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SPATIAL CHANGE AND URBAN DEVELOPMENT HORIZONS IN THE FACE OF ENVIRONMENTAL CHALLENGES IN THE CITY OF SKIKDA - ALGERIA

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ABSTRACT

This article examines the implications of urban spatial change and the prospects for urban development in Skikda in the light of contemporary environmental challenges. The city of Skikda is the result of the stratification of multiple civilisational periods. The choice of Skikda as an industrial centre in eastern Algeria since the 1970s was a turning point, paving the way for rapid urban expansion and substantial transformations in terms of size and purpose, from an agricultural, commercial and tourist vocation to an industrialised urban centre.
The research focuses on examining the consequences of this urban transformation, highlighting its effects on the environment and focusing on the change in environmental indicators. We analyse the results to highlight the discrepancies that have accompanied the different periods of spatial transformation using satellite images with a resolution of 30 M. The article shows the importance of adopting a sustainable approach to urban development horizons in order to meet the contemporary and future challenges of reconciling urban growth, environmental conservation and the protection of the well-being of city residents. In conclusion, the article recommends immediate solutions and an adaptation of planning tools to ensure harmonious and ecologically viable urban development in Skikda.

KEYWORDS

Spatial Change, Urban Development, Environmental Challenges, The City of Skikda

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Introduction:

The growth and development comparable to a living organism, evolves under the influence of multiple historical and geographical factors. Contemporary urban transformations are contributing to an intensification of global consumption, accelerating the depletion of natural resources. This dynamic is leading to growing environmental and health problems, disrupting the ecological balance. Natural and environmental risks are multiplying, particularly in densely industrialised and commercialised urban areas, exacerbating the pressures on ecosystems and threatening public health.

Urbanisation and the development of means of transport intensify pollution, resulting in urban sprawl and the loss of natural areas. Greenhouse gas emissions are exacerbating climate change. A study (The Lancet Planetary Health) reveals that 9 million deaths a year are due to pollution, three times more than those caused by tuberculosis and malaria, which are linked to exposure to toxic substances (Fuller, 2022).

International interest in environmental issues took shape at the Earth Summit in Rio de Janeiro in 1992, organised by the United Nations. This event brought to the fore issues relating to ecosystems and the

management of natural resources, while affirming the importance of sustainable development. This summit gave impetus to major global initiatives, such as the Convention on Climate Change and the Kyoto Protocol, aimed at reducing greenhouse gas emissions. The Convention on Biological Diversity was adopted to preserve biodiversity and exploit its economic and industrial benefits. In 2000, the Cartagena Protocol on Biosafety strengthened the regulation of genetically modified organisms. The Convention to Combat Desertification focused on the problems of drought and land , Bali Action Plan 2007 Poznan Conference 2008 , Copenhagen Accord 2009 (Demaze, 2009), United Nations Climate Change Conference 2015 , United Nations Climate Change Conference in Marrakech 2016 , United Nations Climate Change Conference in Fiji 2017 , United Nations Climate Change Conference in Katowice 2018 and Santiago Conference 2019 Chile (CHAIMI & SALEM, 2020), The Paris Accord was signed on 12 December 2015 and came into force on 4 November 2016 (Diza, 2023). Countries are investing in research to develop sustainable approaches, combining efficiency, viability and strategies adapted to local needs. These initiatives, based on participatory governance, require the commitment of populations and communities to ensure their environmental success.

Geographic information systems (GIS), which first appeared in the 1960s, have become essential for cartography and spatial analysis, enabling customisation and problem-solving. They are now used to facilitate collaboration and data sharing in a variety of fields. Constantly evolving, they play a central role in revealing information and scientific innovation. (Dangermond, 2023). Today, Geographic Information Systems (GIS) have become indispensable and effective tools for a variety of studies because of their ability to process data relating to the environment and spatial changes in urban areas. In particular, they enable satellite images to be analysed at different times, making them even more useful for understanding environmental change.

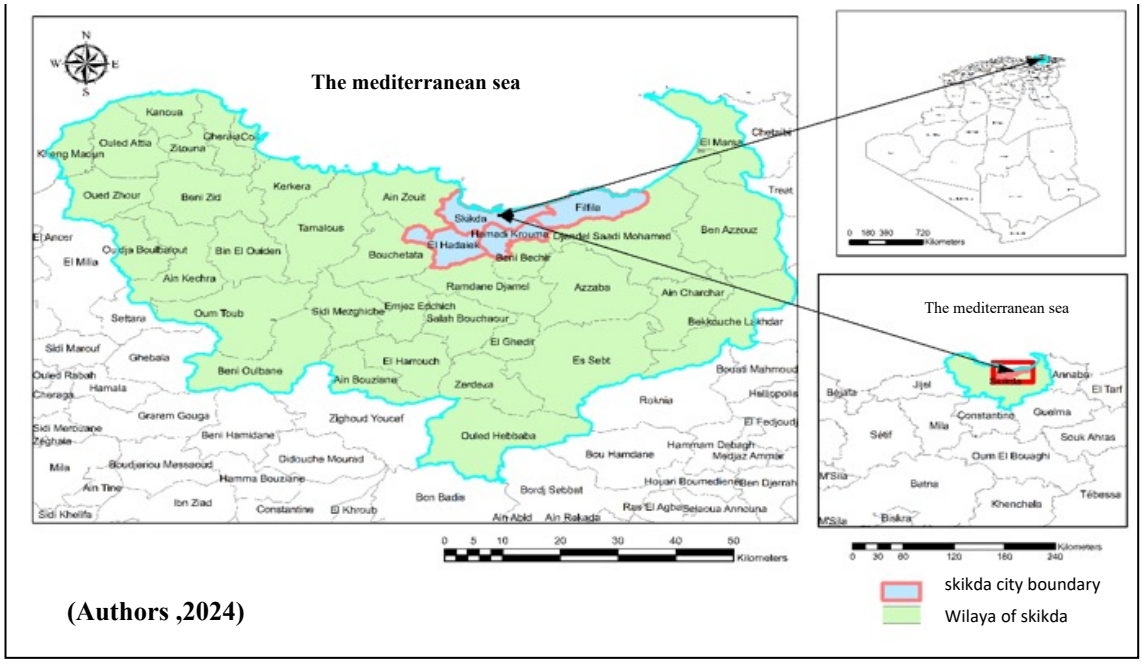
The major spatial transformations that have affected the Algerian territory through the effects of the urbanisation phenomenon has appeared since the French colonisation of Algeria. In 1960, the exodus of at least three million people to the cities was recorded, half of the rural population (Lakjaa, 2014). After independence, the cities formed during the colonial period continued to attract inhabitants at an accelerated rate of urbanisation, with a huge increase in the urban population. In 1963, 31% of Algerian society was urban (Rérat, 2006), and by 2008 this had risen to 68% (Lakjaa, 2014), in 2023 it accounts for 80% (Lacroix, 2023).

