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Urban Sprawl Between Spatial Dynamics and Sustainability Issues Case of the City of Béjaïa, Northern Algeria

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Abstract

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This paper analyzes the evolution of urban sprawl in the city of Béjaïa, located in northern Algeria, by examining land consumption from the country's independence in 1962 to the present day. Using a diachronic approach supported by Geographic Information Systems, the study highlights the increasing artificialization of land and its impacts on the environmental, social, and economic dimensions of sustainable development. The results reveal a diffuse and uncontrolled urban expansion, characterized by fragmented urban fabric, the loss of agricultural and forested land, and growing spatial disparities. A critical analysis of urban planning tools reveals their limited capacity to manage this phenomenon and provide appropriate solutions. This paper aims to encourage local decision-makers to adopt a more forward-looking urban governance strategy, based on the strategic use of geographic information systems and a prospective approach, to promote a more sustainable and balanced urban development.

Keywords: Urban sprawl; Béjaïa; land artificialization; sustainable development; geographic information systems.

1 Introduction

1.1 General Context

Since the second half of the 20th century, urban dynamics worldwide have been profoundly transformed by a major phenomenon: the continuous spatial expansion of cities. “Rapid urbanization in many parts of the world has resulted in inadequate housing, social segregation and the deterioration of open spaces, all of which have had a negative impact on the quality of life for residents” (Husain & Salem, 2024). This process, commonly referred to as urban sprawl, has become one of the key contemporary challenges in sustainable territorial planning. Far from being an isolated or region-specific occurrence, urban sprawl manifests on all continents—in metropolitan as well as medium-sized cities—and is increasingly becoming a dominant mode of urban growth. It is characterized by high land consumption, dispersed urban forms, low density, and uncontrolled expansion of urban peripheries. According to Angel et al. (2021), the global urbanized area doubled between 1990 and 2015—an unprecedented rate in the history of urbanization.

Subsequently, “With the advent of the third millennium, the population of cities has surpassed the rural, with over 50 percent of the world’s population living in urban areas” (Husain & Nafa, 2020), this trend reflects multiple logics—demographic, economic, land-related, but also cultural and political (Softaoğlu, 2019). It simultaneously expresses social aspirations for private homeownership, speculative land strategies, delays in the implementation of urban planning policies, and more or less tolerated forms of self-construction. As such, urban sprawl raises major issues related to land artificialization, ecological fragmentation, public service costs, territorial equity, and climate resilience.

1.2 Theoretical Framework and Sustainability Issues

From a theoretical standpoint, urban sprawl has been widely studied in urban geography, planning, and environmental disciplines. It is generally defined as the expansion of built-up areas beyond the administrative boundaries of cities, often at the expense of agricultural or natural lands. This expansion is marked by low density, fragmented urban fabric, excessive resource consumption, and misalignment with the principles of sustainable territorial development (Rahbarianyazd, 2017).

Early studies on urban form—such as Burgess (1925) with the concentric model, followed by Hoyt (1939) and Harris & Ullman (1945)—laid the conceptual foundations for understanding urban expansion. Since the 1990s, these models have been expanded through critical analyses that integrate the effects of globalization, neoliberal policies, and transformations in urban production systems.

One of the most influential concepts in contemporary debates is that of the compact city (Jenks & Burgess, 2000, Amen, Afara, and Nia 2023; Aziz Amen 2022; Amen and Nia 2020), which contrasts with urban sprawl by promoting density, functional diversity, and reduced spatial resource dependency. This approach is based on the idea that urban concentration enables more efficient infrastructure use, limits greenhouse gas emissions, and reduces pressure on non-urbanized land.

Conversely, the “diffuse city” or “dispersed city” is seen as the outcome of permissive urbanism, fragmented land-use policies, and the cultural ideal of single-family suburban housing (Blais, 2010; Gagné et al., 2020). This model results in inefficient land use, urban fragmentation, and higher infrastructure maintenance costs. Similar patterns are observed in cities such as Erbil (Hariry, 2017) and Famagusta (Nia & Suleiman, 2017), where the erosion of traditional spatial identity illustrates the dysfunctions of sprawling urbanization.

