This period is marked by the discontinued occupation of urban space from 2005 to the present; the built-up area has been characterized by the expansion of peripheral regions, with successive urbanization processes towards the west along major roads (RN10). The graph (Fig. 4;b) below depicts that in 1985, the built-up area was relatively small at 15%, while green space was 25%, and others accounted for 60%. By 2005, the built-up area had increased significantly to 60%, indicating substantial urban sprawl and development, while green space had decreased to 18%, likely due to the expansion of built-up areas, and others remained at 60%. For 2024, the projections show a potential decrease in built-up area to 28%, suggesting more controlled urban growth. Additionally, green space is projected to increase slightly to 22%, possibly due to urban planning efforts to preserve or create more green spaces, while the Others category is projected to increase to 50%, which could indicate either urban renewal efforts or the conversion of some built-up areas back to other land uses. Overall, the data suggests that Tebessa experienced significant urban sprawl between 1985 and 2005. Still, the projections for 2024 indicate a potential shift towards more controlled urban growth, with a decrease in built-up areas and an increase in green spaces and other land uses.
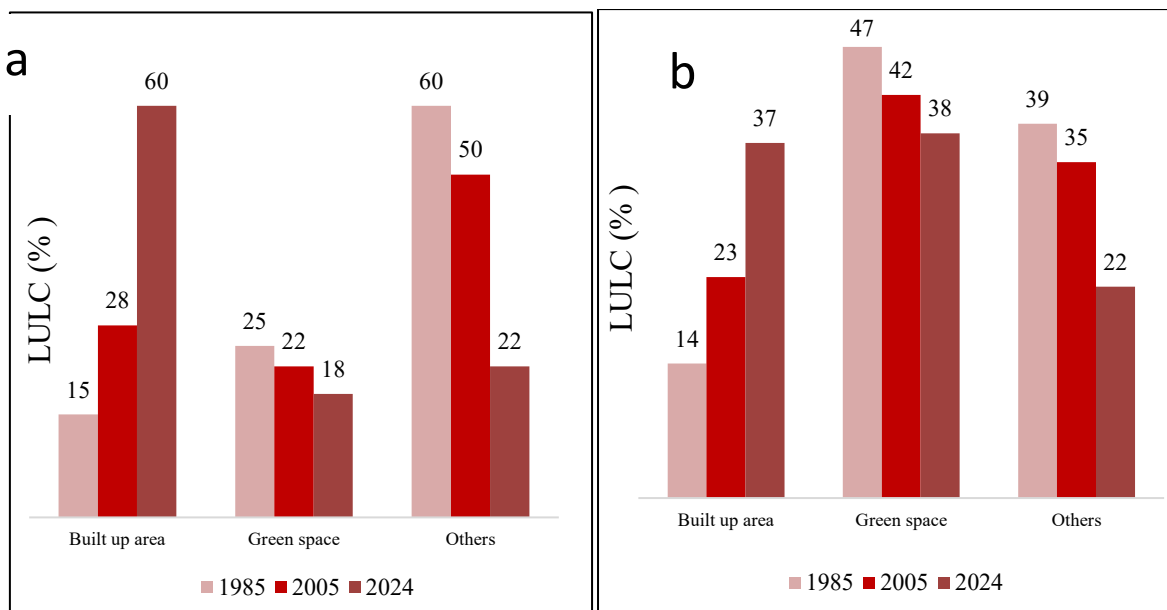

Figure 4: LULC percentage.

Overall, these graphs highlight urban sprawl trends in both cities, with built-up areas expanding at the expense of green spaces and other land cover types, whereas the rate of increase in built-up areas appears to be higher in Skikda.

3.3 Demography and Urban Expansion

Demographic data obtained from the National Statistics Office (ONS) were used to construct the graphs in Figure 5, which illustrate changes in population density in Skikda (graph a) and Tébessa (graph b) for the years 1985, 2005, and the projected figures for 2024. These graphs provide insights into the patterns of urban sprawl in the two cities.

In Tébessa, the population density increased from 608.73 inhabitants per square kilometer in 1985 to 1068.13 inhabitants per square kilometer in 2005, with a further projected increase to 1556.51 inhabitants per square kilometer by 2024. Conversely, Skikda showed consistently higher population density throughout the same periods, starting at 2360.75 inhabitants per square kilometer in 1985, rising to 3082.86 inhabitants per square kilometer in 2005, and is expected to reach 3786.43 inhabitants per square kilometer by 2024.

