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Research Article

Urban Expension Analysis of New Cities in North Africa, using Remote Sensing and GIS Betewen 2004 – 2024. Case Study of Sidi Abdellah, Algeria

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ABSTRACT

This research has discussed the patterns of urban expansion in the new city of Sidi Abdellah, Algiers capital from 2004 to 2024. The time-series analysis was conducted by measuring changes in built-up areas defined with the help of multi-source remote sensing data, such as the GLC_FCS30D dataset, and Sentinel-2B satellite images. The classification of the urban development for the three dates, which includes 2004, 2014, 2024, is performed with a subsequent accuracy assessment and validation of the results obtained. Consequent changes are traced, analyzed and the results demonstrate the features of urban transformation that can be seen as rapid and patterned. This fast change patterned underlines the importance of urban expansion that should be well-designed and effectively implemented. The proposed model of urban expansion focuses on minimizing environmental impacts and preventing environmental degradation, while reserve the urban areas and their expansion. This work provides insights into the patterns of urban expansion in the new city of Sidi Abdellah, Algiers capital, the outcomes of the research can be usable by policymakers, planners and other stakeholders who are engaged in environmental issues.

Keywords: Urban expansion, Remote sensing, GIS, Time-series analysis, Sidi Abdellah, Algeria.

INTRODUCTION

North African cities such as Algiers, Tunis, Cairo and Casablanca in general suffer from overpopulation for several reasons: rural exodus, migration [1], population growth which has exacerbated the problems of housing congestion public services and pollution [2]. All these challenges affect the quality of life and hamper development so it is necessary to work on developing new spatial planning strategies including the adoption of a new cities policy [3].

Since 2008, (law 2008) Algeria has chosen its new cities policy strategy [4] .The new city of Sidi Abdellah located 25 km south-west of Algiers [5]. Was designed in a context of high population growth and pressure on the capital this city project aims to reduce this pressure by offering a sustainable urban development solution, development of the city began at the start of the XXIe century [6], with the aim of responding to population growth diversifying infrastructure and promoting a more rational form of urban development in the long term. This project is part of the new national land-use planning policy which aims to modernize urban infrastructure and ensure a harmonious living environment while balancing regional development. Sidi Abdellah has undergone rapid expansion particularly following the creation of residential, commercial and industrial areas. This study will analyze the urban dynamics of the new City of Sidi Abdellah (2004/2024). The analysis will rely on remote sensing techniques and geographic information system advanced [7]. These tools are essential for observing changes in land use over large geographical areas. In particular, monitoring the spread of urbanization [8]

Remote sensing makes it possible to collect precise and recurrent data on changes in land cover while GIS makes it possible to analyze and visualize them in a geographical space [9], By integrating topographic and socio-economic data the use of satellite imagery [10] for 2004, 2014 and 2024 allows the analysis of changes in land cover and the monitoring

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of transformations in urban, agricultural and forested areas. In 2004 the area was dominated by farmland and forests with limited urbanization.
However, starting in 2014 urban growth accelerated significantly particularly in the south and east of the city as a result of population growth and the construction of residential and commercial infrastructure which led to the exploitation of previously unused areas. This rapid expansion [11] has had environmental consequences in particular the transformation of agricultural land into residential areas which has reduced local food production and the natural areas around the city forests and biodiversity have also been affected and analysis of remote sensing data makes it possible to measure the impact of these changes on the territory [12]. These observations highlight the need to implement sustainable management strategies [13] and therefore it is necessary to minimize the negative environmental impacts associated with the process of urbanization [14] and the study also showed the challenges of managing urban growth in the new city of Sidi Abdellah; despite the good organization of the initial phase of development, future management requires careful planning to avoid random urbanization and ensure the preservation of agricultural areas [15]. Remote sensing data shows that certain areas of the city particularly those close to transport networks could come under increasing pressure in the future. The management of water, waste, energy and environmental protection will be major challenges in guaranteeing the sustainability of urban development and ensuring an acceptable quality of life for residents in the long term.

MATERIALS AND METHODS

1. Study Area:

The new city of Sidi Abdellah is located to the west of Algiers in the Mitidja plain, around 20 km South-West of Algiers close to the center of Algiers and to the East-West motorway making it easily accessible from all parts of the country. In the countryside, the city is located in a strategic area close to the Mediterranean Sea providing a favorable environment for urban development. This location has been chosen to enable it to fulfil its role of relieving congestion in the capital and developing a smart modern urban center with high-quality infrastructure. (Fig.1)