At the heart of this rapid increase in the urban population is the fact that the Algerian economy is becoming increasingly urbanised, with a massive concentration of polluting activities in Algerian cities. What has made the situation worse is the new informal urban forms and the poor distribution of industrial zones and activities within the urban fabric. To remedy the current environmental challenges, the Algerian government is taking measures and actions to improve the environmental situation by promulgating a series of legislative texts aimed at ensuring sustainable urban planning, such as Law No. 03-10 of 19 July 2003 on environmental protection as part of sustainable development. However, the measures taken remain inadequate in view of the negative impact of spatial changes on the environment, and they do not take into account the current global situation, which could affect environmental quality and threaten the public health of city dwellers.

The aim of this contribution is to provide elements of clarification in order to find answers to questions concerning the effects of spatial mutations on environmental feedbacks which represent the state of affairs in the city, taking as an example the urban region of Skikda in order to make urban development horizons which ensure a sustainable and healthy city. This study also aims to provide decision-makers with a perspective on environmental quality in the study area, in order to meet the major challenges associated with climate change and pollution, thus endangering the lives of the population.

Presentation of the study area:

The city of Skikda comprises four communes (Skikda, Hamadi Krouma, El Hadaiek and Filfila) covering an area of 211.8 km². Situated on the northern shore of the Mediterranean, in the southern Gulf of Stora, it occupies a strategic position 510 km east of Algiers and close to several major cities such as Constantine and Annaba. Skikda is a tourist, industrial and agricultural centre with a wealth of potential for urban and socio-economic development. Since 1970, its role as an industrial hub, with a 1,200-hectare petrochemical zone, has accelerated its spatial and functional growth, reinforcing its national and regional importance.



Map N°1: location of the study area (the town of SKIKDA)

Methods and materials:

This research explores urban transformations in the study area since 1970, using the IMRAD model. It combines the analysis of satellite images with climatic and demographic data to assess the impact of urban expansion on the environment. Statistical models and field data are used to understand the causes of current dynamics. The key indicators identified guide the assessment and prospects for urban development, as summarised in the tables below:

Table 1. The indices used in this study

Indicator	**The role**
Urban growth	This indicator analyses the dynamics of urban growth, its evolving forms and functions, and its environmental impact. It examines scenarios for estimating the annual growth rate and its relationship with environmental quality.
The urbanisation rate index	This part of the study examines the evolution of the urban population and its impact on the environment and development, by analysing the factors responsible for this growth and their urban consequences.
The population Density index	Measures the number of people in a given area in relation to the size of the territory and examines the relationship with the environmental quality of the city and the challenges it faces
The Vegetation Index (NDVI))	Highlights the evaluation of vegetation changes between different periods, providing in-depth details on the current situation of the city of Skikda.
Sea water quality index and water requirements	This indicator will examine the impacts on seawater quality in the city of Skikda, using it as a representative case study, with particular emphasis on water consumption linked to industrial activities.

(Authors ,2024).

We analysed satellite images with a spatial resolution of 30 metres, acquired in the 1970s, 1980s, 1990s, 2000s, 2009s, 2016s and 2024s, selected for their link with major transformations in the urban and environmental landscape. These data were processed using QGIS, a geographic information system, to assess the current state of the environment. The analysis includes the calculation of the Normalised Difference Vegetation Index (NDVI), a standardised tool for measuring vegetation cover and its variations over time:

NDVI=(NIR−Red) / (NIR + Red)

Where:
- NIR (Near-Infrared Band): Wavelength range from 0.6 to 0.7 µm.
- Red (Red Band): Wavelength range from 0.5 to 0.6 µm.

Regarding the environmental impact of seawater desalination plants on seawater salinity, the following mathematical model was applied: $C_{local} = \{(C_{brine} * V_{brine}) + (C_{sea} * D)\} / \{V_{brine} + D\}$ (Silvano , Fontenelle Rodrigues, Colonna Rosman, & Rosman, 2024) .

Where:
- C_{local}: Salinity after mixing in the affected area (g/L).
- V_{in}: Volume of desalinated seawater (m^3).
- C_{sea}: Initial salinity of seawater (g/L).
- V_{brine}: Volume of brine discharged (typically Vin/2V_{\text{in}}/2Vin/2).
- C_{brine}: Salinity of the discharged brine (Csea×2C_{\text{sea}} \times 2Csea×2).
- D: Volume of surrounding water used to dilute the brine.