The consistently higher population density in Skikda compared to Tébessa suggests a more rapid and extensive pattern of urban sprawl, assuming comparable economic and developmental conditions. As the population grows, the demand for housing, infrastructure, and urban services also increases, leading to the conversion of more land into urban use and contributing to the observed sprawl patterns. The substantial projected increases in population density for both cities by 2024 indicate that urban sprawl is likely to continue. This may result in the expansion of built-up areas into previously undeveloped or rural zones, involving the transformation of green spaces, agricultural lands, or other land cover types to accommodate the growing population and the accompanying urban development.
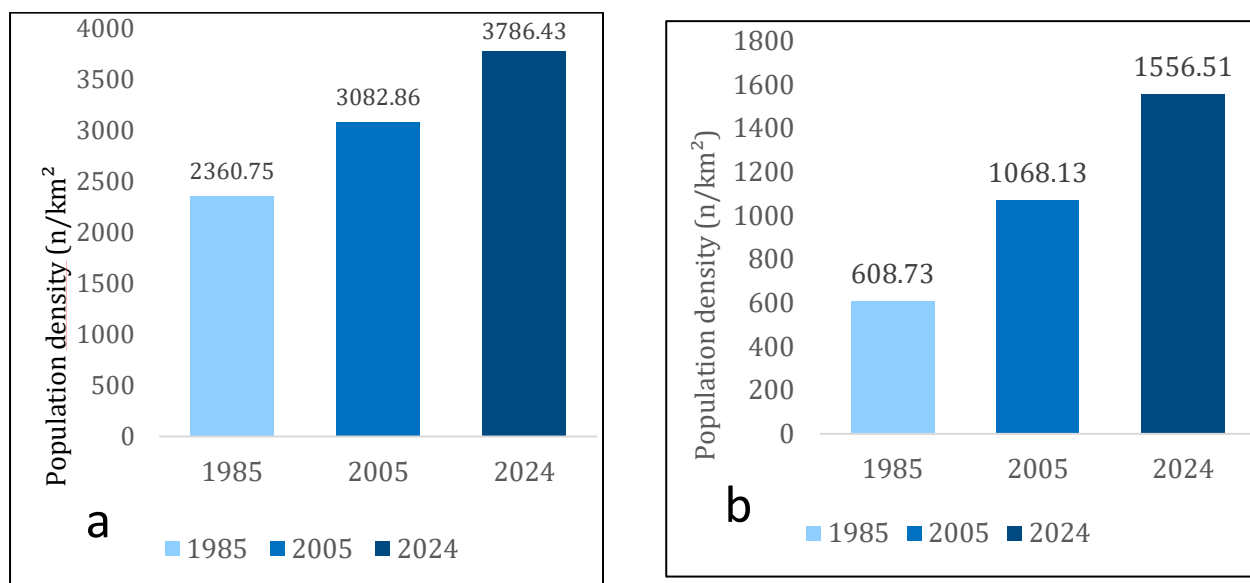
Figure 5. Population Density: a -Skikda, b- Tebessa.

A variety of factors beyond population density, such as urban planning policies, economic activities, transportation infrastructure, and environmental considerations, influence Urban sprawl patterns. In both Tebessa and Skikda, effective urban planning and sustainable development strategies are crucial to managing urban growth while preserving green spaces, protecting natural resources, and ensuring a balanced and livable urban environment.

4. Discussion

Urban sprawl in Algeria, as described by DECHAICHA (2020), began in the 1970s and is specifically characterized by the dispersed expansion of metropolitan centers. This phenomenon was driven by two primary factors: a rapid population increase in the years immediately following independence and significant rural-to-urban migration (Abdelhakim, 2023). As a result, CNES (2002) and ONS (2011) report that Algeria experienced swift and inadequately regulated urban growth, particularly within small and medium-sized municipalities. This expansion has substantially influenced the country's urban system and population distribution.