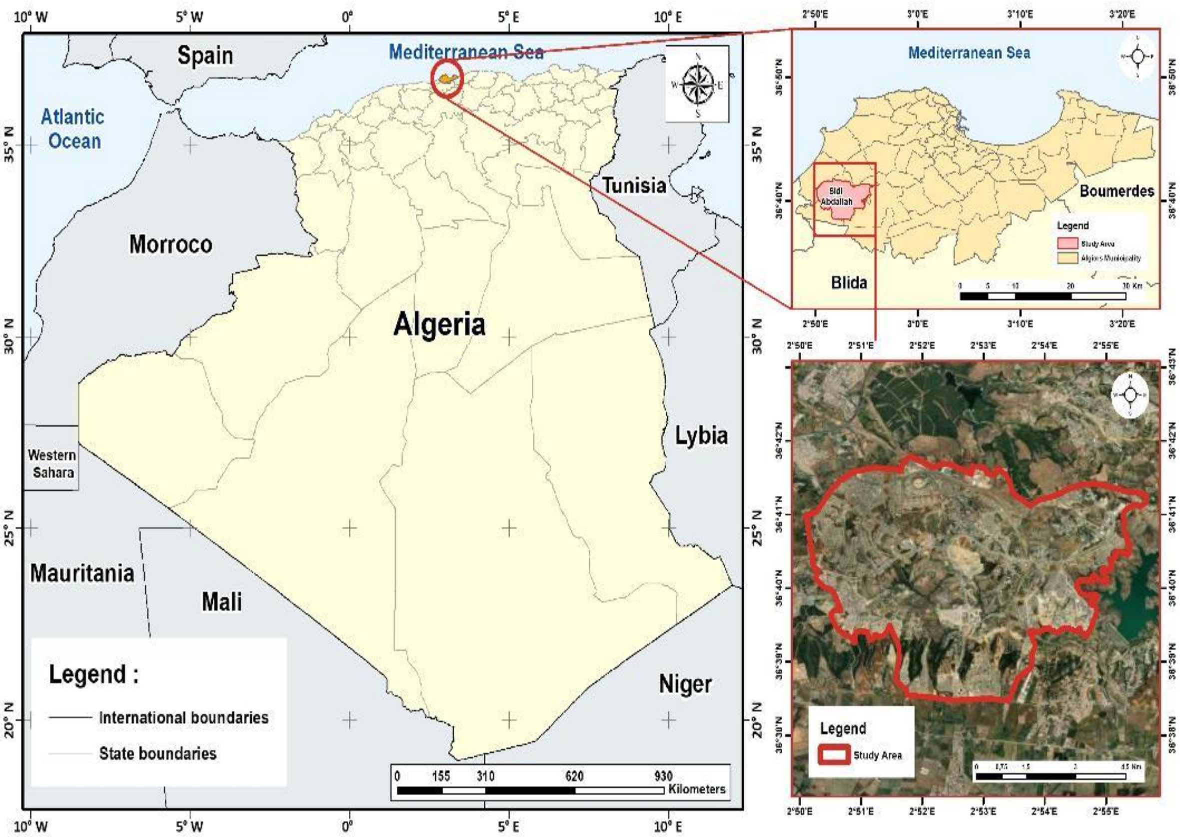

Figure1: Study area new city Sidi Abdellah, Algeria

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2. Data acquisition:

2.1. GLC_FCS30D (2004, 2014):

The GLC_FCS30D is a global land cover dataset with a resolution of 30 meters covering the period from 1985 to 2022 [16] ; this dataset is accessible via Google Earth Engine (GEE) and provides a fine-grained classification system with 36 classes for this study the classes relevant to urban areas were identified in particular the Impervious surfaces class which represents urban and built-up areas, The dataset used covers the years 2000 to 2014 with data available annually and at five-year intervals. The GLC_FCS30D dataset provides an overview of land cover changes including the dynamics of urbanization forest cover and other land use categories [17]. We used it to analyze the phenomenon of urban expansion over the years 2004 and 2014 (two decades later) in the new city of Sidi Abdellah. (Table1)

2.2. Sentinel-2B image2024:

Satellite spiral-imagery sentinels ology [18] derived mainly from the product for September 24, 2005, was selected for the analysis of 2005. The data was pre-processed, with an overall cloud coverage ratio of 10%. The tile ID for these images is T31SDA, and WGS 1984 (zone 31N) is the coordinate system employed. Sentinel-2 images provide high-resolution (10-meter) multispectral data [19] which was used for training samples and classification. The images need to be pre-processed to correct radiometry, remove atmospheric effects and mask clouds, followed by mosaicking and geometric calibration using Sentinel-2B data from 2024 [20,21]. We can produce highly accurate maps to analyze local phenomena such as urbanization, changes in vegetation and agriculture in study area new city of Sidi Abdellah. (Table1)

Table1: data acquisition (GLC_FCS30D in 2004, 2014 and Sentinel-2B image 2024)

Dataset	Source	Resolution	Projection	Date	Classes	Band Combinations
GLC_FCS30D	Google Earth Engine	30 m	WGS 1984	2004, 2014	Impervious Surfaces and other grouped land use categories	**36** classes simplified and regrouped into broader categories
Sentinel-2B	Copernicus (ESA)	10 m	WGS 1984 Zone 31 North	18/04/2024 (Cloud Cover: less then10%)	MLC Classification trained on supervised samples	(Bands 11, 8, 4) (Bands 12, 11, 4)
Study area	PBMD	Vector	WGS 1984 Zone 31 North	2004	/	/