These results provide a foundation for developing a precise strategy for sustainable urban development in Skikda, focusing on mitigating negative environmental impacts that compromise the quality of life in the city's urban areas.

Results and discussion:

This study explores the interaction of factors influencing the spatial and environmental transformations of Skikda. It analyses key data to understand their role in urban dynamics and their cumulative impact on the city's development.

1- Rapid Urban Growth Amidst the Transition to an Industrial Role for the City of Skikda:

The following section looks at urban growth over time in order to assess land consumption in the context of urbanisation. A systematic analysis has been used, examining the spatial and temporal evolution of the built-up area over distinct periods, from 1970 to 2024. This approach made it possible to identify the main drivers of the expansion of the urban fabric and to understand in detail its environmental impact on the city of Skikda. Table (2) illustrates the percentage rates of built-up area consumption in the study area over the period from 1970 to 2024.:

Table 2. Changes in built-up area in the study zone (1970-2024)

Year	**1970**	**1980**	**1990**	**2000**	**2009**	**2016**	**2024**
Percentage of built-up area (%) of the city as a whole	1,2	6,4	9,74	12,11	14,8	18,4	19,48
Built-up area (hectares)	254,4	1399,2	2064,88	2567,32	3137,6	3900,8	4129 ,76

(Authors ,2024).

The data shows a spectacular increase in the built-up area in Skikda, multiplying by 19 between 1970 and 2024, from 1.2% to 19.48% of the total surface area. This expansion represents some 3,875.36 hectares in 54 years. The following section examines the growth dynamics for each period in order to identify the causes of this rapid change and its environmental and urban impacts:

1-1- The period from 1962 to 1970: This period saw a considerable rural exodus after independence, mainly due to the availability of vacant housing left by departing colonial settlers (Map n°2–A). In 1966, the migration rate reached 26.10% (ONS, 1966, 1977,1987,2008). This demographic trend was exacerbated by the absence of adequate urban planning mechanisms and tools to manage rapid population growth in the post-independence context. As a result, this migration has put considerable pressure on the city's urban infrastructure and natural environment.

1-2- The period from 1971 to 1980: In the 1970s, Skikda underwent significant urban and industrial development, notably with the launch of the petrochemical complex in 1971, covering 335 hectares. This project positioned the city as a national and international energy hub, integrating refineries and hydrocarbon

infrastructures. The creation of a modernised industrial and oil port has boosted logistics capacity, supporting the export of petrochemical products and economic development.

Skikda's rapid industrialisation led to an average urban expansion of 114.45 hectares per year (Map n°2–B), transforming fertile agricultural land into industrial zones. This political decision turned Skikda into a major industrial city, attracting a large workforce and stimulating strong demographic growth. In 1977, the rate of migration to the city reached 47.70% (ONS, 1966, 1977,1987,2008)., testifying to its economic and industrial boom.

The rapid growth of Skikda has led to an increased demand for infrastructure and housing, but the housing programmes implemented have not been sufficient to meet this need, creating a persistent imbalance. This situation has encouraged the emergence of informal settlements and the uncontrolled expansion of urban areas, revealing the impact of industrial growth on urbanisation. The lack of integrated planning strategies and effective regulatory frameworks has exacerbated these challenges, leading to environmental degradation, increased pressure on resources and a lower quality of life. These problems compromise the sustainable and harmonious development of the city.

1-3- The period from 1981 to 1990: Between 1981 and 1990, Skikda saw considerable transformation thanks to projects aimed at strengthening its industrial infrastructure and urban development. Annual urban expansion reached 66.67 hectares year (Map n°2–C), supported by national policies of modernisation and economic diversification. Petrochemical facilities have been modernised to increase production, and new 1 200-hectare industrial estates have been created to attract businesses. The commercial and oil port has been expanded with new quays and logistics infrastructure to support the hydrocarbon trade. In response to population growth, housing programmes have been launched, building new modern neighbourhoods on the outskirts of the city.

In the late 1980s and early 1990s, Skikda experienced urban planning projects marked by inadequate spatial planning. The introduction of the subdivision policy led to a transition towards a housing model favouring individual investment, but many subdivisions were built on sloping land, without basic infrastructure and often without respecting urban planning standards. This uncoordinated urban growth has exacerbated the fragility of the area, increasing environmental risks such as urban infiltration and flooding. New residential areas have sprung up, but without rigorous planning, leading to urbanisation in inappropriate areas, encroaching on catchment areas. This period consolidated Skikda's industrial role, but rapid, unregulated growth led to major problems, such as environmental degradation and increased demand for infrastructure. The absence of sustainable urban planning frameworks and a strategic vision has contributed to the environmental challenge in the region.

A number of measures were taken to mitigate the environmental impact of rapid industrialisation, including Law 83-03 of 9 February 1983, one of the first pieces of environmental legislation in Algeria. This law aimed to establish fundamental principles for environmental protection, introducing industrial waste management projects and pollution controls in urban and industrial areas. However, risk management strategies, conservation practices and urban development frameworks remain inadequate, exacerbating environmental challenges. This period has also been marked by economic difficulties, including falling oil prices and reduced government support for development initiatives. In response to the growing demand for housing, the government has encouraged private investment in reconstruction and urban development.

1-4- The period from 1991 to 2000: The 1990s were marked by transformation and challenges for Skikda, with the introduction of new land policies, such as Law 90-25 and Law 90-29, which laid the foundations for urban expansion. However, this growth was poorly managed, revealing inefficiencies in planning and governance. Between 1991 and 2000, Skikda's urban area grew considerably, from 254.4 hectares in 1970 to 2,064.88 hectares, with an annual expansion rate of 50.24 hectares (Map n°2–D). Despite this growth, urban sprawl has been marked by fragmentation and incoherence, with unregulated developments contributing to spatial disorganisation. This uncontrolled expansion has highlighted the absence of effective planning mechanisms.