4.1. Differences between urban sprawl in Skikda and Tebessa

This study highlights distinct trends in urban expansion in the medium-sized Algerian cities of Skikda and Tébessa over the past four decades. The findings demonstrate a significant increase in urbanization in both cities, with Skikda exhibiting a more rapid and extensive growth rate—its built-up area expanded by 68% from 1985 to 2024, outpacing Tébessa's 45% growth. The analysis also showed significant changes in land use, with built-up areas expanding at the expense of green spaces and other types of land cover. These findings align with previous studies on urbanization patterns in Algeria's small and medium-sized cities. For instance, Mostari et al. (2021) documented a notable increase in urbanization in Mostaghanem, a coastal city where urbanized areas grew from 2,604 hectares in 1985 to 5,049 hectares in 2015.

Similarly, Gherbi & Toumi (2024) reported that the inland city of Khenchela experienced rapid population growth and high migration rates from 2008 to 2022, resulting in severe urban challenges such as housing shortages, unplanned expansion into agricultural lands, and the depletion of buildable land. Additionally, Skikda demonstrated a higher population density growth due to migration flows compared to Tébessa, suggesting a potentially more pronounced urban sprawl. These findings are consistent with Côte (1994), who emphasized the role of population growth and rural-to-urban migration in driving urban sprawl in Algeria.
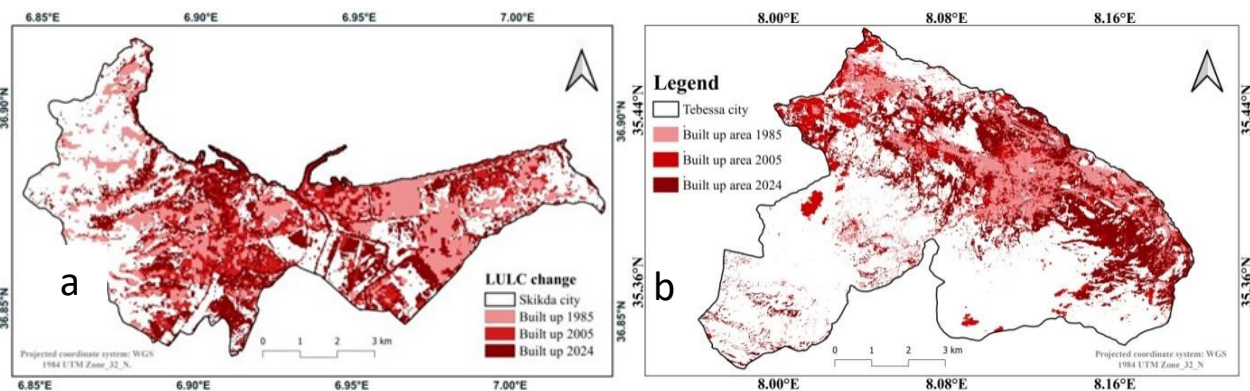

Figure 6. Built- up area: a- Skikda ,b - Tebessa.

4. 2. Land use/land cover change drivers:

The expansion patterns in both cities showed significant spatial and temporal disparities. Two distinct sprawl models have been identified, possibly shaped by these drivers (Abdelhakim, 2023):

4.2.1. Socio-economic factors

Skikda's advantageous coastal location has attracted substantial investments in petrochemicals and shipping, leading to rapid economic growth and urban expansion. A pivotal moment in Skikda's development occurred in 1971 with the establishment of an industrial zone, transforming the city from an agricultural area into a diversified industrial center (Hadef & Hadef, 2022). This transformation enhanced Skikda's prominence at the state level, especially after the administrative reorganization in 1974. Consequently, the city underwent significant changes in its economic structure, shifting from a focus on agriculture and tourism to becoming a hub for the industrial and service sectors.

In contrast, Tébessa, situated within the "Steppe and Saharan Atlas Zone," initially faced challenges such as a low population density, limited agricultural output, a lack of industrial activity, inadequate infrastructure, and minimal urban development (Hadjela & Menacer, 2023). The city's economic foundation was primarily built on mining, while development efforts were directed towards housing, urban planning, administrative services, education, public health, public works, and water management. Agriculture, industry, and tourism were considered secondary priorities (Gherzouli & Labii, 2020). Due to these divergent economic orientations, Skikda's urbanization has progressed at a faster rate than that of Tébessa.

4.2. 2. Planning and Policy Impact

The impact of urban planning and policy on the growth of Skikda and Tébessa reveals a complex and often counterproductive dynamic. Rather than curbing expansion, urban policies and regulations have often unintentionally facilitated it (Saidi et al., 2023). Urban planning tools derived from Law n° 90-29 have been inadequate in managing the rapid growth of both cities, often accompanying rather than controlling urban sprawl. This inadequacy can be partly attributed to delays in the preparation and approval of these planning instruments (Aggoune, 2024).

