

THREE MODES OF URBAN PLANNING TO FRONT SPATIAL GROWTH

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Abstract- During the last years, the spatial growth of Algiers took disquieting proportions, increase per the project of metropolization of the city, which aims at providing it with mega-projects to strengthen its competitiveness on the Mediterranean and international scene. Among the worrying consequences of this growth, we note the urban sprawl at the expense of the agricultural land of the Mitidja plain and the coastal urbanization. The objective of this study is first, to analyze and measure this spatial growth using GIS methods, to trace the trends and modes of progression of the built-up area at the city and second, to bring the necessary recommendations to control this growth and reduce its undesirable effects.

Keywords: Spatial Growth, GIS, Metrics, Algiers.

1. INTRODUCTION

Urban growth reflects a general increase in the built-up area or in the size of the population of an urban area. This phenomenon has been studied by several researchers in different disciplines; demographers, urban planners, geographers, and even in the field of modelling [1]. Angel has addressed analysis growth using GIS techniques [3]. Urban growth has many facets, which are economic, demographic, and spatial aspects. It is the analysis of the phenomena of extension and densification of agglomerations [4], the oil-drop like extension of cities, or also the sprawl, which leads to a diffuse city. Sprawl is one of the most widely studied forms of growth. It is characterized by the development outside the urban centers, and uncoordinated growth [5]. It is indicated by discontinuous, fragmented occupation and random density. It causes urban imbalance and environmental damage.

The present study will be limited to the spatial growth of the state of Algiers, by setting aside the other demographic and economic factors; for lack of sufficient data on the activities, and their modes of Occupation. The objective of the article is to analyze the spatial growth of Algiers, to determine the factors that drive this growth, and to propose urban development models that ensure sustainability in the region in the face of the irreversible phenomenon of urban sprawl and thus to rationalize the consumption of urban land. The results of this analysis aim to impact urban policy and contribute to controlling this sprawl.

2. SPATIAL GROWTH PATTERNS AND METRICS

In literature, there are several studies on the modes of spatial growth. Different forms of growth have been identified [6], and grouped into four categories. The first is the growth by compactness where the infilling [7], of open spaces within built-up areas by densification, and thus an increase in density. The second is growth by contiguity, or the extension of built-up areas by other contiguous areas, which is characterized by a non-urban area being urbanized and surrounded by 50% or less of the existing urban area. The third is discontinuous growth in urban patches or dispersed leapfrogging [8]. The last is polycentricity, which is the growth on the periphery that leads to the formation of sub-centers, which vary in size, activity, and degree of connectivity to the urban whole.

There are different metrics, the number of which amounts to 160 techniques [6]. These metrics have been gathered into three large groups: landscape metrics, geospatial metrics, and spatial statistics. These metrics identify the physical properties of the metropolitan form. They are as follows, Size, Density, Coverage, Polycentricity, Compactness, Discontinuity, Expandability, and Land Use Mix.

3. DATA AND METHODS

The article follows two logics; a chronological order starting from the historical data on the city of Algiers to their update and geographic scale that departs from the state to the municipality. To produce the map of the built-up area of Algiers and its evolution over a long period (1830-2022), several data were combined, the periodization was done according to the available maps. This assembly is carried out in two periods, that of (1830 - 1962) which is based on the images and the maps of the colonial archives made available on the sites: Gallica.bnf.fr and Alger-roi.fr. For the post-independence period (1962-2022), maps from the National Institute of Cartography and satellite maps were combined. A vector file of the built environment of Algiers, established by the CNERU (National Center for Applied Urban Studies and Research), during the elaboration of the Master Plan for Algiers Development and Urbanism (PDAU 2016) was used and updated by the author, based on the satellite images of Google Earth Pro, and the use of ArcGIS. All the collected graphic documents were geo-localized and superimposed on the background of the current state of the

built environment of Algiers. The second step consists of measuring the spatial growth of Algiers. On using measurement techniques, two main studies were adopted [6]. The scope of this research is limited to the physical space, and is based mainly on geospatial metrics used by geographers and urban planners. Due to the lack of detailed data on the distribution of urban activities by sector, the measure of land use mix was discarded. Only the parameters related to the built environment and space were taken into account in this study.

4. MEASURING GROWTH AT THE STATE LEVEL

In order to analyze the different facets of spatial growth in Algiers, various and complementary tools were used. Following the chronological order in the pattern of land use and building growth, each tool will serve to illuminate one aspect of urban growth.