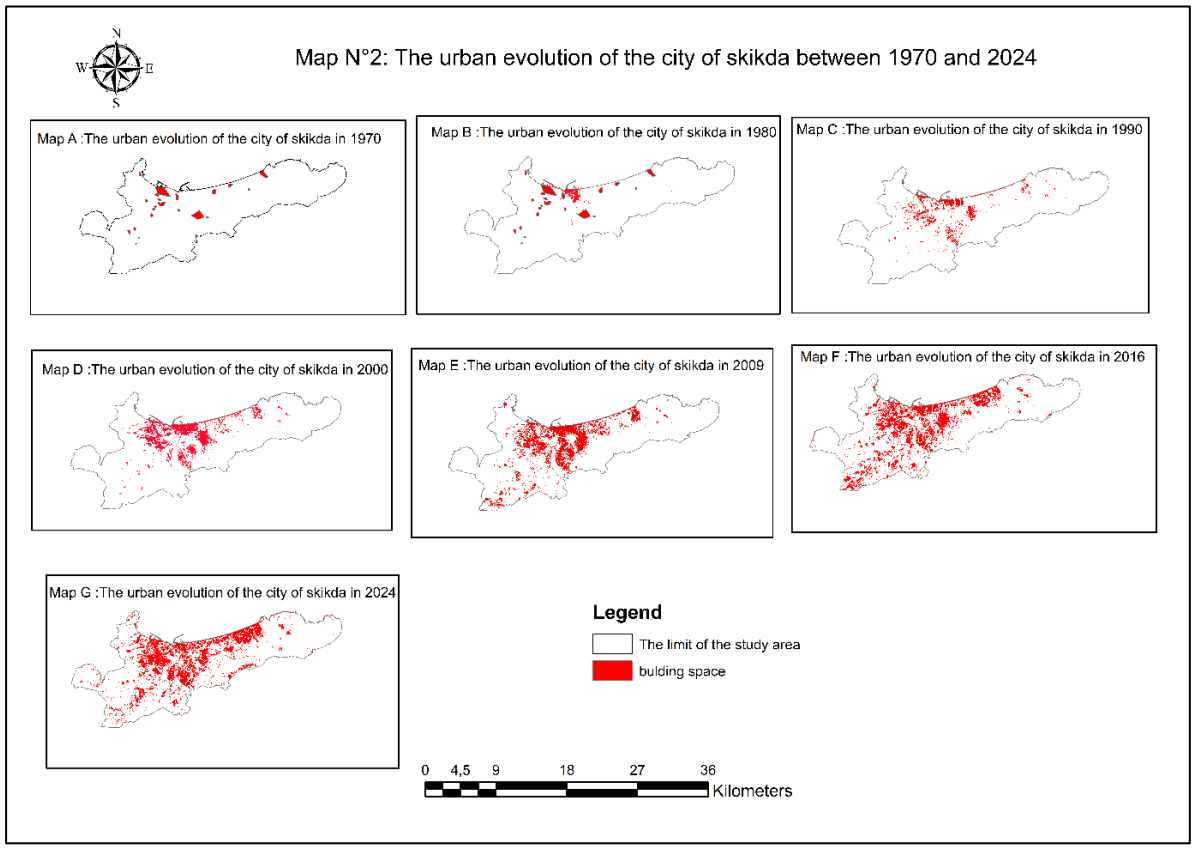
Algeria's (black decade) had a profound impact on Skikda's urban development, exacerbated by socio-economic and security crises. Internal migration due to insecurity intensified the housing crisis, leading to a proliferation of informal settlements in environmentally sensitive areas, such as flood plains and unstable slopes, increasing vulnerability to natural hazards. The rapid construction of low-cost housing has accentuated urban incoherence, exacerbating socio-spatial challenges. Expansion into high-risk areas has degraded the environment and reduced the city's resilience in the face of natural and man-made pressures. In addition, the emergence of poorly integrated neighbourhoods has encouraged social and spatial segregation, undermining

urban cohesion. Demographic pressure, fuelled by industrialisation, inadequate social housing programmes and unplanned urbanisation have exacerbated environmental vulnerabilities. This period has undermined urban infrastructures, generating considerable spatial and environmental challenges.

1-5- The period from 2001 to 2009: After 2000, Skikda adopted the national housing policy, based on individual financial participation, thus facilitating programmes such as those of the AADL Agency and contributory social housing. These projects were located on geo-technically stable land, close to the main areas of activity, favouring accessibility and supporting economic and social stability. However, the city's expansion has been limited by major geographical constraints: the Mediterranean Sea to the north, hilly terrain to the west, agricultural land to the south and an industrial zone to the east. These obstacles have hindered homogeneous growth and complicated urban planning.

Urban development has evolved from a period of trial and error to improvised solutions, marked by a lack of coherent urban policy, resulting in fragmented growth. The city has expanded by 63.36 hectares per year (Map n°2–E), fuelled by demographic and industrial growth. This rapid, unregulated growth has intensified demand for natural resources, exacerbating environmental pressures, including encroachment on fertile agricultural land and disruption of the ecological balance. This uncontrolled expansion has also increased vulnerability to environmental risks such as erosion, flooding and land degradation, despite the introduction of environmental regulations via Executive Decree 06-198, which defines the regulations applicable to establishments classified for environmental protection.