In Tébessa, urban development benefited from planning tools such as the Master Plan for Urban Development (PDAU) and Land Use Plan (POS), housing programs, improved infrastructure, and the establishment of peri-urban zones with industrial areas, an airport, and dispersed new housing zones (ZHUN). However, the "Black Decade" led to unplanned urbanization, prompting a shift towards horizontal expansion marked by both collective and individual housing in new neighborhoods, including projects like the "Doukkane" urban center with 11,000 planned housing units and ongoing developments like Boulhaf Dyr.

Skikda, which became an administrative division in 1974, focused its urban planning policies on expanding southward and developing a 1,400-hectare industrial zone. This led to the formation of informal settlements in areas such as Bouabaz and Salah Boulkeroua, alongside expansions in the eastern and western directions. Planning efforts also included territorial divisions and various housing initiatives, such as the L'Espérance, 700-unit, and 500-unit developments, as well as new habitat zones (ZHUN), AADL, and participatory housing projects in locations like Boulkeroua and Merdj Eddib, all contributing to a comprehensive urban strategy for Skikda.

Despite the numerous policies and planning instruments, both cities have experienced uncontrolled urban sprawl and the substantial consumption of scarce, non-renewable land. This underscores the need for more effective laws and urban planning tools to manage urban growth (Nemouchi, 2023).

4.2. 3. Topographical Influence

Topographical factors, such as elevation and slope, have significantly influenced the direction of urban growth in both cities. In Skikda, geographical features, including the Mediterranean Sea to the north and mountain ranges to the east and west, along with a petrochemical zone in the east, have constrained the city's expansion. These natural barriers have limited the city's growth, directing it toward the southern regions, where it increasingly encroaches on agricultural land. Recent assessments indicate that Skikda requires an annual increase of over 30 hectares of land to accommodate its growing population, often at the expense of valuable agricultural land on its southern periphery.

In Tébessa, the varied terrain, characterized by plains and mountains—where mountainous terrain accounts for over 50% of the total area—has significantly influenced the city's development patterns. The city's geographical constraints have led to two main types of growth:

Structuring lines: Natural or artificial linear features, such as valleys, ridges, roadways, or rivers, that provide logical routes for urban expansion.

Restricted plains and flat areas: Limited flat regions have become highly desirable for development due to their suitability for construction and ease of accessibility.