4.1. The Directional Distribution Tool

This tool identifies the general trend of a set of points according to the dominant direction. Technically, this tool allows the identification of the general trend of a set of points or surfaces (in this case the building), to measure, it is common to calculate the standard distance separately in the x , y and z directions using Equation (1). These measurements define the axes of an ellipse encompassing the distribution of features. Technically this tool defines the major axis of the ellipse encompassing the building blocks in its geographical territory.

$$C = \begin{pmatrix} \text{var}(x) & \text{cov}(x, y) \\ \text{cov}(x, y) & \text{var}(y) \end{pmatrix} = \frac{1}{n} \begin{pmatrix} \sum_{i=1}^n \tilde{x}_i^2 & \sum_{i=1}^n \tilde{x}_i \tilde{y}_i \\ \sum_{i=1}^n \tilde{x}_i \tilde{y}_i & \sum_{i=1}^n \tilde{y}_i^2 \end{pmatrix} \quad (1)$$

where,

$$\text{var}(x) = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2 = \frac{1}{n} \sum_{i=1}^n \tilde{x}_i^2$$

$$\text{cov}(x, y) = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y}) = \frac{1}{n} \sum_{i=1}^n \tilde{x}_i \tilde{y}_i$$

$$\text{var}(y) = \frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2 = \frac{1}{n} \sum_{i=1}^n \tilde{y}_i^2$$

According to Figure 1, the growth of Algiers underwent a linear spread in two distinct directions during the colonial period. At the beginning of colonization, the city moved southward along the coast. From 1912, the pace gradually changed direction towards the East while remaining adjacent to the coast what constituted the current bay of Algiers. After the independence, and since 1962, the progression of the built-up area around the bay continues while being detached from the bay. Thus, the direction of extension continued towards the East. The Industrial Zone of Rouiba (red arrow), which ran along the national road RN5 connecting Algiers to Constantine marks this continuity. From the 1980s onwards, the growth of Algiers was gradually led towards the South and the South-West, moving away from the sea. Since the years 2000 until our days, the extension seems to continue its pace towards the interior of the country in direction of the small satellite city, Blida and that in the absence of any physical constraint. The realization of the East-West highway and the presence of the Mitidja plain seem to be the two factors driving this growth. The opening on the market economy, and the multiplication of the investments especially at the level of the capital led to the development in oil spot of the built framework far from any urban control.

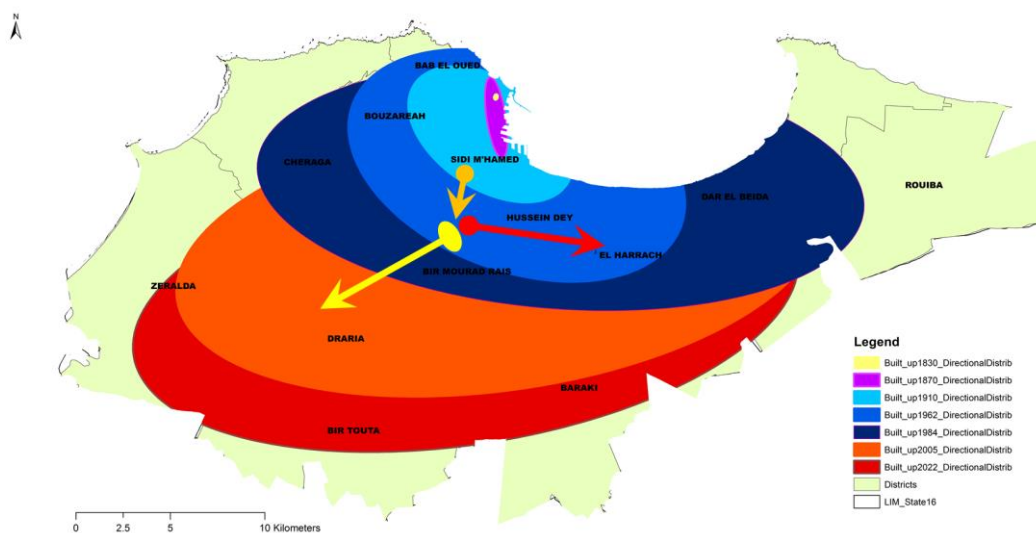


Figure 1. Directional distribution of Algiers state (1830-2022)

4.2. The Aggregation Tool

This tool allows us to resample a frame to a coarser resolution with the aggregation method. We consider that an aggregate is the result of an agglomeration of constructions at a given distance. The closer the aggregates

are to each other, the greater the agglomeration. Conversely, their distance from each other produces a scattering of small secondary clusters. Figures 2 and 3 illustrate the progression of the urban area from 1984 to 2022.