3. Methodology:

The workflow used in this study is illustrated in the diagram below. (Fig.2)

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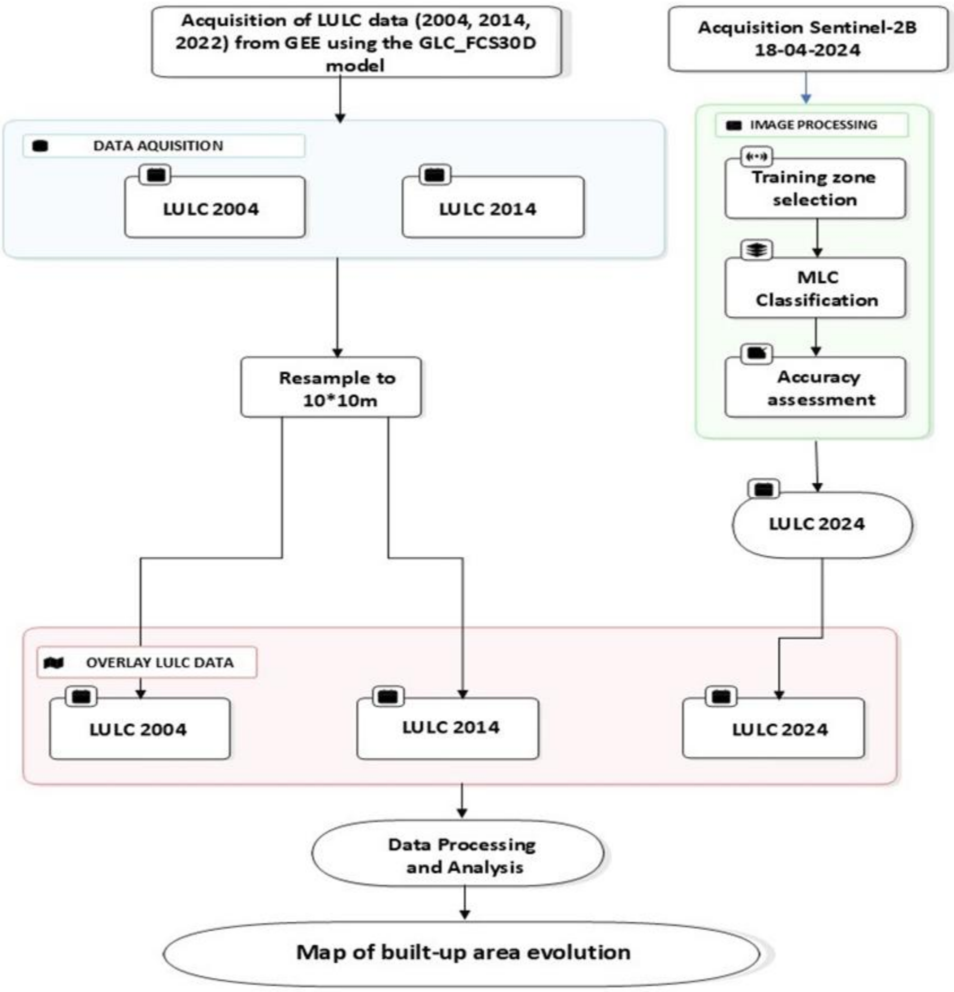

Figure 2: a flowchart of Methodology - (Source: Author realized)

3.1 Preprocessing of GLC_FCS30D Data

To generate an image collection illustrating land cover changes, the GLC_FCS30D dataset was preprocessed. The dataset was processed using a script in Google Earth Engine and using the annual data from 2004 to 2014 inclusive, a mosaic of land cover classifications was produced. The steps taken were as follows.

3.1.1. Recoding of classes:

GLC_FCS30D has a detailed classification system that includes 35 subclasses of ground coverage to analyze the course of land use changes accurately [22]. However this detailed classification system also makes it possible to group these sometimes dialectically opposed units together so as best facilitate analysis by relevant authorities and to compare data sets on a large scale. Vegetation that grows in discrete patches is grouped with bare land under the general classification, as they share many spectral characteristics as well as common land use patterns or environments in which to thrive [23] Similar systems of land-cover classification have been proposed for countries in Europe but still follow international standards set at the continental level. These systems try to balance both accuracy and detail on the one hand, and ease of use and practicality on the other: this aims to give rise to classifications that will be understandable across different temporal as well as spatial dimensions. These classifications are an important tool for data analysis and comparison, ensuring a sufficiently high degree of accuracy in remote sensing and resource management failure prevention. [24]. Bringing together detailed ground coverage classifications people can deal with the difficulties brought about by multi-spectral analysis, thus fostering the practical usability of data sets including GLC_FCS30D [25].