1-6- The period from 2010 to 2016: During this period, Skikda experienced significant urban growth, with an annual average of 109.02 hectares (Map n°2–F), stimulated by major projects, particularly in the housing sector. More than 5,000 residential units have been built to replace substandard housing and reallocate vacant land. Large-scale projects have been launched, such as a new administrative district and the extension of the industrial estate. An urban development plan has led to the expansion of the urban perimeter and the creation of new complexes such as Bouzaroura and Mssiouane. Efforts have been made to address environmental concerns, but the city still faces challenges linked to the legacy of the past and the growing demand for resources, exacerbated by climate change. The construction of several seawater desalination plants to meet drinking water shortages is also having a negative impact on the environment and biodiversity.



1-7- The period from 2017 to 2024: This period was marked by a significant slowdown in urban growth, with an extension of no more than 28.62 hectares. This deceleration was mainly due to the COVID-19 pandemic and the economic crisis that affected Algeria, disrupting many development projects. Although the implementation of these projects has been reduced, initiatives have been taken to improve the city's environmental conditions, such as the creation of the FilFLa wastewater treatment plant. However, the effectiveness of this plant remains limited, extending its benefits only to certain areas. This has highlighted the impact of global health crises and local economic difficulties on urbanisation. The focus on environmental initiatives, such as wastewater management, indicates a growing awareness of the importance of urban sustainability. However, the limited scope of these efforts highlights the need for more comprehensive and integrated strategies to address urban environmental challenges.

2- Significant transformations in the demographic composition of Skikda due to rapid urban expansion:

The urban growth and urbanization process often leads to significant spatial transformations that deeply impact the natural environment. As cities expand to accommodate growing populations, several environmental challenges arise, including increased resource demand and greater pressure on land to support activities that meet population needs. In this context, a thorough assessment of the urban dynamics in Skikda begins with an analysis of the urbanization rate and its associated impacts. The graph below presents the urbanization rates of Skikda over different periods, providing insights into the city's spatial and demographic development trends.

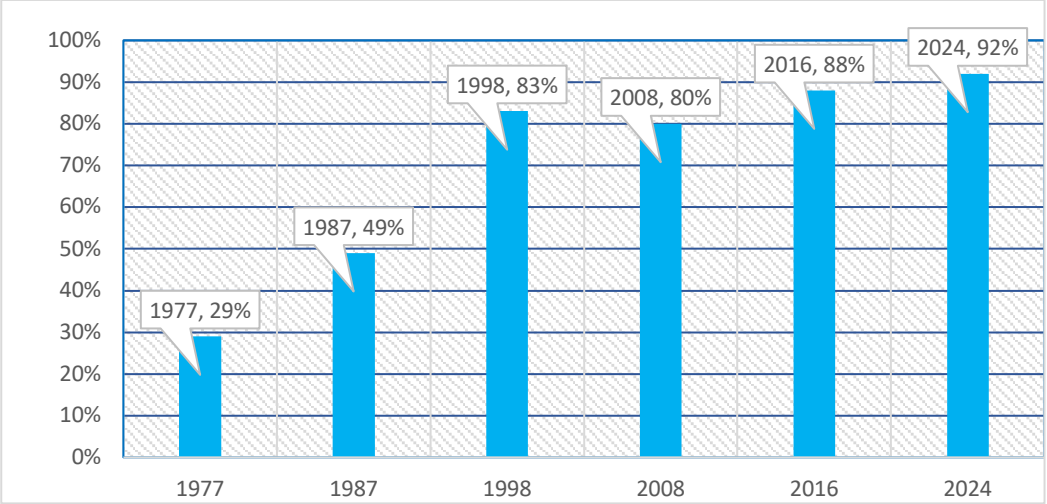


Fig. 1. Evolution of urbanisation rates in Skikda from 1977 to 2024. (Authors ,2024)
(ONS, 1966, 1977,1987,2008) (DUAC Skikda, 2024)

The provided data graph clearly shows that Skikda has experienced varying urbanization rates, indicating complex demographic changes at different stages of its development. In 1977, the urban sector represented 29% of the total population, increasing to 82% in 1987. However, urbanization slowed by 2008, representing only 80% of the population, with a peak of 91% in urban areas. These data reflect the complex dynamics of spatial transformation and population distribution in Skikda's urban area. The petrochemical industry has played a significant role in shaping the city's urbanization trajectory, with its urbanization rate more than tripling over four and a half decades.

In addition to industrial development, other contributing factors include natural population growth, which exceeds the national average at 1.97% per year compared to the national rate of 1.72%. Internal migration to Skikda, driven by deteriorating conditions in other parts of the province, also plays a significant role, with migrants attracted by job opportunities, economic stability, and the city's central location. The city centre, with its diverse range of activities, acts as a stabilizing force, drawing people from surrounding areas. However, rapid urban expansion has placed significant pressure on the environment, resulting in notable changes to the urban landscape. Increased demand for resources, along with rising waste and wastewater production, has highlighted the need for services that align with the evolving urban structure and demographic

dynamics. Consequently, urban sprawl has increased land consumption and encroached on natural areas, leading to environmental degradation.