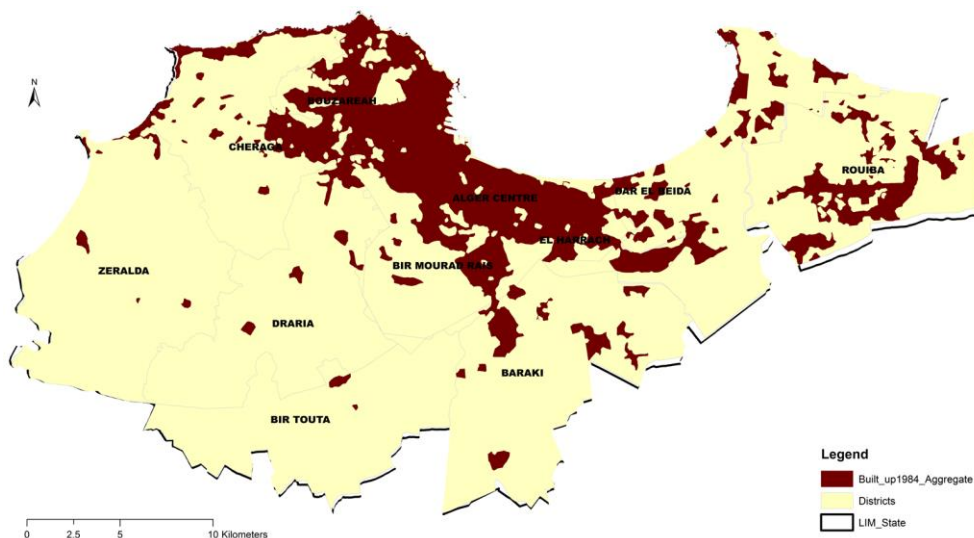


Figure 2. Aggregation of Algiers state in 1984

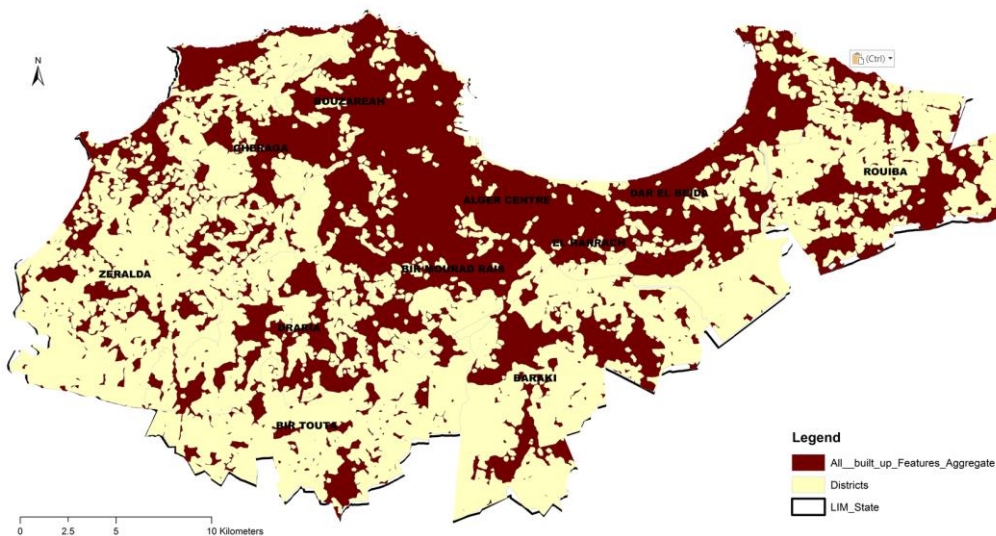


Figure 3. Aggregation of Algiers state in 2022

In Algiers case, an aggregate is the result of an agglomeration of buildings built at a distance of 200 m, a criterion adopted from the Africa polis study [9].

Table 1. Increase in the number of aggregates

Year	Number of aggregates	Growth mode	Localization
1830	1	Compactness	Old town (Kasbah)
1870	14	Compactness Extension	Kasbah extramural
1910	21	Compactness low Discontinuity	Central city
1962	33	Compactness Medium Discontinuity	Central city and 1st ring
1984	96	Compactness Discontinuity	Central city 1st and 2nd ring
2022	453	leapfrogging polycentricity	State (municipalities)

Regarding the classification of the urban areas, to the Algerian regulations, it considers an agglomeration as a grouping of buildings with at least equal to 100, such that

none of them is separated from the nearest by more than 200 meters. Thus, since 1831, the city has progressed arithmetically during the colonial period. Table 1 show this increase from one cluster to 14 in 1871, to 21 in 1910, and finally to 33 in 1962. During the independence period, the progression becomes geometric by tripling from 33 to 96 in 1984, then quadrupling in 2022 and increasing to 453 aggregates.