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3.1.2. Resampling

We resembled the data to an accuracy of (10×10) meters using the nearest neighbor method. In this manner, we aligned it with Sentinel-2 data so that we could obtain an accurate representation. [26]. for its superiority in maintaining the categorical nature of land cover data during reworking, a nearest neighbor approach was preferred to more common interpolation techniques such as Know or cubist convolution. This way it avoided introducing artificial intermediate values and made sure the discrete ground cover classifications stayed sound [27]. Nearest neighbor is especially suitable for datasets where the boundaries between categories are so important, such as urban studies and the need to identify impervious surfaces with precision [28]. The processing transforms the GLC_FCS30D data into the high-resolution Sentinel-2 images, and makes it possible to apply more in-depth analysis of land cover changes over time. The GLC_FCS30D data The GLC_FCS30D dataset has been applied in a wide variety of studies on land cover dynamics and environmental monitoring, [16]. Presented as the first global 30-meter land cover dynamics monitoring product to possess an accurate classification system from 1985 through 2022 Created by identifying local changes in pixel Landsat time series and visualizing the entire process of global wind erosion reduction stimulated by climate change & land use [29]; it is an essential tool for understanding and explaining environmental changes Been used to create high-time precision micro forest cover products. It has shown its versatility in various environmental studies and experiments. These applications show how useful the dataset is for the analysis of land cover changes and how important is in environmental and climate research.

3.2 Sentinel_2B Image Classification:

As to 2024 data, the training samples for 2024 were chosen based on field data and visually interpreted from the Sentinel-2B satellite images, 250 training samples were divided equally into 5 land-use categories, and 50 samples for each category were assigned. This equal distribution results into a representative distribution for all classes decreasing the bias and improving the accuracy of the classification procedure, moreover, equal allocation is more effective for classes with different extend [30] and avoids an over-representation of the dominant categories whereby such studies recommend stratified sampling strategy to increase the representation and classification reliability [31].

Assigning 50 points to each category meets the accepted guidelines for supervised classification, highlighting the importance of sufficient sample size to capture spectral variation within each category, permitting an accurate differentiation of land-use types, even in the case of smaller or homogenous categories, and securing the robustness of the end land-use map [32,33] additional recommendations about the effective use of Sentinel images are found in Sentinel-2 User Guide. 2016.

To enhance visibility of urban areas color compositions of Sentinel-2 bands (bands 11, 8, 4) and (bands 12, 11, 4) are utilized. The urban features are better differentiated by the resultant impervious surfaces and made-up areas; a previous study also showed that these band ratios were used to highlight impervious surfaces and made-up areas since they yield satisfactory results, maximum likelihood classification (MLC) was used for the classification procedure on account of its appropriateness for normally distributed data [34] All the operations were performed in QGIS, using the semi-automatic classification plugin (SCP) that allows for an effective method of multispectral image classification. This procedure is consistent with works for LULC mapping; recent papers stress the necessity of integrating field data.

RESULTS AND DISCUSSION

In the context of this title, we will address the two most important elements of assessing the accuracy of land cover through the classification processes that we will carry out on the basis of the data obtained, while the second element, which is no less important than the first, consists of analyzing the state of change in land cover.

4. Accuracy Assessment of Land Cover

4.1. Classification:

Accurate assessments of Sentinel-2B datasets show us the strength and reliability of classification processes and for a guaranteed unbiased assessment, the Equalized Stratified Random Sampling method was used, ensuring a balanced representation of all categories for land coverage within the verification dataset [35,36]. This aims to reduce the approach to sampling bias by distributing checkpoints proportionally across different categories, providing a more accurate reflection of classification performance across all categories.

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Table 2: Accuracy assessment results for GLC_FCS30D and Sentinel-2B classifications.

Dataset	Year	Number of Validation Points	Overall Accuracy (%)	Kappa Coefficient	User Accuracy (%)	Producer Accuracy (%)
Sentinel-2B	2024	500	90	0.90	90	90

The classification of Sentinel-2B conducted in 24 gives an overall accuracy of 90.0% and KAPPA coefficient 0.90. So high accuracy value showed that the MLC method (application Maximum Likelihood Classification to Sentinel-2B images) gave good results which could be used for further urbanization analysis with confidence (Table 2).

User and product accuracy of the model was 90%, deemed to be reliable for indicating actual cover and distribution. This is particularly significant from the standpoint of categories because may fail categories effectively [34]. The KAPPA coefficient is particularly important because it take as into account the probability of agreement occurring by chance, providing a more robust measure of classification accuracy than only overall accuracy [37]. With this Kappa value (0.90) --which is excellent--we know that the MLC method correctly determines an area within urban or built-up regions as urban, that is, a built-up region; and conversely for non-built regions. The stratified random sampling method came in as it was necessary for the survey to ensure that each land cover type was represented in the validation data, but it also deepened the reliability of the assessment results. This methodological rigor of theirs is an absolute prerequisite for researching and analyzing urbanization, because it gives results out classification and later interpretation.

