MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 2, 2026, Pages 1207-1215

ENVIRONMENTAL MANAGEMENT OF URBAN SPRAWL AND SUSTAINABILITY CHALLENGES IN THE MITIDJA PLAIN, ALGERIA (1990–2050)

Abdellah Guebli[1], Azzeddine Bellout[2], Mohamed Elhadi Kaci[3], Ali Boulbadaoui [4], Reda Rafa[5],Abdelaziz Zouatini [6]

1. Department of History, Geography, University of Bouira, Algeria, Email: a.guebli@univ-bouira.dz, https://orcid.org/0009-0007-0955-8739, Address: Drissi Yahia Bouira Street – 10000.
2. Department of Sociology, Demography, University of Bouira, Algeria, Email: a.bellout@univ-bouira.dz https://orcid.org/0000-0003-3508-9714 /, Address: Drissi Yahia Bouira Street – 10000.
3. Department of Sociology, Sociology, University of Bouira, Algeria, Email: mo.kaci@univ-bouira.dz, Address: Drissi Yahia Bouira Street – 10000.
4. Department of Psychology, University of Bouira, Algeria, Email: a.boulbadaoui@univ-bouira.dz, Address: Drissi Yahia Bouira Street – 10000.
5. Department of Human Sciences, University of Bouira, Algeria, Email: r.rafa@univ-bouira.dz, Address: Drissi Yahia Bouira Street – 10000.
6. Laboratory of Individual, Family, and SocietyApproach, Faculty of Social Sciences and Humanities, University of Bouira, Algérie, Email: a.zouatini@univ-bouira.dz, Address:Drissi Yahia Bouira Street – 10000.

RECIEVED: 15/09/2025 ACCEPTED : 03/03/2026 PUBLISHED: 14/05/2026

ABSTRACT
Urban sprawl in the Mitidja Plain has become a major environmental management challenge affecting agricultural land and water resources. This study analyzes the spatial dynamics of urban expansion and its sustainability impacts in the Mitidja Plain, Algeria, between 1990 and 2050 using GIS and Remote Sensing techniques. The results reveal a significant increase in built-up areas at the expense of fertile agricultural land, accompanied by growing pressure on groundwater resources through reduced recharge, increasing pollution risks, and rising water demand. Spatial analysis also highlights the concentration of industrial and urban activities in environmentally vulnerable areas. The study emphasizes the need for sustainable urban planning, integrated environmental management, and GIS-based monitoring systems to mitigate future environmental degradation and improve natural resource sustainability in the region.
Keywords: Urban Sprawl; Agricultural Land ; Environmental Management; Sustainability; Water Resources; GIS; Mitidja Plain; Algeria.