Figure 4 illustrates this result, which allows us to characterize this sprawl as discontinuous. In the absence of any physical constraint and urban control, the city of Algiers today experiences spatial growth in discontinuous aggregation. Small villages and groups of houses are developing into agglomerations far from any urban action by local authorities. Several factors have favored this phenomenon, notably the migration of populations - in search of employment - towards the capital. Their installation in the periphery, thanks to the lucrative land market for financial backers, is often done in illicit constructions, thus forming "undeclared urban entities".

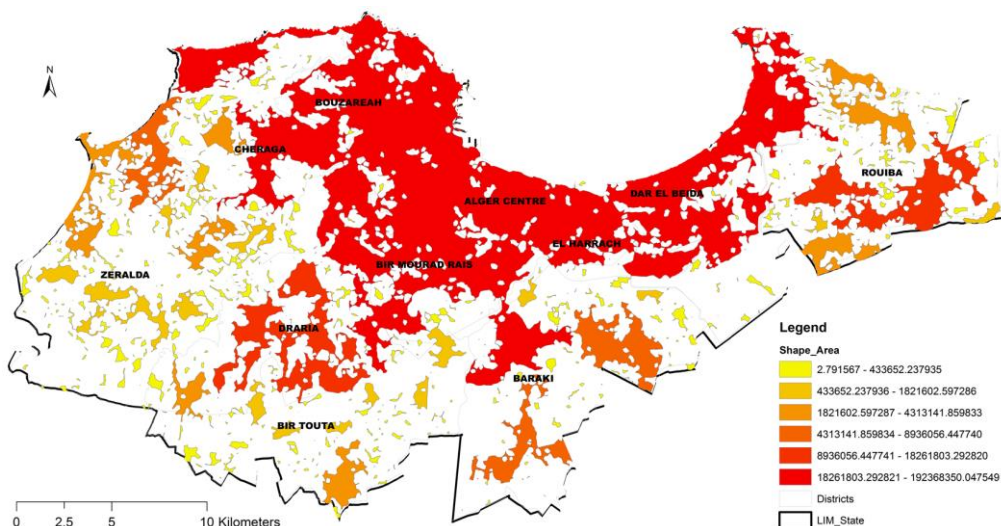


Figure 4. Aggregate building in the state of Algiers, Urban entities ranging from small aggregates of 3 ha to the largest conurbation

4.3. The Kernel Density Tool

This tool is another estimation technique that focuses more on the probability density function of a random variable. It allows us to better analyze the distribution of data (points) studied when using a traditional histogram. Thus, the more the density increases, the more the probability of a kernel appears. The Equation (2) allows us to identify kernels of different density.

$$Density = \frac{1}{(radius)^2} \sum_{i=1}^n \left[\frac{3}{\pi} \cdot pop_i \left(1 - \left(\frac{dist_i}{radius} \right)^2 \right)^2 \right] \quad (2)$$

For $dist_i < radius$, $i = 1, \dots, n$ are the input points. Only points within the radius of the location (x,y) should be included in the sum.

pop_i is the value of the population field of point I , which is an optional parameter.

$dist_i$ is the distance between the point i and the location (x,y) .

Due to a lack of data on the number of building floors, the building footprint was chosen to measure size and density.

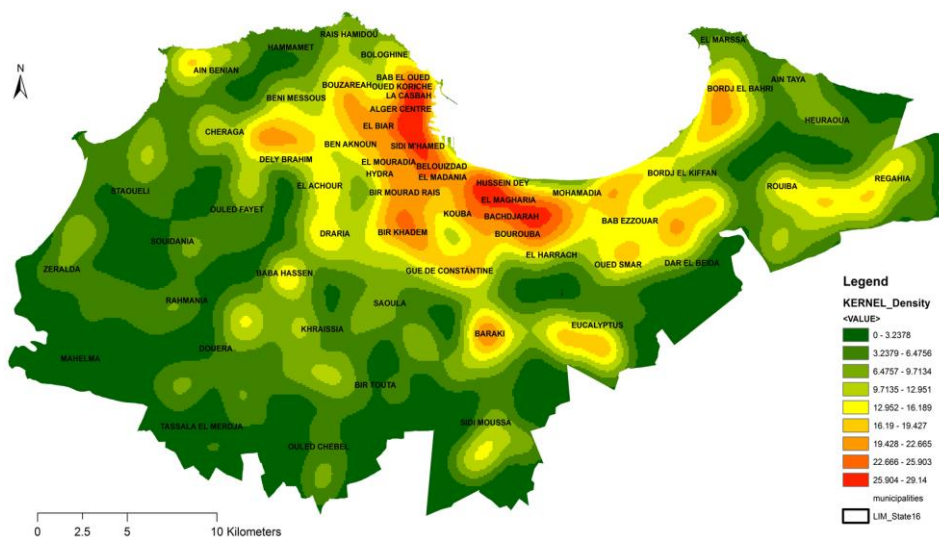


Figure 5. Kernel density of Algiers state

Figure 5 shows the estimation and distribution of core density in Algiers State in three zones: Zone 1 (from red to orange) is the central city (called hyper Centre), which includes the very dense municipalities (Baba El Oued, Oued Koriche, La Kasbah, Sidi M'Hamed, core city, Belouizded, Hussein Dey), which are also the oldest of the city. To this polycentric core is added another crown of municipalities, which were established at the end of the