4.2. Land Cover Change Analysis:

Following the preprocessing and classification, the land cover datasets for 2004, 2014, and 2024 (Fig3) and (Fig 4), were compared to analyze urban expansion within the study area (Table 3).

The analysis specifically focused on tracking changes in built-up areas (impervious surfaces).

Table 3: LULC change between 2004 and 2024 (Source: Author realized 2025).

LULC Classes	2004		2014		Area changes 2004 / 2014 Km²	2024		Area changes 2014 / 2024 Km²
	Area Km²	%	Area Km²	%		Area Km²	%	
Impervious surfaces	2,72	8,28	4,48	13,63	1,76	13,04	39,71	8,56
Forest	2,59	7,87	2,74	8,34	0,15	1,34	4,07	-1,40
Bare areas	1,22	3,71	1,43	4,35	0,21	8,32	25,35	6,89
Cropland	26,29	80,05	23,86	72,66	-2,43	6,44	19,61	-17,42
Grassland & Sparse vegetation & Mangrove	0,03	0,09	0,33	1,02	0,31	3,70	11,26	3,36

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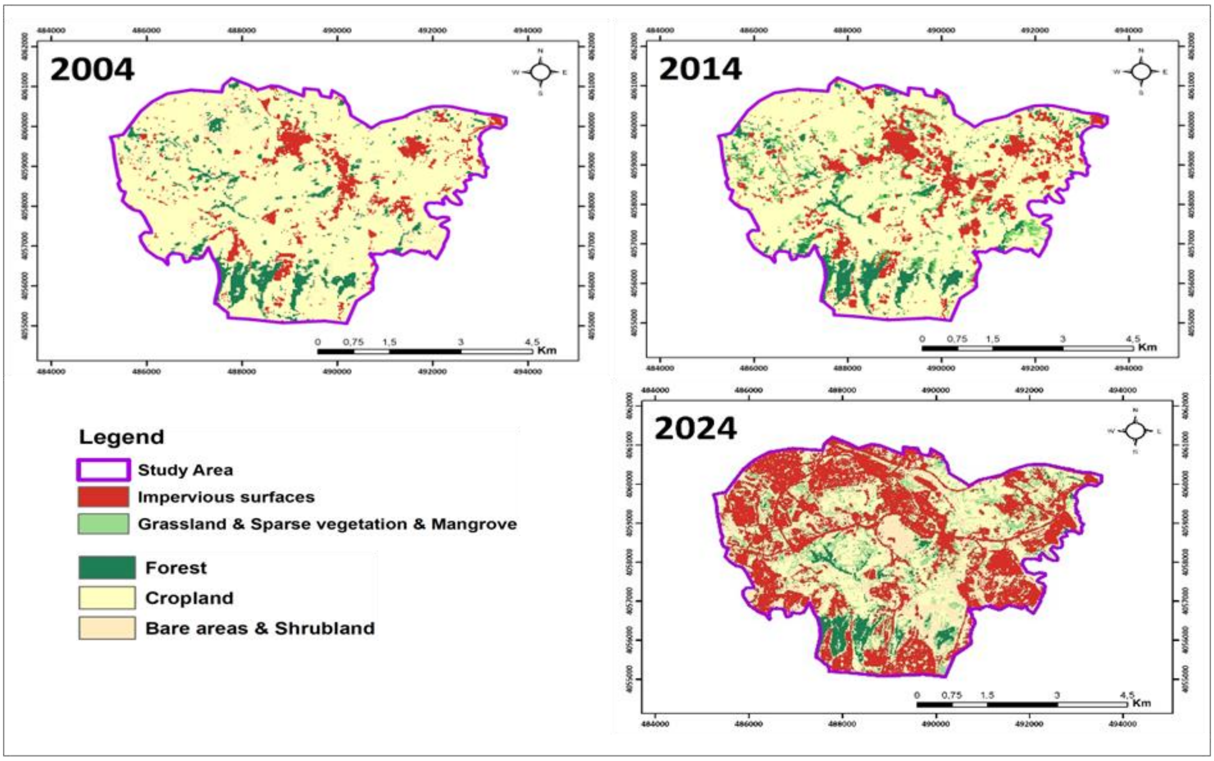
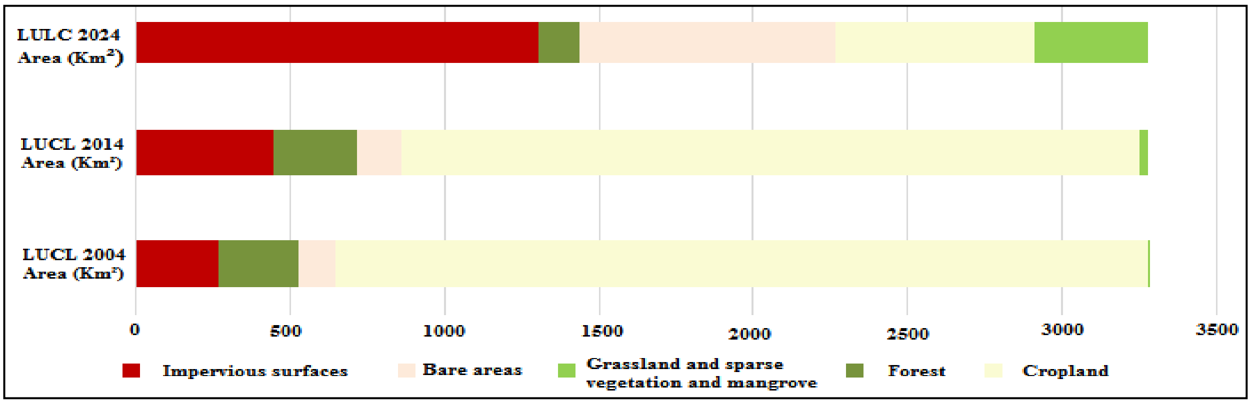