3- Changes in Population Density in Skikda: Implications for Environmental Change and Ecosystem Strain:

This indicator is used to analyse the population density within the urban perimeter of Skikda, which comprises four communes covering 211.8 km². The study examines the evolution of this density over the phases of urban development, using statistical data from the Office National of Statistics. Figure N°2 illustrates this demographic evolution:

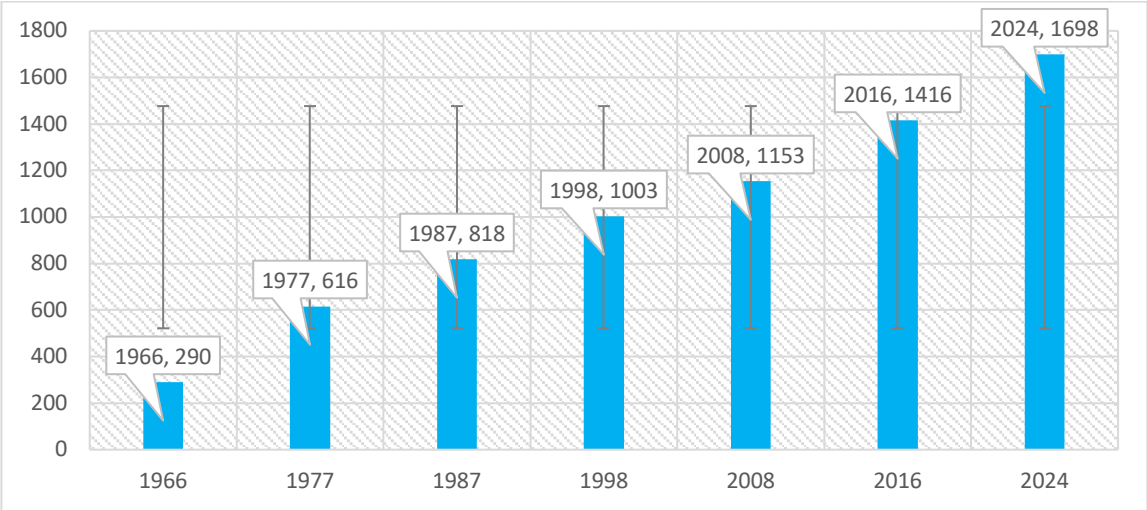


Fig. 2. Population density and the evolution of urbanization rates in the city of Skikda from 1966 to 2024. (ONS, 1966, 1977,1987,2008) (DUAC Skikda, 2024)

The city of Skikda has seen a rapid rise in population density, from 290 people per km² in 1966 to over 1,698 people per km² today, following the establishment of industrial estates. This development reflects a shift from an agricultural economy to an industrial one. The concentration of the population has led to a high demand for urban infrastructure, particularly housing, transport and public services, pushing the city to expand into suburban areas. This has also led to increased pressure on the road network, with increased traffic and industrial activity, exacerbating pollution levels, including emissions of CO2, NO2, PM2.5 and PM10, as well as noise pollution. This rapid urbanisation has also led to a deterioration in the local environment, notably through the loss of biodiversity. Urban planning tools have proved insufficient to meet the city's growing needs, particularly in terms of environmental management. It is therefore necessary to put in place sustainable planning strategies aimed at preserving green spaces, promoting green infrastructure and improving the management of natural resources, in order to encourage resilient urban development and reduce the negative impacts of urbanisation.

4- Urban Growth and Its Impact on Vegetation Cover: The Challenges of Rapid Urban Transformation in Skikda:

Vegetation cover, which is essential for environmental protection, changed significantly in Skikda between 1970 and 2024, influenced by urban and spatial transformations. These changes were measured using the NDVI index and area calculations. The results detailing these changes are presented in Table 3.

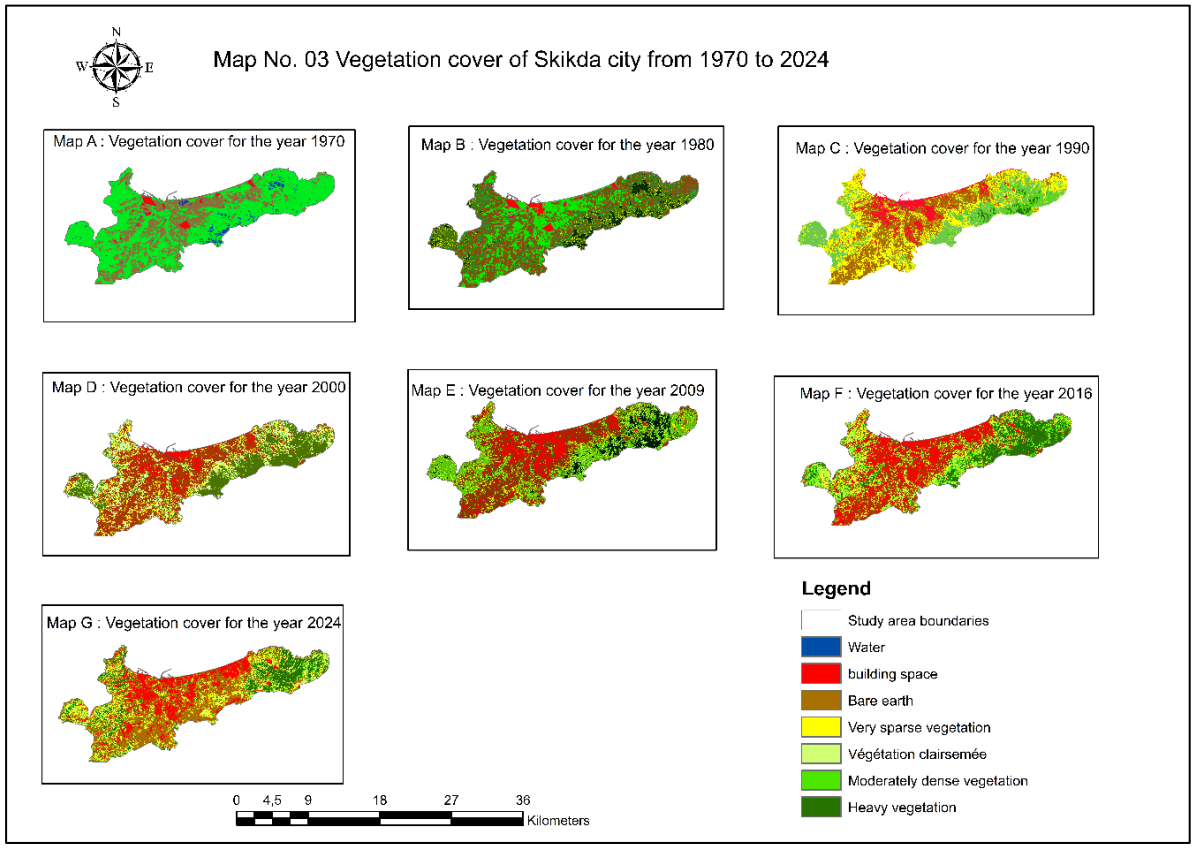
Table 3. Vegetation cover in the city of Skikda from 1970 to 2024