Urban sprawl is also central to policies aimed at curbing land artificialization. According to the European Environment Agency (2020), urban expansion is one of the leading drivers of biodiversity loss, ecosystem degradation, and soil erosion. The concept of zero net land take (ZNLT), incorporated in sustainable planning strategies, aims to reverse this trend by promoting densification and brownfield redevelopment.

In Global South cities—particularly in North Africa—urban sprawl takes on a distinct dimension. It is often driven by self-built housing, gaps in urban planning, unanticipated internal migration, and limited land regulation capacity. These realities call for adapting Western theoretical models to local contexts, accounting for hybrid forms, informal practices, and institutional constraints (UN-Habitat, 2022). Recent studies in Algeria confirm these observations, such as in Skikda and Tébessa (Lounis et al., 2024) and in Mostaganem (Benameur et al., 2024), where spatial dynamics reflect similar dysfunctions as those observed in Béjaïa.

Finally, analyzing urban sprawl requires a critical reflection on spatial planning tools. Regulatory instruments (POS, PDAU), master plans, and strategic planning documents must be assessed in terms of their capacity to guide the spatial evolution of cities. This calls for improved integration of geographic data, increased transparency in land-use decision-making, and inclusive territorial governance capable of translating sustainability principles into concrete planning practices (Sadri, 2017).

1.3 Specificities of the Algerian Context

In Algeria, urbanization accelerated from the 1970s onward due to rapid population growth, planned industrialization, and internal migration. Initially concentrated in major metropolitan areas (Algiers, Oran, Constantine), urbanization gradually extended to medium-sized cities, particularly along the coast. The absence of rigorous planning, slow implementation of urban development documents, and the mismatch between housing demand and public supply fostered the emergence of sprawling urban forms—often informal, low-density, and poorly connected to infrastructure.

According to the National Office of Statistics (ONS, 2022), more than 74% of Algeria’s population now lives in urban areas, and this figure continues to rise. However, this urban growth has not been accompanied by a coherent territorial planning strategy. On the contrary, many cities have experienced the proliferation of peripheral subdivisions, unregulated housing zones, and construction on agricultural, forested, or flood-prone lands. This situation reveals not only a crisis in land management, but also the limited institutional capacity to anticipate spatial dynamics and implement integrated planning (Valipour et al., 2017).

1.4 Le cas de Béjaïa : un territoire en transformation

The city of Béjaïa, located on the northern coast of Algeria, represents a significant example of the contemporary dynamics of accelerated urbanization in medium-sized cities across the Maghreb. Its demographic and spatial evolution since Algerian independence reflects a profound transformation of its urban fabric and patterns of land use.

Between 1966 and 2018, Béjaïa’s population increased from approximately 50,000 to nearly 200,000 inhabitants—a fourfold rise over just five decades. This growth was driven by several factors: natural population increase, internal migration from surrounding rural areas, the development of the tertiary sector, and the city’s economic appeal linked to its port, university, and administrative functions. These dynamics have exerted considerable pressure on municipal land resources.

The spatial expansion of the city has mainly occurred toward the east (Sidi-Ali-Lebhar), the west (Ibourassen, Gouraya), and the south (Sidi Boudrahem, Ihaddaden), progressively encroaching on agricultural lands and peripheral natural areas. This peri-central and peripheral growth was not adequately guided by the existing planning documents, particularly the PDAU (Master Plan for Development and Urbanism) and the POS (Land Use Plans), the implementation of which remains limited.

A lack of coordination between local institutions, weak land management, and the absence of effective territorial monitoring tools have contributed to a scattered urbanization process, characterized by opportunistic and fragmented expansion. This situation has been exacerbated by land speculation dynamics, the proliferation of informal or retrospectively legalized subdivisions, and a strong social demand for single-family housing.