1. Introduction

Urban sprawl has become one of the most significant environmental management challenges facing rapidly developing regions worldwide. The accelerated expansion of urban areas, driven by demographic growth, economic transformation, and socio-spatial changes, has profoundly altered land-use patterns and threatened the sustainability of natural resources, particularly in Mediterranean environments characterized by ecological fragility and limited land and water availability (Guan et al., 2011; Foley et al., 2005; Seto et al., 2012 ;Bellout et al., 2020a). In many developing countries, uncontrolled urbanization combined with weak spatial planning policies has intensified pressure on fertile agricultural lands and hydrological systems, generating complex environmental and socio-economic challenges (Deep & Saklani, 2014; Lambin & Geist, 2006; Salvati et al., 2012).Land Use and Land Cover Change (LUCC) has consequently emerged as a major field of research in environmental sustainability and territorial management studies. The continuous conversion of agricultural and natural lands into built-up areas contributes not only to landscape fragmentation but also to soil sealing, ecosystem degradation, groundwater recharge reduction, and increasing environmental vulnerability (Foley et al., 2005; Verburg et al., 2015). Moreover, the replacement of permeable vegetated surfaces with artificial infrastructures significantly alters hydrological processes by increasing surface runoff and reducing infiltration capacities, thereby threatening groundwater sustainability and regional ecological balance (Benali et al., 2020; Paul & Meyer, 2001; Berland et al., 2017). Mediterranean urban regions are particularly exposed to these dynamics due to rapid demographic concentration, industrial development, and increasing environmental stress linked to climate variability. Several studies conducted in southern Europe and North Africa have demonstrated that urban sprawl constitutes a direct threat to food security, water resources, and long-term sustainability (Salvati et al., 2012; Hegazy & Kaloop, 2015). Similar trends are increasingly observed in Algeria, especially in the northern coastal regions where urban growth is expanding at the expense of highly productive agricultural plains and environmentally sensitive areas (Houimli et al., 2022; Bellout et al., 2020a).Among the most vulnerable Algerian regions, the Mitidja Plain occupies a strategic position due to its agricultural importance, demographic concentration, and hydrological significance(Bouderbala, 2019; Senadi et al., 2024). Located in northern Algeria, the Mitidja Plain represents one of the country's most productive agricultural basins and constitutes a major socio-economic corridor surrounding the capital city of Algiers(Houimli et al., 2022). However, during recent decades, the region has experienced accelerated urban growth associated with population increase, industrial expansion, infrastructure development, and rural-to-urban migration. This rapid urbanization has progressively transformed agricultural and natural landscapes into urbanized areas, generating growing environmental pressures on land and water resources (Senadi et al., 2024; Benali et al., 2020).In addition to agricultural land loss, the expansion of urban and industrial areas in the Mitidja Plain has intensified environmental pressures on groundwater systems (Benali et al., 2020; Talbi et al., 2020). Increasing impervious surfaces reduce natural groundwater recharge processes, while industrial discharge, urban wastewater, and diffuse pollution contribute to groundwater quality degradation (Paul & Meyer, 2001; Berland et al., 2017). Simultaneously, rising domestic, industrial, and agricultural water demands have increased pressure on already vulnerable hydrological resources, particularly under projected climate change conditions characterized by declining precipitation and recurrent drought episodes (Bouderbala, 2019).

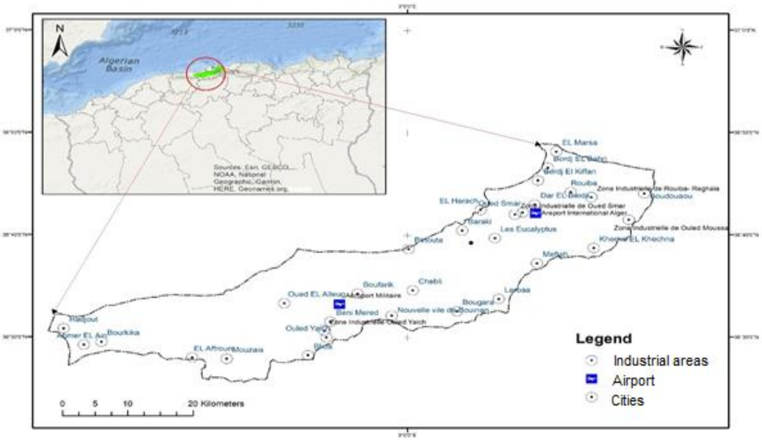
To address these environmental management challenges, recent scientific research increasingly relies on the integration of Geographic Information Systems (GIS), Remote Sensing (RS), and spatial modeling approaches. These technologies provide efficient and cost-effective tools for monitoring urban dynamics, analyzing LUCC processes, evaluating environmental impacts, and simulating future land-use scenarios (Wang, 2001; Zhu et al., 2019). Furthermore, predictive models such as Cellular Automata (CA)-Markov models are widely employed to forecast future urban expansion and support sustainable territorial planning strategies (Koomen, 2011).Despite the growing importance of these approaches, Algeria still suffers from limited availability of updated spatial databases and insufficient environmental monitoring systems capable of assessing the long-term impacts of urbanization on natural resources. Existing studies often focus primarily on land-use transformations while paying comparatively less attention to the interrelationships between urban sprawl, water resource degradation, and environmental sustainability. Consequently, there remains a significant need for integrated studies combining spatial analysis, environmental assessment, and sustainability-oriented approaches in rapidly urbanizing Algerian regions.Within this context, the present study aims to analyze the spatial and temporal dynamics of urban sprawl in the Mitidja Plain between 1990 and 2050 and to assess its environmental implications for agricultural land and water resources using GIS, Remote Sensing, and predictive spatial modeling techniques. The study focuses on examining Land Use and Land Cover Changes (LUCC) over the period 1990–2020, predicting future urban expansion patterns up to 2050 through the CA-Markov model, and evaluating the environmental impacts of urban sprawl on agricultural land and groundwater sustainability. In addition, the research seeks to contribute to the development of sustainable environmental management strategies and GIS-based monitoring systems capable of supporting natural resource conservation and improving territorial planning policies in the region.