colonial period. These are El Biar, El Mouradia, El Madania, Hydra, Bir Mourad Rais, Bachdjarah, and El Magharia. Zone 2 (in yellow), characterized by an average density, which is half that of the previous one, groups together the municipalities of the 2nd ring, most of which were born during the first period of independence. These are the municipalities of Bab-Ezzouar, Rouiba, in the East, and El Achour, Draria, Baba Hassen, in the West.

As for zone 3 (in green), it groups together the least dense municipalities, which form the periphery of Algiers state, most of which were annexed as a result of the successive administrative divisions of the national territory into departments and States. These are mainly outskirts municipalities such as Birtouta, Mhalema, Sidi Moussa, and Barraki.

This distribution of building density reflects the concentration of the population and activities. It reflects the daily urban mobility and the mode of use of road networks and means of transport, which is characterized by the phenomenon of the work-home pendulum.

4.4. The Tessellation Tool

This technique has the merit of dividing the territory of the city and its region according to a specific geometric unit and classifying it into categories according to use. The size of the unit of measurement is always random and depends on its usefulness in terms of urban analysis and use. In urban planning, it can range from 1 ha to 1 km². In this work, it has been determined in a surface of 25 Ha per polygon, which allows a better estimation of the built-up area. Figure 6 allows us to note that the densification in the central city can reach more than 60%, whereas it progressively decreases towards the periphery, where the built-up area represents only 2% of the surface of the unit.

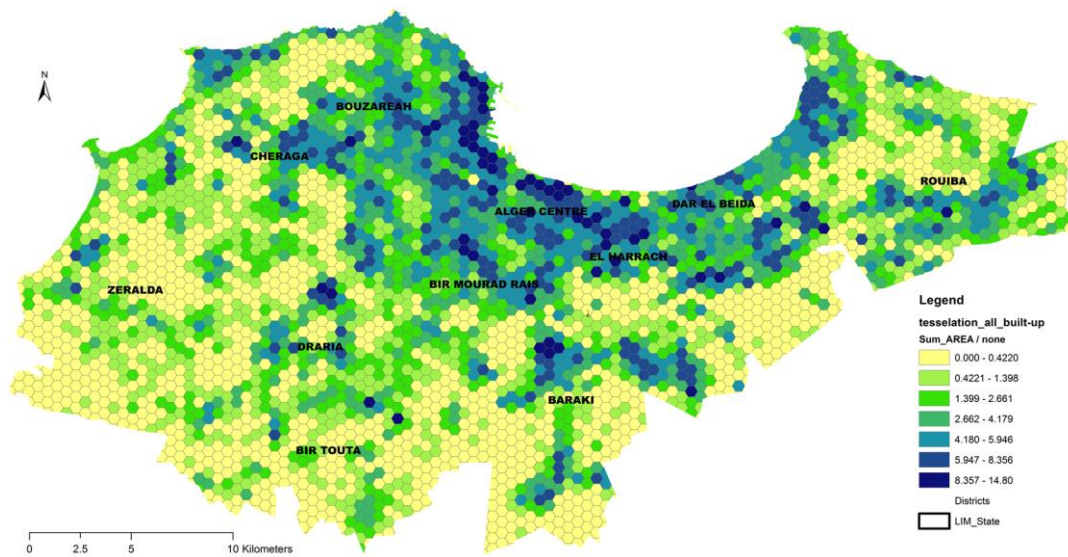


Figure 6. Tessellation of Algiers State

In spite of the contrast between the two categories, the mode of distribution of the units shows us that the great interaction between the built and the unbuilt exposes the natural space to the phenomenon of continuous crumbling.

This technique also makes it possible to identify entirely empty units that constitute the land potential for expansion, and to identify areas to be protected from uncontrolled sprawl.