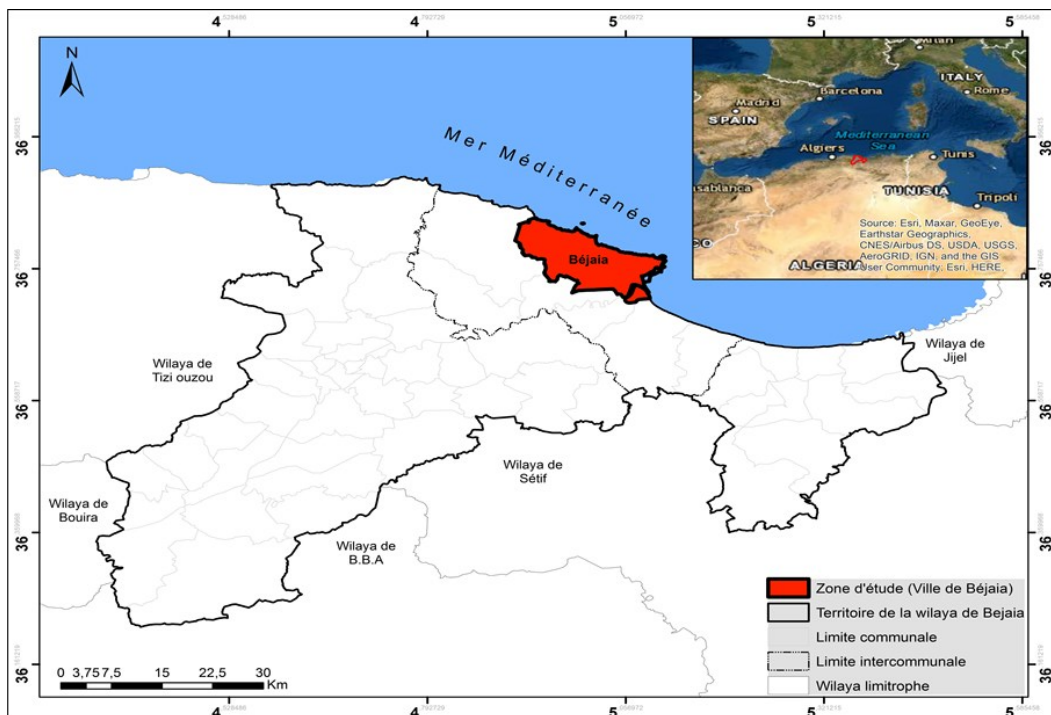


Figure 1. Geographical Location of the City of Béjaia. Source: BOUNOUNI, 2020.



Figure 2. Spatial Evolution of the City of Béjaia (1833–2018). Source: BOUNOUNI, 2020.

The growth of the urban footprint is quantified in the table below. It highlights three main phases:

- a period of slow growth from 1833 to 1962;
- moderate acceleration between 1962 and 1997;
- rapid and pronounced expansion during the last two decades (1997–2018), with an estimated urbanization rate of 0.91 km² per year (i.e., 91 hectares per year).

Table 1. Spatial Growth of the City of Béjaïa.

Year	1833	1890	1958	1962	1974	1997	2018
Area (km ²)	0,175	0,289	1,071	1,598	4,579	10,053	28,329

This rapid urbanization has not only increased the overall size of the urbanized area but also transformed its morphology. The Gravelius compactness index, used to assess the shape of urban form, reveals a gradual degradation of spatial cohesion.

As shown in Table 2, Béjaïa’s urban form, relatively compact in 1958 (index = 1.23), has become increasingly diffuse, fragmented, and linear, particularly since 2000. The index reaches 3.36 in 2018, indicating significant dispersion of the built environment and a "finger-like" urban sprawl pattern following road axes, often lacking cohesive urban integration. This configuration presents major challenges for service provision, infrastructure optimization (water, sanitation, electricity), and public transport management.