2. Materials and Methods

2.1. Study Area

The Mitidja Plain is one of the most important agro-ecological and hydrological regions in northern Algeria, characterized by its strategic geographical position between the Tell Atlas Mountains and the coastal zone(Bellout et al., 2020b). Covering approximately 1,400 km², it forms a major peri-urban agricultural basin surrounding the metropolitan area of Algiers and represents a key interface between urban, agricultural, and natural systems. Administratively, the plain extends across four provinces: Algiers, Blida, Boumerdes, and Tipaza(Figure 1).

Figure 1. Location of the study area



Source: Author's.

The region is characterized by a typical Mediterranean climate with mild, wet winters and hot, dry summers, with annual precipitation generally ranging between 600 and 800 mm depending on spatial variation. Combined with deep alluvial soils of high fertility, these conditions have historically supported intensive and diversified agricultural production, making the Mitidja Plain one of the most productive agricultural zones in Algeria (Hegazy & Kaloop, 2015). The area also hosts significant groundwater resources stored in alluvial aquifers, which constitute a crucial water supply source for agricultural irrigation, domestic consumption, and industrial use in surrounding urban centers (Paul & Meyer, 2001).

However, the Mitidja Plain has undergone rapid and continuous environmental transformation due to increasing anthropogenic pressure. Urban expansion driven by population growth, industrialization, and infrastructure development has progressively encroached upon agricultural lands, leading to significant land-use change and landscape fragmentation (Seto et al., 2012 ; Bellout et al., 2020b). This process has been particularly intense in peri-urban zones influenced by the expansion of the Algiers metropolitan area, where agricultural lands are systematically converted into residential, industrial, and transport infrastructures (Salvati et al., 2012).In parallel, this rapid urbanization has significantly altered the hydrological functioning of the basin. The increase in impervious surfaces has reduced natural infiltration rates, disrupted groundwater recharge processes, and intensified surface runoff. These changes, combined with increasing water demand and anthropogenic pollution sources, have placed considerable stress on the aquifer system and contributed to its progressive degradation (Berland et al., 2017). Such processes are consistent with broader findings on urban hydrology, which demonstrate that land-use change is a key driver of groundwater vulnerability and ecosystem disruption in rapidly urbanizing regions (Verburg et al., 2015).

Moreover, the Mitidja Plain is increasingly affected by the combined impacts of climate variability and human activities, including recurrent drought episodes and rising temperatures, which further exacerbate water scarcity and environmental stress (IPCC, 2021). The interaction between climate pressures and uncontrolled urban growth intensifies the fragility of the region's agro-hydrological system, threatening its long-term sustainability (Lambin & Geist, 2006). Consequently, the Mitidja Plain represents a critical case study for understanding the complex interactions between urban expansion, land-use change, and environmental sustainability in Mediterranean peri-urban landscapes.

2.2. Methodology

The methodological framework adopted in this study combines Geographic Information Systems (GIS), Remote Sensing (RS), and predictive spatial modeling techniques to analyze the dynamics of urban sprawl and its environmental impacts in the Mitidja Plain between 1990 and 2050. Multi-temporal Landsat satellite imagery acquired for the years 1990, 2005, 2015, and 2020 from the USGS Earth Explorer platform
was used to monitor Land Use and Land Cover Changes (LUCC) within the study area. The satellite images underwent several preprocessing operations, including geometric correction, atmospheric correction, radiometric calibration, mosaicking, and clipping according to the administrative boundaries of the Mitidja Plain. Spatial analysis and image processing were performed using ArcGIS Pro, and TerrSet. A supervised classification method was applied to generate LULC maps based on four principal land-use categories: cultivated land, fruit tree orchards, fallow land, and built-up areas. Change detection analysis was subsequently conducted to quantify the spatial transformations, urban expansion rates, and agricultural land losses observed during the study period.