Figure 3: urban extension between period 2004, 2014 and 2024



As can be seen from the maps tracking the urban expansion of New city of Sidi Abdellah over the period 2004-2024 **(**Figure 4**)**, which highlighted significant differences giving us a very clear picture of the vast spatial mutation of the study area over 20 years the most significant change was seen in impervious surfaces (built-up areas), which increased significantly from 2.72 km² (8.28% of the total surface area) in 2004 to 13.04 km2 (39.71%) in 2024. This represents a net increase of 10.32 square kilometers, with the greatest expansion occurring between 2014 and 2024 (+8.56 square kilometers). **(**Figure 5**)**, **(**Figure 6**)** and **(**Figure 7**)**

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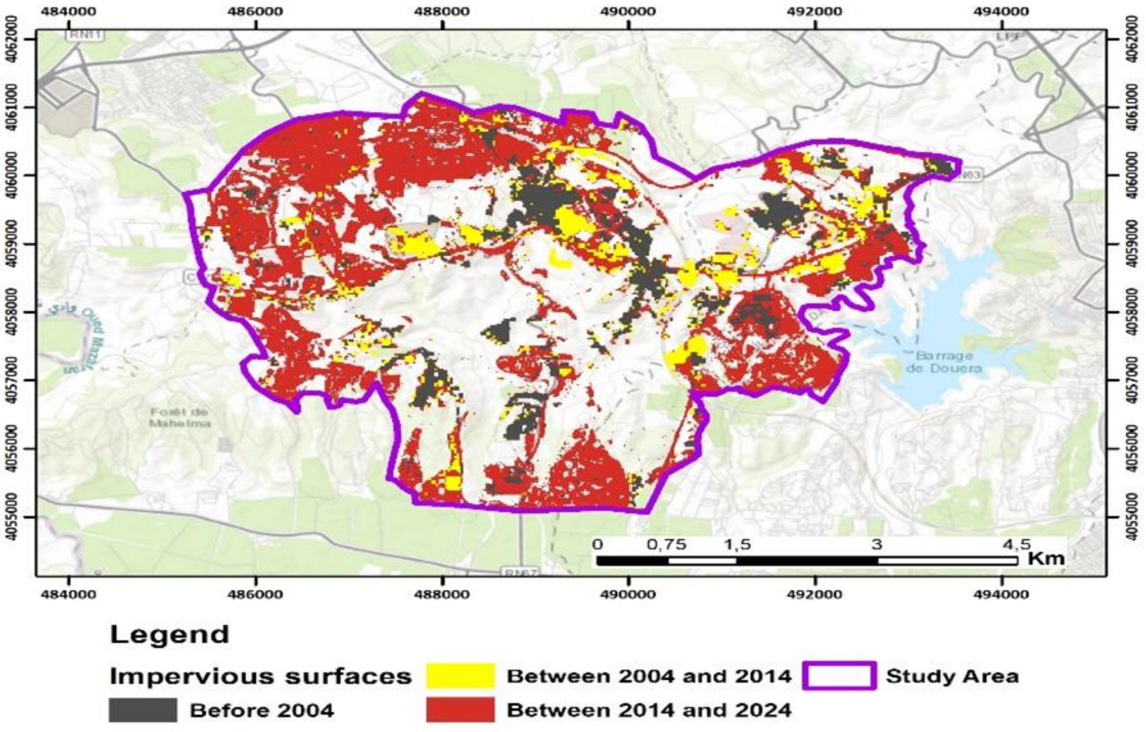

Figure 5: LULC change between 2004 and 2024 (Source: Author realized, 2025)