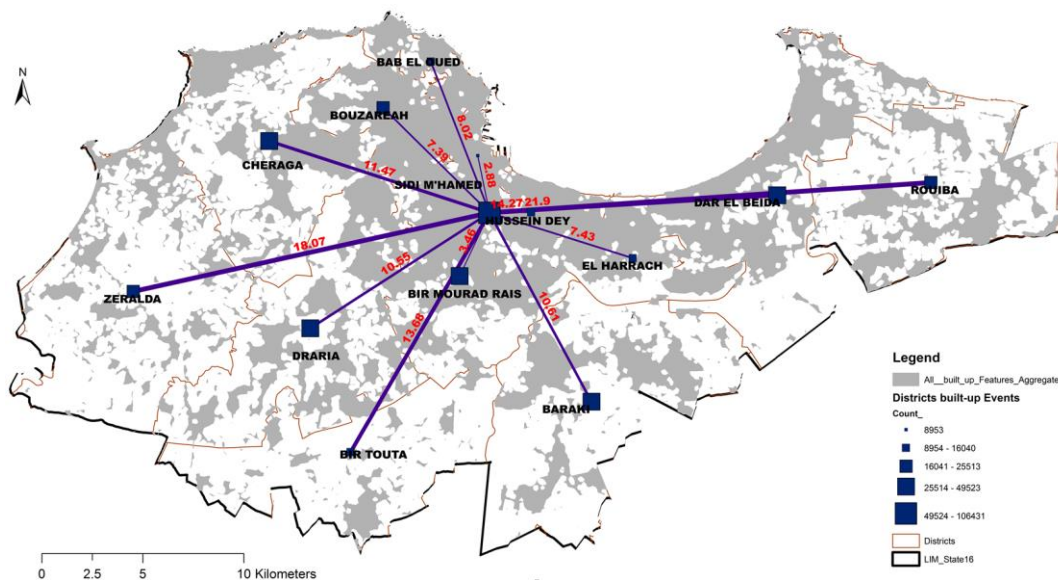


Figure 7. Urban polycentricity in Algiers, urban centers and their distance from the historic center

4.5. Polycentricity

By definition, an urban center is an urban agglomeration made up of a central municipality and a group of nearby municipalities, an urban unit offering 5,000 jobs or more and not belonging to the suburban ring of another urban center [10]. A center by propagation can drag non-urban spaces into the urban area and thus encompass a rural area and become a new secondary center, this is the phenomenon of diffusion. The center of Algiers, which is essentially the historic city, was a succession of new centralities. Figure 7 shows that secondary poles emerge around a main pole, due to the increased density in the central area of the city.

Following the demographic increase and the administrative division of 1984, the municipalities have experienced a multiplication of constructions on their territories. Algiers passed from an inner city and a suburb, to a polycentric structure. First, was the appearance of the economic zone (ZI Rouiba) in the East favoring a new secondary pole in Dar El Baida. During the 2000s, the city expanded towards the West and the South, accentuated by the location of new employment poles. Figure 7 shows their distance from the central pole (≈ 10 km) in the districts of Cheraga, Baraki and Draria. This has favored an extension by contiguity in these directions, and has allowed the appearance of new secondary centers.

Today, new polarities are emerging; the peripheral municipalities that were mostly villages and farms, Hawshes, have become urban. The district of Birtouta which, thanks to its location near the East-West highway (towards state of Blida) and the new economic pole (along the road axis), gives the example of this growth. Finally, the new city of Sidi Abdellah, planned for 45,000 housing units, constitutes the future secondary pole in the West. It represents the retained development trend of Algiers towards the west. It is supposed to mitigate the growth on the coast. However, its location on the periphery leads to an expansion in oil spot, which accentuates the nibbling of

agricultural land, in addition to the uncontrolled proliferation of built areas on the entire adjacent town of Mhalema. At present, the most distant secondary centers (more than 20 km) such as Rouiba in the East and Zeralda in the West remain stable, some secondary centers (10 km) of the inner center are experiencing an increase, because of the multiplicity of activities and businesses in them.

5. GROWTH AT THE MUNICIPAL LEVEL

5.1. Urbanization by Municipality

In this section, the analysis of growth will be limited to the communal level. The 57 municipalities that make up the State of Algiers can be classified into several categories according to their creation dates, their size in terms of population and space, their locations and their densities. For academic purposes, the classification of municipalities in this study is limited to the density of buildings per hectare (buildings/Ha). Accordingly, the municipalities have been reduced to three distinct classes, ranging from the densest to the least dense. Within the sections, the urban evolution of the municipalities is presented in chronological order. The historical context of this growth makes it possible to present the parameters that dictated it and to understand its spatial logic according to the periods and management methods.

5.2. Density of Municipalities

Among the major criteria distinguishing the 57 municipalities spread over an area of 1190 km², we can cite the chronology and the density of the built-up areas. The geography of the municipalities forming successive homogeneous rings clearly reflects this double differentiation. At first glance, the former municipalities forming the old city still retain their higher densities. The second ring, surrounding the former city, forms the second category. The municipalities annexed during the last administrative divisions represents the third ring.