Table 1. Main Datasets and Spatial Sources Used in the Study

Dataset	Source	Spatial Resolution	Period	Purpose
Landsat TM	USGS Earth Explorer	30 m	1990	Historical LUCC analysis
Landsat ETM+	USGS Earth Explorer	30 m	2005	Urban growth monitoring
Landsat OLI/TIRS	USGS Earth Explorer	30 m	2015–2020	Recent LUCC assessment
Administrative Boundaries	National Cartographic Data	Vector	2020	Study area delimitation
Road Network Data	Open Street Map	Vector	2020	Urban accessibility analysis
Groundwater Layers	Hydrogeological studies	Vector/Raster	Various	Environmental assessment

Source: Author's.

To simulate future land-use dynamics and predict urban expansion patterns up to 2050, a hybrid Cellular Automata–Markov (CA-Markov) model was employed. The Markov chain component estimated land-use transition probabilities according to the following equation:

$$P_{ij} = \frac{n_{ij}}{\sum_{j=1}^{m} n_{ij}}$$

where P_{ij} represents the probability of transition from land-use class i to class j, and n_{ij} corresponds to the number of pixels converted between classes. To improve the spatial realism of future projections, the Cellular Automata model integrated neighborhood interactions and land suitability conditions according to the transition function:

$$S_{t+1} = f(S_t, N, L)$$

where S_t represents the land-use state at time t, N corresponds to neighborhood effects, and L refers to spatial suitability factors controlling future urban growth allocation. In addition, the annual urban growth rate was calculated using the equation:

$$AGR = \frac{A_2 - A_1}{t_2 - t_1}$$

where A_1 and A_2 correspond respectively to the initial and final urbanized areas during the study period. The generated predictive scenarios were finally analyzed through GIS-based environmental assessment techniques to evaluate the implications of projected urban growth on agricultural sustainability, groundwater recharge zones, land-resource pressures, hydrological vulnerability, and long-term environmental sustainability within the Mitidja Plain.

3. Results and Discussion

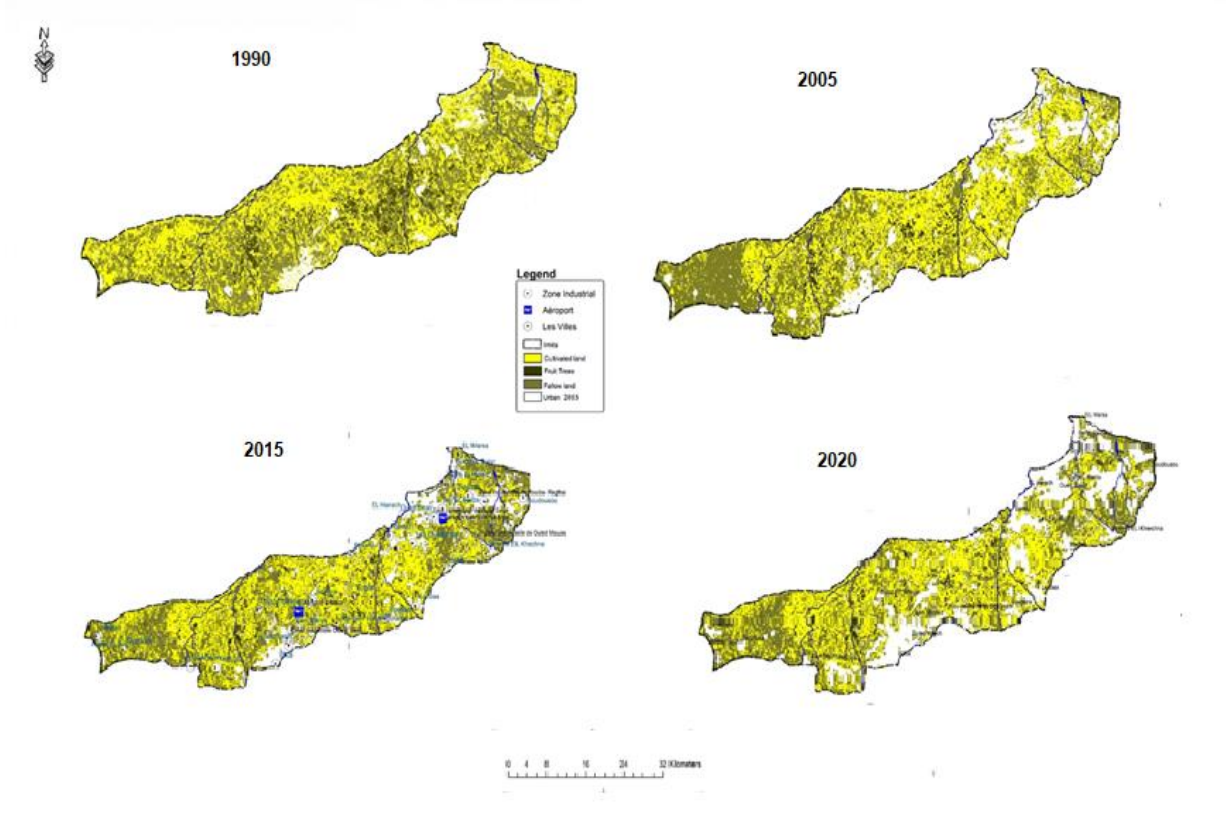
3.1 Urban Sprawl Dynamics and Environmental Sustainability in the Mitidja Plain