Year	Very sparse vegetation (%)	Sparse vegetation (%)	Moderately dense vegetation (%)	dense vegetation (%)	Total percentage of vegetation area (%)
1970	11,2	18,1	13,2	30,1	72,6
1980	10,3	17,2	11,5	25,5	64,5
1990	20,76	16,27	7,7	17,53	62,26
2000	8,1	17	5,2	22,9	53,2
2009	7,3	25,2	7,5	10,1	50,1
2016	7	22,2	9,5	9,8	48,5
2024	12,8	11,73	3,48	16,4	44,41

(Authors ,2024).

Analysis of the data shows a significant decline in vegetation cover in Skikda, from 72.6% in 1970 to 44.41% in 2024. This decline began in the 1980s with the construction of an industrial estate, occupying 1,200 hectares of prime agricultural land. This transformation triggered increasing urbanisation, with greater consumption of land for various projects. As a result, natural areas were increasingly invaded, leading to a steady decline in vegetation. Urban pressure has had a major impact on the city's natural environment.

Human activities, such as industrial development and fires, as well as environmental factors, such as climate change, decreasing rainfall and rising temperatures, have all contributed to this decline. The dramatic reduction in areas of dense vegetation (Map 03), from 30.1% in 1970 to 9.8% in 2016, is particularly alarming. Although the government's reforestation efforts have increased this figure to 16.4% by 2024, these gains are insufficient to counteract the effects of rapid urban sprawl, which has intensified in recent years.



(Author's, 2024)

5- Increase in Water Consumption and Its Environmental Impact in the City of Skikda: Insights from Completed Projects:

This analysis looks at the impact of water consumption on the quality of seawater in Skikda, associated with increased demand due to population growth. It uses an average of 120 litres per person to estimate water requirements. The following tables detail the evolution of this demand over several periods.

Table 4. The water needs in the city of Skikda from 1970 to 2024

Year	1977	1987	1998	2008	2016	2024
Number of populations	130592	173370	212664	244526	300125	360004
Quantity of water consumption (M 3)	15671,04	20804,4	25519,68	29343,12	36015	43200,48

(ONS, 1966, 1977,1987,2008) (DUAC Skikda, 2024) , (Authors, 2024)

The table above highlights a sharp increase in demand for water, with consumption tripling between 1977 and 2024, due to urban and demographic expansion. The transition to petrochemical activities has intensified this demand, with the industrial zone consuming around 10,460 m³ of water per day (EGZIK, 2021). This high level of consumption is putting pressure on water resources, especially in summer, despite a natural hydrological capacity fed by rainfall, rivers and dams, at a time when climate change is worsening the situation.

To combat the water deficit in Skikda, two new desalination plants have been built: one at Ben M'hidi, producing 103,500 m³/day of drinking water for Skikda and the surrounding area, and the other in an industrial zone, equipped with demineralisation plants supplying 4,000 m³/day of water for industry (Wilaya of Skikda, 2024).

These industrial installations do, however, have major environmental impacts, particularly due to the increased concentration of salts, which can have a negative effect on marine biodiversity. To analyse this impact, we used the following mathematical model:

$$C_{local} = \{(C_{brine} * V_{brine}) + (C_{sea} * D)\} / \{V_{brine} + D\}$$

The following is an explanation of local data for the city of Skikda:

C_{local} : (g/L) ; V_{in} = 107 500 m³ ; C_{sea} = 37 g/L : V_{brine} : Vin/2V_{in}/2) = 53750 M3
$C_{brine\_}$: (C sea * 2) = 74 g/L ; D : 1 000 000 m³/jour,
Donc C_{local} = { (74 g/L*53750 M3) + (37 g/L *1 000 000 m³/jour) } / {74 g/L +1 000 000}=40 ,97g/L .

After the dilution, the local salinity increases by 40.97 -37=3.97 g/L, or around 10.72% relative to the initial salinity.

This situation poses a threat to the city's marine biodiversity and requires the implementation of a number of measures to preserve the ecosystem. These measures include treating the water to reduce its salinity before it is discharged, regularly monitoring environmental standards and promoting the reuse of desalinated water for non-potable applications (such as agriculture and industry), or even its reintroduction into natural systems.

Skikda's transformation from an agricultural and service town into a big petrochemical industrial centre has profoundly changed its urban landscape, giving rise to a series of natural and industrial risks. This transformation, carried out without any environmental impact studies or adequate accompanying measures, has upset the balance of the region by favouring heavy industry to the detriment of its natural and tourist potential. As a result, environmental degradation has intensified, accompanied by an increase in demand for land to meet the residential and service needs of a growing population. Bad planning decisions, such as the siting of developments in high-risk areas, have exacerbated these problems. The industrial zone, which acts as a physical and functional barrier, has fragmented the city, breaking up its coastal continuity, increasing travel distances and exacerbating gas emissions - a major factor in pollution, alongside industrial emissions.