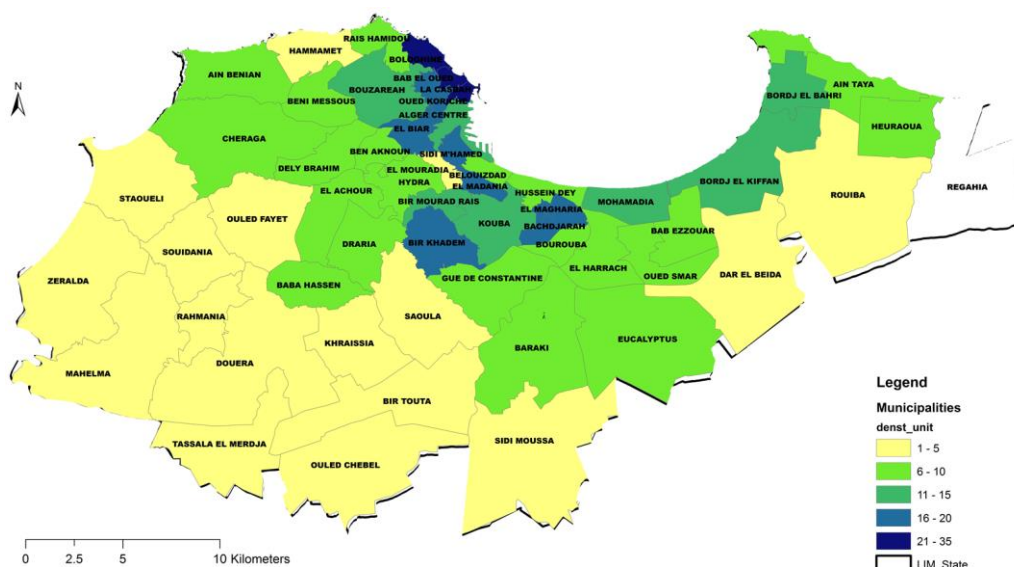


Figure 8. Unit density of Algiers municipalities

The density results are summarized in Figure 8 and Table 2. First, the most saturated municipalities (dark blue) are those located on the bay. These include the old center and Sidi M'hamed. Despite their gradual depopulation in recent years, following the deterioration of the housing stock, particularly in the historic core (Kasbah), they still have a high density. Then come the municipalities located on the eastern and western periphery (Baraki, Bab Ezzouar, Cheraga, etc.) whose urban planning is fragmented into aggregates that are the least dense. In addition to new urban areas, they include individual housing estates, most of which are informal and are the result of private parceling. As for the rest of the municipalities that occupy the largest space in the State of Algiers, they are practically urban nuclei that are established in a virgin space with an agricultural vocation. The municipalities of Tessella el Merdja, Ouled Chebel, and Rahmania are examples. The exception is the New Town; Ville Nouvelle Sidi Abdallah, located in the municipality of Mahelma, which has experienced accelerated development as a satellite city of the capital.

Table 2. Distribution of municipalities in Algiers according to their unit density

Municipalities	Density Unit	
	Nb built/ total area (ha)	
Central city	15-35	
2nd ring	7-15	
3rd ring	1-7	
		Classification
		High
		Medium
		Low

6. AUTHOR'S CONTRIBUTION

On facing the urban sprawl, public authorities consider that it should be primarily tackled at the national scale. A cascade of schemes and plans were established in order to establish a decentralizing policy and achieve a territorial balance. The National Spatial Planning (2030) envisages strategies to control urbanization, requalify the city, and reorganize the territory. On the ground, among the undertaken macro actions, are the launch of many New Towns, (Sidi Abdallah and Bouinan). However, creating new cities was limited to the provision of housing. Basic amenities and job opportunities were mostly delayed.

At the regional level, the metropolitan territory that comprises the capital and the three adjacent States; Boumerdes, Blida and Tipaza, are still maintaining the spatial growth above the national trend. Regardless of the administrative borders, many peripheral settlements of the Algiers state are conurbating with that of the adjacent States. A Metropolitan Plan (called SDAAM) was thus established. The newly developed inter-communal mobility, and public transport although it reduced the traffic jam, seems to have accelerated metropolitan spatial growth. Within the capital State, many programmes of rental and promotional housing have been initiated, in order to tackle the housing crisis and anticipate urban development. Most of these new schemes are located at the outskirts of the capital, which is already subjected to a dynamic informal land market. Accordingly, both parts, i.e., the formal and informal sectors, are contributing in the promotion of new settlements at the periphery. The Master Plan is another instrument that is set for the capital and its

municipalities. Among the recommendations of this tool is the creation of green pockets, called urban agri-parcs, that supposedly allow to limit the urban sprawl, and protect the remaining agriculture large pockets.