1.5 Research Problem and Objectives

In light of the above, a central question emerges: how can we characterize and understand the dynamics of urban sprawl in a medium-sized city such as Béjaïa, and what responses can be considered to better manage the evolution of its territory? This research has three main objectives:

- To document the evolution of Béjaïa’s urban footprint from 1962 to 2020 using Geographic Information Systems (GIS);
- To identify the driving factors behind this spatial growth, whether demographic, regulatory, or land-based;
- To propose concrete recommendations for sustainable urban planning, based on densification, resource preservation, and renewed territorial governance.

This study is intended to be both descriptive, analytical, and forward-looking. It follows an action-research approach, serving local authorities, urban planning professionals, and citizens concerned with the future of their city. More broadly, it contributes to the scientific debate on urban transitions in cities of the Global South and the long-term conditions of their territorial sustainability.

2 Materials and Methods

2.1 Methodological Approach

This study adopts a diachronic and multidisciplinary approach aimed at characterizing the spatial transformation of the city of Béjaïa between 1962 and 2020. It combines spatial analysis tools, demographic and land-based data, and critical examination of urban planning instruments to understand the patterns and drivers of urban sprawl. The methodology is organized around three main axes:

- Multitemporal cartographic analysis, to reconstruct and quantify the evolution of the urban footprint;
- Quantitative analysis of demographic growth, land consumption, and housing patterns;
- Critical evaluation of urban planning tools (PDAU, POS) to assess their regulatory effectiveness in controlling urban expansion.

These methodological choices are directly aligned with the research objectives defined in Section 1.5.

2.2 Data Sources and Nature

The study relies on a diverse range of validated and cross-verified data sources:

- Historical topographic maps at scales 1:25,000 and 1:50,000 ;
- Landsat satellite imagery (30 m resolution) for the years 1984, 2001, 2010, 2020, and 2024, processed using ArcGIS Pro and ENVI software. Supervised classification techniques and NDVI/NDBI indices were applied to distinguish built-up areas and vegetation cover;
- Population and Housing Census data (RGPH) from 1966 to 2018, provided by the National Office of Statistics (ONS);
- Urban planning documents including the Master Plan for Development and Urban Planning (PDAU 2009–2025) and zoning plans (POS);
- Local statistical records from the Directorate of Planning and Budget Monitoring (DPSB) and the Directorate of Urban Planning, Architecture and Construction (DUAC) of Béjaïa province.

2.3 Data Processing and Analysis

All spatial data (maps and satellite images) were georeferenced, orthorectified, and vectorized using ArcGIS Pro. Urbanized areas were delineated for each reference year, allowing the reconstruction of Béjaïa’s urban footprint over six decades. Key metrics calculated include:

- Total built-up area per year;
- Annual urban growth rates and speeds;
- Urban form indicators: gross density, Gravelius compactness index, and fragmentation coefficient.

The statistical component was handled via Excel and SPSS to analyze:

- Annual population growth rate;
- Urban density by sector;
- Evolution of housing stock composition;

- Correlations between demographic expansion and land consumption.

A qualitative and critical content analysis was also conducted on the PDAU and POS documents to examine the alignment between planning provisions and actual urban dynamics. This analysis compared planned extension areas with observed expansion zones, highlighting regulatory gaps and implementation delays.

2.4 Study Limitations

As with any empirical research, this study faces some limitations:

- Cartographic precision is lower for maps prior to 1984, potentially affecting early urban footprint reconstructions;
- Demographic data are aggregated at the commune level, limiting insights into intra-urban mobility and micro-scale changes;
- Access to land registry data and detailed regulatory documents remains restricted, preventing deeper institutional diagnostics.

However, the triangulation of multiple data sources, the combination of quantitative and qualitative methods, and the spatial-temporal consistency of the dataset ensure the scientific robustness and validity of the results.