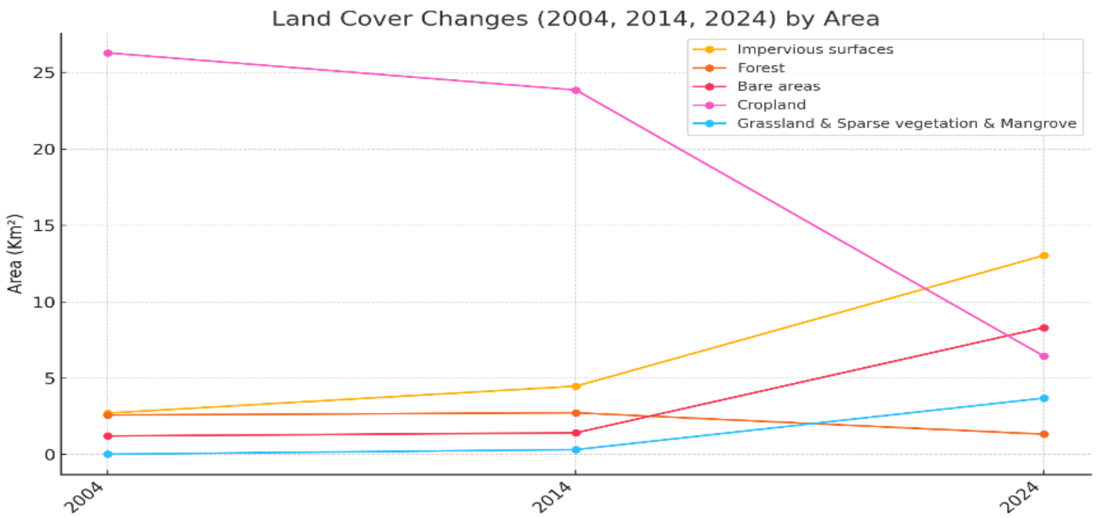

Figure 6: Land cover changes (2004, 2014, and 2024) by area. (Source: Author realized, 2025)

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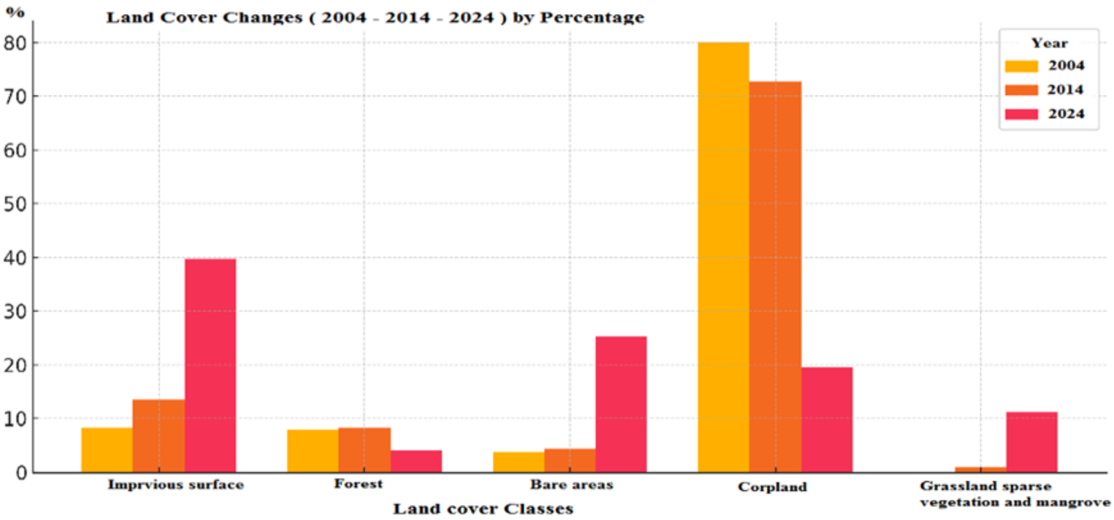

Figure 7: Land cover changes (2004, 2014, and 2024) by percentage. (Source: Author realized, 2025)

This rapid and accelerated urban transformation shows that the rate at which the new city formation proceeds is a point of break because all political and peoples' factors have been combined together in Sidi Abdullah so once decisions of establishment were made next door under capital influence, course it naturally had to expand as well However, the new city is engineering-based and it is pointed out that city planning should be adapted to this in order to strike a balance between urban expansion and environmental and social needs for the people residing there thereby achieving its projected goals. It can be seen from land use maps that in just 20 years, in 2004 by contrast with where we were at 1985 only 30% of the land had residential permit therefore 99.80% (26.04km²) today is rural land or operations and employment land. Urban development has meant agricultural have been displaced from 6.44 square km in 2004 all the way down to 0.03 km² by 2024 areas marked on the map are part of an article describing virgin land area of 19.61 %. Urban construction activities have been particularly pronounced. As a result, desertification land area from 1.22 km in 2004 expanded to 8.32 km² 2024. Urban zones have expanded rapidly as well from 2004 (0.03 km2) to 2024 (3.7 km²). Forest area is decreasing somewhat--from 2.59 squares kilometers (7.87%) in 2004 to 1.34 square kilometers (4.07%) by 2024 -, indicating scarce deforestation or land handed over to toll booth these trends conform not only to the growth and development pattern experienced in other parts of China but also global trends.