These topographical influences have shaped the distinctive urban growth trajectories observed in both cities.
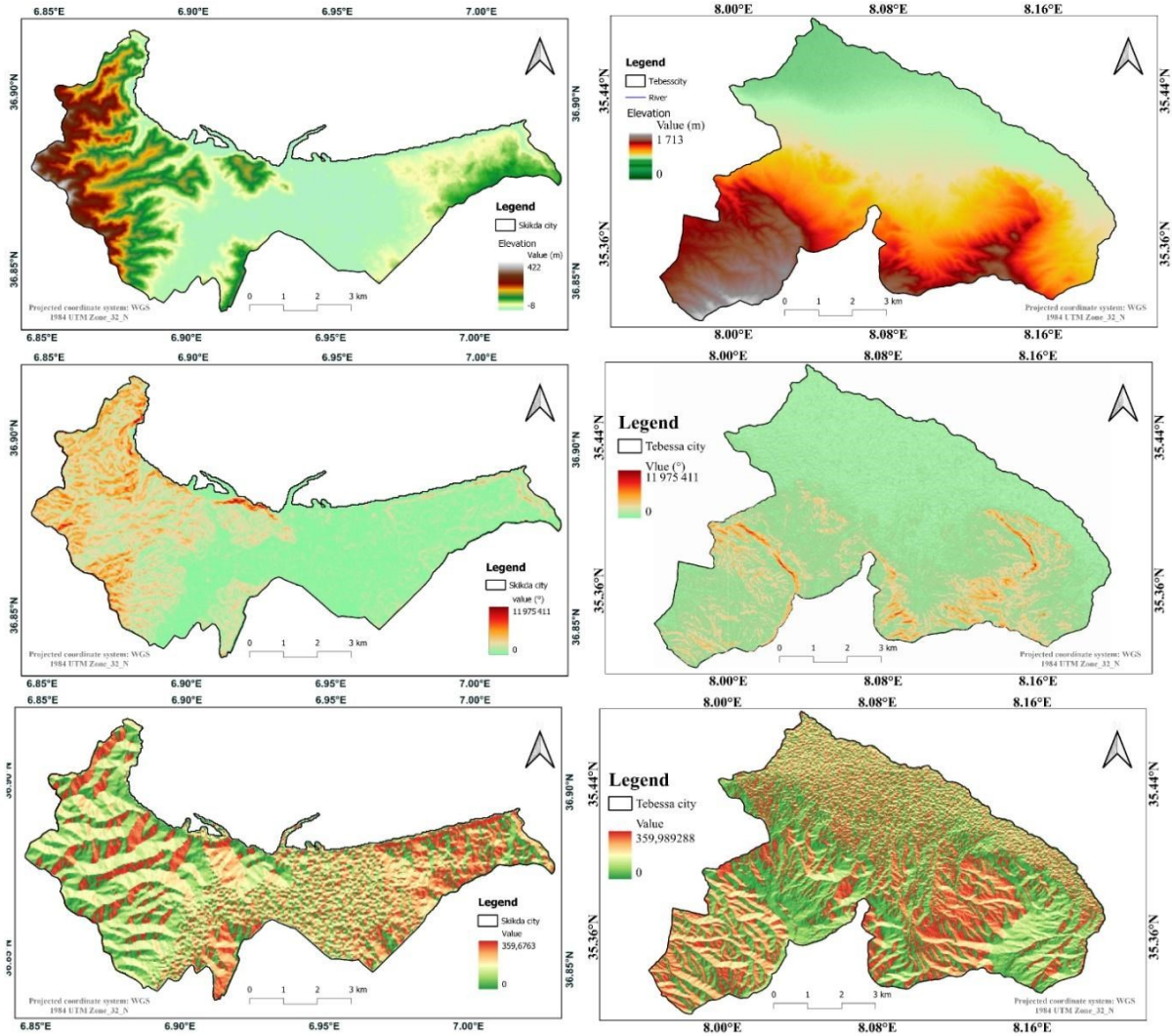
Figure 7. natural topography: elevation, slope, aspect; a- Skikda, b-Tebessa.

Table 4: description of the natural topography of the two cities.

Feature	Skikda	Tebessa
Elevation	Range: 0 to 592 meters, Higher elevations in the west, Lower elevations in the east (coastal area)	Range: 0 to 1,713 meters, Higher elevations surrounding the city, Lower elevations in central and northern parts
Slope	Steeper gradients in the western mountainous area, Gentler slopes towards the east, relatively flat areas in central and eastern parts	- Complex pattern of steep and gentle slopes throughout, Significant areas of steep terrain surrounding the city center
Aspect	- Varied pattern of slope directions, Predominance of east and southeast-facing slopes in the western mountainous area, less pronounced aspect variation in the flatter eastern part	- Intricate pattern of slope directions, a Mix of slope aspects throughout the city area, Indicates more complex, hilly, or undulating terrain
Overall Topography	Clear east-west topographic gradient, Mountains in the west, Flatter areas towards the coast in the east	More complex and varied topography: Higher overall elevations, Surrounded by mountainous terrain, more rugged landscape throughout

These findings align with theories of differential urbanization (Geyer & Kontuly, 1993), which posit that city at different stages of development exhibit varying patterns of growth. Skikda's rapid, scattered growth resembles the early stages of this model, while Tébessa's more controlled expansion aligns with the later stages.

The results have substantial ramifications for urban planning and policy in Algeria. The significant growth of urban areas, especially in Skikda, highlights the necessity for improved land use management strategies to protect natural areas and promote sustainable urban growth. By 2024, the possibility of reversing the current urban sprawl tendencies in Tébessa indicates that specific strategies can successfully control the city's expansion.

An important advantage of this study is its comparative methodology, which enables a detailed comprehension of urban expansion patterns in various metropolitan settings in Algeria. Utilizing data spanning from 1985 to 2024 offers a broad perspective on patterns in urban development. In addition, the combination of remote sensing data and demographic information provides a comprehensive examination of urban sprawl.