Assessing the planning instruments that are stated above although necessary, is beyond the scope of the present article. Although recommendations that are made below will heavily depend on the national and regional policy, the article will be limited to the communal level. The control of sprawl depends on the specificities of each municipality; its rate of urbanization, its spatial characteristics, land use pattern and economic resources. Land is the major aspect that should structure any control policies and establish a regulatory framework. Spatial growth must also take into account the requirements of sustainable development.

Accordingly, three modes of control are recommended. The first mode consists of monitoring growth through Urban Densification. It concerns the old municipalities (old town) and deals with the main character of the municipalities concerned, that is centrality. Densification, consists of favoring compactness of built-up areas, while preserving the its physical character. It also consists to intensifying urban spaces, and directing the urban growth to the existing urban areas. This policy has many advantages in terms of transport, mobility, housing and functional mix. In Algiers, it will allow the recovery of wastelands that count for more than 2,000 hectares (Master Plan, 2016). However, densification should not be the same as in all urban areas. Adopting restructuring and renovation actions that allow the modernization of central services and activities, in accordance with the legislation in force, depend on the physical state of the buildings and land status. Within this policy, it is also necessary to reinforce and accelerate the safeguarding and preservation actions regarding the historic center (Kasbah), whose heritage value is indisputable.

The second mode for monitoring growth is Urban Infill that regards the municipalities of the 2nd ring. It is more efficient to make profit from the unused lands, the existing infrastructure and services than creating new development areas. This mode consists of urban renewal operations that deals with the dilapidated old industrial zones. Recovering, rehabilitating and enhancing brownfields into productive areas should be coupled with the optimization of existing public facilities [11]. Urban fabric in these municipalities is characterized by its dispersed development. It thus requires a detailed analysis of infill sites capacities. The thorough classification of plots must thus be made. Mixed land uses with essential concordance between housing and facilities and an improvement of the accessibility of these areas, which are increasingly attractive, is also recommended.

The third mode evolves around the Green Urbanism and regards suburban municipalities. It consists of preserving the present character of the newly annexed municipalities. Installing a Green Urbanism consists of limiting the built-up area in favor of natural resources. The actions that can be taken consists of promoting the Green-Belt concept at the municipal level.

Such a policy has been adopted in other cities around the world and has proven to be an effective way of dealing with urban sprawl; At the local level, a similar measure was recommended by the Master Plan, but did not see the light of day. On investigating the delay in their implementation, the long administrative procedures, were found to be a major reason. It takes almost two years to elaborate a Land-Use Plan (POS), that regulates Land-Use in a municipality. Once established, it is frequently transgressed. Away from the administration, the low price of agricultural land, that is mostly private, and speculation is the major factor of diffuse urbanization. Firm and permanent control on the green pockets is an environmental and economic requirement. Urban boundaries through clear perimeters and buffer zones should be set. These boundaries and zones should be reviewed periodically while assessing the future demand for land.

7. CONCLUSION

The city of Algiers is facing a continuous urban growth and a fast land consumption that is at the expense of the most valuable natural resource, Mittidja, the fertile plain of central Algeria. This growth is mainly due to the double national imbalance, North-South, and large cities Vs inlands. The regional imbalance and the primacy of Algiers is further accentuated by the many structuring projects that are recently launched.

In the absence of restraining measures, the encroachment on agricultural land would inevitably persist. Controlling urban growth would not be achieved without at national policy that helps improving the living conditions in the cities of the interior. Providing services and employment in other cities, and developing transport network would be the priority in any regional policy. Such recommendations also apply to the new towns Sidi Abdellah and Bouinan that have been recently created.

The numerical techniques used in this study allow us to highlight the spatial growth patterns of Algiers and consider the urban planning policies that should be adopted. Following the classification of the municipalities, three modes of control would be proposed. The first mode is densification, which regards the oldest communes; particularly in the central areas where the built environment has deteriorated. Avoiding coastal development, which affects the waterfront landscape, would be part of this policy. The second mode concerns suburban municipalities. Urban infill concerns the reconversion and restructuring of wastelands and industrial areas that do not possess any urban quality to enhance land use to productiveness. Finally, the green urbanism regards the third category of municipalities. There is a vital necessary to circumscribe the built-up area, and establish effective control on protected green pockets.

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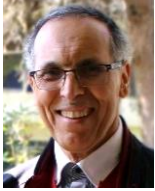
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