These challenges are also highlighted by the explosion in the number of informal and unauthorised dwellings, underlining the inadequacy of existing urban planning tools to cope with rapid urbanisation. Environmental indicators confirm the harmful effects of these transformations, underlining the urgent need for sustainable urban planning strategies. These strategies must take into account the intrinsic characteristics of the region, exploit its untapped potential and mitigate the risks to natural and human systems.

Conclusions.

The city of Skikda exemplifies a complex urban scenario characterised by strong contrasts. On the one hand, it has significant development potential in various sectors within its urban limits. On the other, the city faces pressing environmental challenges, rooted in a complex history of spatial transformation. These dynamics underline the continuing vulnerability of Skikda's urban territory, largely attributed to the inability of stakeholders to effectively manage the rapid spatial and temporal changes it has undergone.

This vulnerability is exacerbated by urban planning frameworks that have failed to keep pace with the city's transformations. In particular, the government strategies that encouraged urban growth between 1974 and 1990 increased the vulnerability of the urban fabric, adding to the environmental and structural challenges that already existed.

The solution to these problems lies in the adoption of a coordinated and participatory urban planning approach that integrates environmental preservation, social sustainability and the optimisation of Skikda's intrinsic development potential. This approach needs to be underpinned by a comprehensive urban development strategy that aligns with the city's multifaceted nature and adapts to its changing needs. This strategy must prioritise resilience and sustainability, focusing on safeguarding the city while harnessing its full potential for balanced growth. It must also meet the challenges of urban change by adapting development approaches to the specific requirements of each period. In addition, the strategy must incorporate adaptive tools and robust mechanisms capable of responding to the dynamic spatial transformations taking place in the study area, thereby ensuring the creation of a sustainable and resilient urban environment.

The urban development plan for Skikda, which aims to preserve natural spaces, vegetation cover and agricultural land in a context of increasing urbanisation, should focus on optimising unoccupied spaces within the existing urban fabric. This approach includes reorganising the city centre, diversifying its functions to reflect changing urban dynamics, and enriching it with cultural and recreational activities to promote sustainable urban development. These efforts must be integrated into a harmonious urban development strategy that reconciles environmental protection, functional diversity and the well-being of residents.

Skikda faces a dual challenge: safeguarding its historic identity while adapting to future requirements. By reconciling development, environmental management and community participation, the city can achieve sustainable growth.

Recommendations and perspectives:

- Strengthen urban planning and regulation: Improve urban planning tools and regulatory frameworks to guide sustainable and coherent urban development.
- Relocating and integrating informal settlements: Prioritise the relocation and integration of informal settlements, focusing on minimising environmental risks and improving living conditions.
- Environmentally-friendly urban expansion: Promote urban growth that preserves agricultural land, minimises environmental vulnerabilities and protects natural resources.
- Resilience to demographic and economic pressures: Support sustainable urbanisation to improve resilience to population growth and economic change, ensuring sustainable development for future generations.

This multi-dimensional strategy emphasises proactive planning, environmental conservation and inclusive growth as fundamental principles of Skikda's sustainable urban future.

REFERENCES

1. CHAIMI, Y., & SALEM, A. (2020). International Agreements and Environmental Protection: an overview. *Al Bashaer Economic Journal*, 908-921.
2. Dangermond, J. (2023, 10 24). *esri*. Retrieved from esri: https://www.esri.ch/fr-ch/was-ist-gis/die-geschichte-des-gis
3. Demaze, M. T. (2009). International conventions on the environment: ratifications and commitments by developed and developing countries. *Geographic information Éditions Armand Colin*, 84-99.
4. Diza, A. (2023, février 2). *www.alliancesolidaire.org*. Retrieved from alliancesolidaire: https://alliancesolidaire.org/2023/02/02/les-conventions-et-conferences-internationales-pour-le-climat/
5. DUAC Skikda. (2024). *Report on the Revision of the Master Plan for Planning and Urban Development of the Skikda City Group.* SKIKDA: Directorate of urban planning, architecture and construction of the wilaya of Skikda.
6. EGZIK. (2021). *Report on the industrial zone and the environment.* SKIKDA: The Skikda industrial zone management company.
7. Fuller, R. (2022, JUNE). Polution and health: a progress update. *The Lancet Planetary Health*, 1-25.

8. Lacroix, I. (2023, octobre 27). *Perspective Monde* . Retrieved from Perspective Monde : https://perspective.usherbrooke.ca/bilan/servlet/BMTendanceStatPays/?codeStat=SP.URB.TOTL.IN.ZS&codePays=DZA&codeTheme=1
9. Lakjaa, A. (2014). Algeria: the meaning and challenges of urbanisation from below. *DEVENIRS URBAINS*, 325-372.
10. ONS. (1966, 1977,1987,2008). *The general population and housing census of the years 1967, 1977, 1987, 1988 and 2008.* Algeria: national statistics office.
11. Rérat, P. (2006). Urban mutations, demographic mutations. Contribution to the explanation of the demographic decline of city centers. *Regional and Urban Economic Review*, 725-750.
12. Silvano , P., Fontenelle Rodrigues, M., Colonna Rosman, P., & Rosman, P. (2024). A novel tool for modeling the near- and far-field dispersion of brine effluent from desalination plants. *frontiers in marine sciences*, 1-14.
13. Wilaya of Skikda. (2024, 11 30). *Potential of the wilaya: Skikda*. Retrieved from interieur.gov.dz/Monographie: https://interieur.gov.dz/Monographie/detail_axe.php?wilaya=21&type=potentialite