However, this study has limitations. The reliance on Landsat imagery may have led to some inaccuracies in land cover classification, particularly in distinguishing between different types of built-up areas. Furthermore, the projections for 2024 are based on historical trends and may not fully account for recent policy changes or economic shifts. Despite these limitations, our study contributes valuable insights into the urban sprawl dynamics of medium-sized Algerian cities, an area previously understudied.

Future research should focus on:

1. Conducting more detailed analyses of the types of urban development (e.g., residential, industrial, commercial) to better understand the nature of urban sprawl in these cities.

2. Examining the environmental and social impacts of the observed urban sprawl patterns, particularly in terms of ecosystem services and quality of life.

3. Exploring the effectiveness of different urban planning strategies in managing urban sprawl in medium-sized Algerian cities.

This study reveals distinct patterns of urban sprawl in Skikda and Tébessa, highlighting the importance of considering local contexts in urban development strategies. The findings underscore the need for tailored, sustainable urban planning approaches to manage urban growth effectively in medium-sized Algerian cities.

5. Conclusion

Consistent with the general trend of rapid urbanization in developing nations, urban sprawl has become an ongoing issue in Algeria. As populations congregate in cities, they grow outward, frequently in an unsustainable way. This is particularly relevant in medium-sized cities, which have grown substantially yet have been less researched than big cities. Against this backdrop, our study's comparative analysis of urban sprawl patterns in Skikda and Tébessa from 1985 to 2024 supports our hypothesis that varied socio-economic drivers, land-use policies, and topographic factors influence significantly different urbanization trajectories. The findings reveal Skikda's rapid, scattered growth (68% increase in the built-up area) driven by coastal industrial development, contrasting with Tébessa's more controlled expansion (45% increase) shaped by its inland location and distinct economic priorities. These results contribute to the understudied field of medium-sized city dynamics in Algeria, challenging one-size-fits-all urban planning approaches and highlighting the critical role of local context in shaping urban growth. The broader implications for urban policy in Algeria include the need for differentiated management strategies based on city type, strengthened planning instruments, and balanced approaches to economic development and sustainability. However, limitations such as potential inaccuracies in land cover classification, projections based on historical trends, limited socio-economic factor exploration, and the focus on only two cities impact the study's generalizability. Based

on these findings, we recommend implementing tailored growth management strategies, prioritizing green space preservation through stricter zoning, encouraging compact development, and integrating climate change considerations into urban planning. Future research should address detailed analyses of urban development types, the environmental and social impacts of sprawl, the effectiveness of various planning strategies, the role of informal settlements, and the expansion of the study to a larger sample of cities across Algeria. By pursuing these directions, future studies can build upon our work to develop more comprehensive and effective urban planning strategies for sustainable development in Algeria and similar contexts, thereby addressing the critical challenges of rapid urbanization in developing countries.

Conflicts of Interest
The authors declare no conflicts of interest.

Data availability statement
The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary material.

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References
Abdelhakim, H. (2023). Urban Space Between Sprawl And Compactness, Which Urban Form Is Adequate For A Better Growth Of Cities? Examples, Cities Of Algeria. 22(7).

Abdelkebir, B., Guesri, M., Mokhtari, E., & Engel, B. (2023). Simulation of Rainfall-Runoff process using SWAT model in Bouhamdane watershed, Algeria. Glasnik Srpskog Geografskog Drustva, 103(2), 279-292. https://doi.org/10.2298/GSGD2302279A

Aggoune, K. (2024). A dynamic urban landscape in Algeria : Actors, mechanisms and governance challenges. Al-Basha'ir Economic Journal: Taheri Mohammed University, Bechar - Faculty of Economics, Business and Management Sciences 10(2), 650-662. https://doi.org/10.33704/1748-010-002-039

Ahmadpour, A., & Shahraki, M. R. (2019). Land-Use Change Scenarios. In W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, & T. Wall (Éds.), Zero Hunger (p. 1-9). Springer International Publishing. https://doi.org/10.1007/978-3-319-69626-3_31-1

Asabere, S. B., Acheampong, R. A., Ashiagbor, G., Beckers, S. C., Keck, M., Erasmi, S., Schanze, J., & Sauer, D. (2020). Urbanization, land use transformation and spatio-environmental impacts:

Analyses of trends and implications in major metropolitan regions of Ghana. Land Use Policy, 96, 104707. https://doi.org/10.1016/j.landusepol.2020.104707