3 Résultats

3.1 Spatial Growth of the Urban Area

The diachronic analysis of the urbanized surface in Béjaïa reveals spectacular growth since Algeria’s independence. This expansion, far from being homogeneous, has followed varied rhythms depending on political periods, land policies, and socioeconomic contexts. The post-independence period was marked by urban development concentrated around the historic city center, while the following decades witnessed the city's outward expansion, particularly as a result of rapid demographic growth, spontaneous urbanization, and insufficient institutional control. Between 1962 and 1974, urban expansion remained moderate, with an average annual growth rate of approximately 0.25 km²/year. Starting in the 1980s and 1990s, urban growth accelerated in response to strong housing demand and the emergence of new, often unplanned, neighborhoods. The analysis reveals a qualitative leap in the dynamics of urbanization between 1997 and 2018, during which the city added nearly 18 km² of urbanized area, at an average rate of 0.91 km²/year.

This expansion reflects rapid land consumption, occurring at the expense of agricultural and natural areas, particularly in valleys and piedmont zones. The phenomenon is accompanied by territorial fragmentation, with linear extensions following roadways or seizing punctual land opportunities. This spatial configuration complicates the implementation of a coherent network of public services and infrastructure and increases development costs for the municipality.

Table 2. Spatial Growth of the City of Béjaïa. Source: Adapted from Bounouni, 2018, based on historical maps of Béjaïa.

Year	Urban Area (km ²)	Annual Growth (km ² /year)
1962	1,598	–
1974	4,579	0,248
1997	0,053	0,342
2018	8,329	0,677

The most significant phase of urbanization occurred in the last two decades (1997–2018), with a land consumption rate estimated at 0.91 km²/year, equivalent to 91 hectares/year.

3.2 Urban Form and Compactness Indices

The use of the Gravelius index allows us to assess the shape of Béjaïa's urban footprint over time. This index, which compares the actual shape of an urban perimeter to that of a circle with the same surface area (the most geometrically compact form), indicates the degree of compactness or dispersion of the urban fabric.

The results show a clear trend toward an increasingly diffuse configuration. In 1962, the city had a relatively compact form with an index of 1.42. This value increased significantly to reach 3.36 in 2018, indicating an elongation of the urban perimeter without a proportional densification of the built-up area.

This morphological drift is reflected in ribbon-like urbanization, fragmentation of built-up areas, and the emergence of isolated urban pockets (satellite neighborhoods, peripheral residential zones). This inefficient urban structure leads to increased dependence on linear infrastructure (roads, networks) and makes it difficult to optimize resources related to transport, sanitation, and energy.

Evaluating compactness also raises the question of the coherence of territorial planning: Has urbanization followed a comprehensive vision, or is it the result of piecemeal and opportunistic decisions? The findings presented here tend to support the latter hypothesis.

Table 3. Evolution of the Compactness Index of the City of Béjaïa. Source: DPSB, based on topographic maps analyzed with ArcGIS Pro.

Year	Area (km ²)	Perimeter (km)	Compactness Index
1962	1,598	6,43	1,42
1974	4,579	1 5,41	2,02
1997	0,053	1 8,44	1,63
2018	2 8,329	63,85	3,36

It is evident that the compactness index increases significantly, indicating a diffuse urban expansion, with fragmented urban fabric and linear land consumption toward the urban peripheries.

3.3 Demographic Growth and Housing Stock

In parallel with this spatial transformation, the city of Béjaïa has experienced sustained demographic growth. Between 1966 and 2018, the population nearly quadrupled. This increase is due not only to a high birth rate but also to significant migratory movements, particularly from surrounding rural areas to the urban center in search of employment and services.

This phenomenon generated increasing pressure on land and contributed to the rapid development of the housing stock. The number of housing units rose from 30,820 in 1998 to 50,139 in 2018, reflecting a significant—though often poorly regulated—response to housing demand.

This expansion occurred mainly in the form of individual housing, which accounted for nearly 60% of the stock in 2018. Although socially valued, this form of housing is highly space-consuming and poorly aligned with urban densification objectives. It contributes to the peripheral and dispersed occupation of urban territory, increasing infrastructure costs and worsening functional imbalances between central and peripheral districts.