DISCUSSION

Urban growth in the study area mirrors patterns that can be seen in other cities around the Mediterranean in these regions the process of urbanization usually takes the form expansion impervious surfaces at expense agricultural lands triggered by economic development population increases and infrastructure projects. For example, such studies on the cities of Athens and Istanbul reflect similar patterns Athens expanded residential zones between 1987 & 2017 ending up with increased land losses for agricultural communities **[38]** .Istanbul also followed this trend habitually: there was a 250 % increase in imperious surfaces between 1984 and 2011 while croplands went downhill by 40 % **[39]**. built-up areas in southern mediterranean Tunisia (Tunis) More than doubled between 1987 and 2017 taking over a good portion of the fertile agricultural wilderness around it cite etudes reveal that in these cities urban growth is often concentrated mostly around peri-urban zones featuring fragmentary land use patterns and an overall decrease in farming productivity.

The Mediterranean climate with its hot dry summers and mild wet winters people working the land almost everywhere enjoy this unique feature of land use around urban areas in such regions in particular heat island effects created if there is no plant cover impervious surfaces go up And the environment suffers**[40]**. In addition, socioeconomic structures in these cities all but ensure that large numbers of people will move from countryside to City. According to**[41]** changes in Tunis resulted in the countryside shrinking by over 50 % Peirce et al. (2022) show how urban development impinges on surrounding cropland nevertheless, single-minded urbanization also presents challenges: water resource management, soil degradation, and loss of biodiversity must be tackled by public authorities with grassroots support from among their citizens Learn

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how Barcelona has dealt successfully with this issue using green infrastructure measures as far back as 1866 when the city walls were demolished in order to remake itself under our own technological civilization as we know it today--the result an environmentally sustainable configuration in touch with both tradition and modernity[42].

Nowadays, the fashion for new cities is part of the urban history of many countries, but Algeria is embarking on this path by adopting the new cities tool as part of a drive to control the urban growth of major cities through a comprehensive spatial planning policy aimed at rebalancing population densities, activities and incomes across the country.

But the question that arises is whether, in relation to the priority objectives of this spatial planning policy and the conditions experienced by the capital Algiers, this tool really constitutes a good urban solution and the optimum response in relation to other modes of intervention in space.

In fact, an analytical study of the various impacts and development prospects for these cities clearly shows that these projects present major constraints and contradictions with the objectives set for them. This is essentially summed up in the choice of sites for these cities, which are too close to the Algiers conurbation.

The main objective of our research is to see if the new cities built in Algeria are succeeding in rebalancing the Algerian territory in terms of the spatial distribution of the population.

Our results show that these new cities succeed in rebalancing the territory by acting as a pole of attraction, provided that the new cities are located further from the major metropolises.

In fact, we have found that metropolises have more resistance. If the new cities are located in their immediate vicinity

On the other hand, it must be admitted that the planning of a new city does not offer a magic solution to the problem of the asphyxiation of metropolises, if this planning is not based on a forward-looking diagnosis and is based above all on taking into consideration the effect of the political decision which plays the major role in development and spatial planning.

To achieve this, Algeria's planning policy must necessarily recommend solutions, the two main lines of which are based on:

- Immediate cessation of new cities projects in the first ring (coastal regions) and the second ring (agricultural land) and reallocation of their projects to urban extension poles.
- The creation of new cities in the High Plateaus in the short and medium term and in the south (Sahara) in the long term.

CONCLUSION

The metropolitan expansion of the new City of Sidi Abdellah, Algeria (2004–2024) involves a radical shift from a landscape being rural to a contemporary armature of the new urban morphology addressing the pressing needs of decongesting the population density of Algiers. Birthed as part of a deliberate policy response to urban congestion and sub-standard living conditions in the capital, the rapid expansion of the city met urgent needs for shelter, infrastructure and services. However, with this rapid growth come multiple environmental, economic, and societal challenges that really need to be made with the future in mind.

Land use and land cover classification based on satellite imagery indicates the transition from agricultural/forest covered land to 'hard built-up area', indicating the magnitude of impact of urbanization on biodiversity and ecological equilibrium. Land-use change has been increasing due to expanded transportation networks, as well as increased residential building, underscoring the importance of sustainable urban planning.

In this regard, remote sensing and GIS have played a crucial role for monitoring urban dynamics, land-use change analysis, and environmental impact mitigation [43,44]. These instruments make monitoring of urban sprawl, reduction of natural areas and resource management (in particular regarding water and green spaces) possible on a continuous basis. In the context of Sidi Abdellah their inclusion into planning processes informs adaptive policies and designs sensitive to environmental and social priorities.

Ultimately, "even as Sidi Abdellah has relieved the pressure on Algiers, the speed of its growth has highlighted the urgency of integrating digital, cartographic and technological solutions in the management of cities." These sorts of approaches, extended to other cities, have the potential to facilitate more equitable, sustainable urban-growth objectives integrated with spatial and temporal foresight.

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