Aswal, P., Saini, R., & Tanzeem, M. (2018). Spatio Temporal Monitoring of Urban Sprawl using GIS and Remote Sensing Technique. International Journal of Computer Applications, 182(27), 11-24. https://doi.org/10.5120/ijca2018918100

Auwalu, F. K., & Bello, M. (2023). Exploring the Contemporary Challenges of Urbanization and the Role of Sustainable Urban Development: A Study of Lagos City, Nigeria. Journal of Contemporary Urban Affairs, 7(1), 175-188. https://doi.org/10.25034/ijcua.2023.v7n1-12

Birch, E. L., & Wachter, S. M. (2011). Chapter 1. World Urbanization: The Critical Issue of the Twenty-First Century. In E. L. Birch & S. M. Wachter (Éds.), Global Urbanization (p. 3-23). University of Pennsylvania Press. https://doi.org/10.9783/9780812204476.3

Chettry, V. (2022). Geospatial measurement of urban sprawl using multi-temporal datasets from 1991 to 2021: Case studies of four Indian medium-sized cities. Environmental Monitoring and Assessment, 194(12), 860. https://doi.org/10.1007/s10661-022-10542-6

Côte, M. (1994). L'urbanisation en Algérie: Idées reçues et réalités [Urbanization in Algeria: preconceived ideas and realities]. Travaux de l'Institut de Géographie de Reims, 85(1), 59-72. https://doi.org/10.3406/tigr.1994.1304

Dechaicha, A. (2020). *Compacité et tendances d'étalement urbain. Cas d'étude: Les grandes villes du Bas-Sahara algérien [Compactness and urban sprawl trends. Case study: Large towns in Algeria's Lower Sahara region]* (Doctoral dissertation, Université Mohamed Khider – Biskra). Département d'Architecture.

Fuladlu, K. (2019). Urban Sprawl Negative Impact: Enkomi Return Phase. Journal of Contemporary Urban Affairs, 3(1), 44-51. https://doi.org/10.25034/ijcua.2018.4709

Getu, K., & Bhat, H. G. (2021). Analysis of spatio-temporal dynamics of urban sprawl and growth pattern using geospatial technologies and landscape metrics in Bahir Dar, Northwest Ethiopia. Land Use Policy, 109, 105676. https://doi.org/10.1016/j.landusepol.2021.105676

Geyer, H. S., & Kontuly, T. (1993). A Theoretical Foundation for the Concept of Differential Urbanization. International Regional Science Review, 15(2), 157-177. https://doi.org/10.1177/016001769301500202

Gherzouli, L., & Labii, B. (2020). Les enjeux de la durabilité urbaine: Cas de Tébessa [The challenges of urban sustainability: The case of Tébessa]. *12*(4), 47-61.

Hadef, H., & Hadef, A. (2022). Population and Industrial/City Proximity: Ignorance or Complicity? Case of Skikda, Algeria. International Journal of Innovative Studies in Sociology and Humanities, 7(11), 55-63. https://doi.org/10.20431/2456-4931.071105

Hadjela, Dr. ALi., & Menacer, Kheireddine. (2023). Urban Planning Violations in the Planned Districts: The Case of the District of 120 Dwellings in the City of Tebessa, Algeria. International Journal of Innovative Studies in Sociology and Humanities, 8(1), 58-69. https://doi.org/10.20431/2456-4931.080106

He, Q., Zeng, C., Xie, P., Tan, S., & Wu, J. (2019). Comparison of urban growth patterns and changes between three urban agglomerations in China and three metropolises in the USA from 1995 to 2015. Sustainable Cities and Society, 50, 101649. https://doi.org/10.1016/j.scs.2019.101649

Hu, X., & Yang, J. (2018). Quantitative Analysis of the Urban Factors Limiting Central District Plane Form Expansion: Twenty-one Case Studies of Asian Megacities′ Central Districts. Journal of

Asian Architecture and Building Engineering, 17(2), 345-351. https://doi.org/10.3130/jaabe.17.345

Idowu, D., & Zhou, W. (2021). Land Use and Land Cover Change Assessment in the Context of Flood Hazard in Lagos State, Nigeria. Water, 13(8), 1105. https://doi.org/10.3390/w13081105

Jain, G. V., & Sharma, S. A. (2019). Spatio-temporal analysis of urban growth in selected small, medium, and large Indian cities. Geocarto International, 34(8), 887-908. https://doi.org/10.1080/10106049.2018.1450450