Table 4. Population growth in Béjaïa (1966–2018).

Year	Population
1966	51 794
1977	88 871
1988	118 233
1998	150 195
2008	175 444
2018	190 766

The high demand for housing led to the expansion of the residential stock, which grew from 30,820 housing units in 1998 to 50,139 in 2018—an increase of more than 62%. This dynamic intensified land pressure, particularly for the construction of individual housing.

Table 5. Housing Stock Typology (2018). Source : DPSB, 2018.

Type de logement	Number	Share of Total (%)
Individual housing	19 738	59,75
Collective housing	12 834	38,85
Informal housing	462	1,40

L’habitat individuel, très consommateur de foncier, est majoritaire et explique en grande partie l’étalement linéaire observé, notamment vers l’est et le sud de la commune.

3.4 Correlation between Spatial and Demographic Growth

The collected data reveal a very strong correlation ($R^2 = 0.96$) between demographic growth and the expansion of the urban footprint. This relationship clearly indicates that the evolution of the urbanized area in Béjaïa follows an almost exponential trajectory driven by increasing demographic pressure.

This suggests that population dynamics are a determining factor in the spatial transformation of the city. In the absence of rigorous urban planning, urbanization has occurred opportunistically—wherever land was available—without spatial prioritization or prior infrastructure planning.

Furthermore, the lack of effective land regulation tools and insufficient operational planning (particularly in terms of land use plans, or POS) has allowed for spontaneous or weakly controlled forms of urbanization. This has led to extensive land consumption, often incompatible with the goals of sustainable urban development.

The analysis also shows that the peak in land growth observed between 1997 and 2018 coincides with an acceleration in the pace of residential construction, directly responding to the growing demand for housing. The high proportion of individual housing (nearly 60%) reflects a low-density development model, further expanding the spatial footprint of the urban fabric.

These findings confirm that Béjaïa's spatial evolution is not merely a mechanical consequence of demographic growth, but also the result of a permissive urban development model focused on the immediate satisfaction of residential demand, at the expense of structured and efficient territorial management.

Lastly, urban density and housing typology maps reveal a highly uneven distribution of housing and population. While some central sectors (such as Sidi Ahmed and Ihaddaden) exhibit very high densities, newer or peripheral zones suffer from a lack of infrastructure and public services, exacerbating territorial disparities.

4 Discussion

4.1 Interprétation des résultats

L'analyse diachronique des dynamiques urbaines de Béjaïa met en évidence une nette accélération de l'expansion spatiale à partir des années 1990. Cette croissance, bien que stimulée par une pression démographique soutenue, s'est opérée de manière désorganisée, en l'absence de dispositifs institutionnels adaptés. Les documents de planification urbaine tels que le POS (Plan d'Occupation des Sols) et le PDAU (Plan Directeur d'Aménagement et d'Urbanisme) n'ont pas été actualisés à un rythme suffisant, ce qui a conduit à une urbanisation précédant fréquemment la mise en œuvre des infrastructures de base.

Par ailleurs, l'évolution de l'indice de compacité de Gravelius confirme une transition progressive d'un tissu urbain relativement compact vers un modèle diffus, en rupture avec les principes de durabilité spatiale. La prédominance de l'habitat individuel, qui représentait près de 60 % du parc résidentiel en 2018, renforce cette dynamique centrifuge en favorisant une faible densité d'occupation du sol et une forte consommation foncière.

4.2 Mise en perspective avec la littérature

Les résultats obtenus s'inscrivent dans la lignée des études sur les villes du Sud global, où l'étalement urbain résulte souvent de processus informels, de défaillances en matière de gouvernance et d'une forte pression foncière non maîtrisée. Ces constats rejoignent les critiques formulées par Blais (2010) à l'encontre du modèle suburbain pour son inefficacité spatiale, ainsi que les travaux de Gaigné et al. (2020) qui soulignent le coût environnemental élevé des villes étalées.