Kookana, R. S., Drechsel, P., Jamwal, P., & Vanderzalm, J. (2020). Urbanization and emerging economies: Issues and potential solutions for water and food security. Science of The Total Environment, 732, 139057. https://doi.org/10.1016/j.scitotenv.2020.139057

Lawrence F., F., & Mildred E., A. (2020). Land Use Dynamics and Variations in Sprawl across Municipalities in the Bamenda Urban-scape from 1996-2018. Journal of Sustainable Development, 13(4), 224. https://doi.org/10.5539/jsd.v13n4p224

Leulmi, L., Lazri, Y., Abdelkebir, B., & Bensehla, S. (2023). Assessment of the effect of land use and land cover (LULC) change on depth runoff: Case study of Skikda floods event. Glasnik Srpskog Geografskog Drustva, 103(2), 145-160. https://doi.org/10.2298/GSGD2302145L

Manikandan, S. (2019). Spatial and Temporal Dynamics of Urban Sprawl Using Multi-temporal Images and Relative Shannon Entropy Model in Adama, Ethiopia. Journal of Advanced Research in Geo Sciences & Remote Sensing, 05(3 & 4), 48-57. https://doi.org/10.24321/2455.3190.201801

Mostari, A., Benabdeli, K., & Ferah, T. (2021). Assessment of the impact of urbanization on agricultural and forest areas in the coastal zone of Mostaganem (western Algeria). Ekológia (Bratislava), 40(3), 230-239. https://doi.org/10.2478/eko-2021-0025

Nemouchi, H. (2023). Peri-Urban Pressures: The Interplay of Land Strategies and Urbanization in Algeria's Oran Metropolis. Journal of Contemporary Urban Affairs, 7(2), 1-19. https://doi.org/10.25034/ijcua.2023.v7n2-1

Nuissl, H., & Siedentop, S. (2021). Urbanisation and Land Use Change (p. 75-99). https://doi.org/10.1007/978-3-030-50841-8_5

Oyesiji, O. A. (2023). Spatio-Temporal Measurements of Urban Sprawl Dynamics In Oyo Town, Nigeria. African Journal on Land Policy and Geospatial Sciences, Vol 6, 094-106 Pages. https://doi.org/10.48346/IMIST.PRSM/AJLP-GS.V6I1.34547

Saidi, F. A., Phinzi, K., & Molnár, E. (2023). Urbanization in Algeria: Toward a More Balanced and Sustainable Urban Network? Social Sciences, 12(3), 174. https://doi.org/10.3390/socsci12030174

Salvati, L. (2016). The 'Sprawl Divide': Comparing models of urban dispersion in mono-centric and polycentric Mediterranean cities. European Urban and Regional Studies, 23(3), 338-354. https://doi.org/10.1177/0969776413512843

Sharma, M., Kumar, V., & Kumar, S. (2024). A systematic review of urban sprawl and land use/land cover change studies in India. Sustainable Environment, 10(1), 2331269. https://doi.org/10.1080/27658511.2024.2331269

Siyavuş, A. E., & Aydın, T. N. (2022). A bibliometric analysis of urban sprawl. Papers in Applied Geography, 8(2), 163-184. https://doi.org/10.1080/23754931.2021.1975307

Wu, D., Zheng, L., Wang, Y., Gong, J., Li, J., & Chen, Q. (2023). Urban expansion patterns and their driving forces analysis: A comparison between Chengdu-Chongqing and Middle Reaches of Yangtze River urban agglomerations. Environmental Monitoring and Assessment, 195(9), 1121. https://doi.org/10.1007/s10661-023-11720-w

Wu, J., Wu, C., Zhang, Q., Zhuang, M., Xiao, H., Wu, H., Ouyang, L., Liu, Y., Meng, C., Song, C., Haase, D., & Li, J. (2023). Spatiotemporal Evolution of Urban Agglomeration and Its Impact on Landscape Patterns in the Pearl River Delta, China. Remote Sensing, 15(10), 2520. https://doi.org/10.3390/rs15102520

Xu, F., Wang, Z., Chi, G., Wang, D., Zhang, Z., & Zuo, D. (2021). Differentiation and progress of urban regionalization in China: Perspectives of land use and geography. Applied Geography, 137, 102600. https://doi.org/10.1016/j.apgeog.2021.102600

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