La fragmentation territoriale observée à Béjaïa entre également en résonance avec l'analyse de Watson (2009), pour qui les périphéries urbaines sous-équipées des villes africaines constituent des zones de vulnérabilité sociale croissante. Enfin, le déficit d'intégration entre urbanisation et infrastructure est un thème récurrent des rapports de l'UN-Habitat (2022) portant sur les villes intermédiaires du Maghreb.

4.3 Limites de l'étude

Cette étude présente certaines limites. D'une part, la précision des données cartographiques antérieures à 1984 reste relative, ce qui peut influencer les calculs d'indice de compacité ou de surface urbanisée pour les périodes les plus anciennes. D'autre part, l'absence de données démographiques désagrégées à l'échelle intra-urbaine limite la compréhension fine des dynamiques internes à la commune. Enfin, l'accès restreint à certains documents fonciers et réglementaires a freiné l'analyse institutionnelle approfondie.

4.4 Implications et recommandations

Les résultats obtenus soulignent l'urgence d'un changement de paradigme dans la gouvernance urbaine à Béjaïa. Une transition vers une planification urbaine anticipative s'impose, fondée sur :

- L'intégration systématique des outils géospatiaux de diagnostic (SIG, télédétection) dans la décision publique ;
- Le renforcement des capacités institutionnelles locales en matière d'aménagement ;
- L'adoption d'une stratégie de densification douce, centrée sur la reconversion des friches et la limitation des extensions anarchiques ;
- La protection active des terres agricoles et forestières ;
- Et la coordination intersectorielle entre acteurs publics, privés et associatifs.

Ces mesures doivent constituer les fondements d'un nouveau modèle de développement urbain plus économe en ressources, plus inclusif et plus résilient.

4.5 Conclusion de la discussion

En résumé, les dynamiques d'étalement urbain à Béjaïa traduisent un processus de croissance mal maîtrisé, porté par un modèle résidentiel extensif et une planification déficiente. L'étude confirme l'hypothèse selon laquelle l'absence d'anticipation et de régulation foncière cohérente a favorisé un développement fragmenté, inégalitaire et écologiquement problématique. Ces constats appellent à une reconfiguration en profondeur des politiques urbaines locales, recentrées sur les principes de durabilité et d'équité territoriale.

5 Conclusion

5.1 Summary of Key Findings

This study has shown that Béjaïa's urban growth from 1962 to 2024 was marked by rapid and largely uncontrolled spatial expansion. The urbanized area multiplied more than tenfold in six decades, with the majority of this growth occurring in a fragmented and peripheral manner. The dominance of single-family housing, the absence of proactive planning, and poor land governance have collectively contributed to inefficient spatial development and increased pressure on natural resources.

5.2 Research Problem Revisited

The research addressed the question: *How can the dynamics of urban sprawl in Béjaïa be characterized, and what planning strategies are needed to manage this phenomenon sustainably?* The evidence confirms that demographic pressure, informal settlement practices, and speculative land use—coupled with institutional weaknesses—are the primary drivers of the sprawl. Sustainable urban governance is now an imperative.

5.3 Significance of the Results

The findings contribute to the growing literature on urban transitions in North African intermediate cities. They highlight the risks of sprawl-driven urbanization: environmental degradation, socio-spatial segregation, and unsustainable infrastructure burdens. The study emphasizes the need for compact, integrated, and equitable urban models, supported by robust spatial planning frameworks.

5.4 Study Limitations

Despite its methodological rigor, the research is constrained by limitations including outdated cartographic sources, lack of fine-grained demographic data, and limited access to some institutional archives. These gaps may affect the precision of spatial and policy-related interpretations.

5.5 Directions for Future Research

Future work could examine neighborhood-scale impacts of sprawl, explore participatory cartography to better capture community perspectives, and assess the potential of emerging tools such as growth boundaries and green belts. Combining longitudinal satellite imagery with field surveys could yield deeper insights into adaptive and resilient urban development strategies.

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