3.1.1 Analysis of Spatio-Temporal Changes (1990–2020)

Land Use and Land Cover Change (LULCC) constitutes a key indicator for evaluating environmental sustainability and monitoring the impacts of urban expansion on natural resources. In rapidly urbanizing regions, the analysis of spatio-temporal land transformations provides essential information for environmental management, territorial planning, and sustainable development policies (Verburg et al., 2015). In the Mitidja Plain, urban growth has emerged as one of the principal drivers of environmental transformation, progressively modifying agricultural landscapes, hydrological processes, and ecosystem functions(Bellout et al., 2020a).

To analyze these dynamics, multi-temporal Land Use/Land Cover (LULC) maps were produced for the years 1990, 2005, 2015, and 2020 using Geographic Information Systems (GIS) and Remote Sensing (RS) techniques (Figure 2). The integration of satellite imagery and spatial analysis tools enabled the identification and quantification of major land-use transformations occurring over the study period. Such approaches are increasingly recognized as effective tools for monitoring urban sprawl and assessing environmental change in Mediterranean peri-urban regions (Seto et al., 2012; Zhu et al., 2019).

Figure 2. Land use in the Mitidja Plain in 1990- 2020



Source: author's based on satellite imagery (1990, 2005, 2015, 2020).

The spatial analysis reveals a rapid and continuous expansion of built-up areas at the expense of agricultural and natural lands (Bellout et al., 2020a). Quantitative results indicate that urbanized surfaces increased dramatically from 9,862.66 ha in 1990, representing nearly 7% of the plain, to 36,960.87 ha in 2020, occupying more than 27% of the total study area (Table 2; Figure 3). Consequently, urban sprawl consumed more than 27,000 ha of highly productive agricultural land within only three decades, corresponding to an average annual loss exceeding 900 ha. These findings confirm the existence of intense peri-urban expansion processes affecting one of Algeria's most strategic agricultural basins.

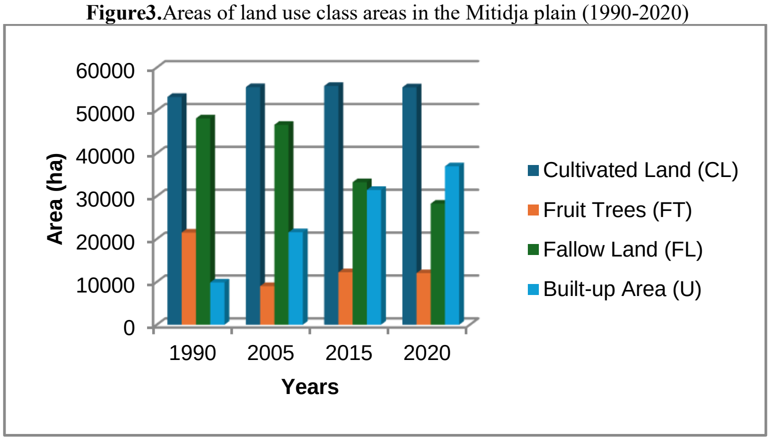
Table 2. Land-use classification (ha) by LULC type (1990–2020)

LULC Type	1990	2005	2015	2020
Cultivated Land (CL)	53135.40	55419.62	55700.00	55369.63
Fruit Trees (FT)	21500.98	9008.08	12236.70	12036.70
Fallow Land (FL)	48121.15	46624.73	33249.31	28252.99
Built-up Area (Urban)	9862.66	21567.76	31434.18	36960.87

Source: author's based on satellite imagery (1990, 2005, 2015, 2020).

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 2, 2026, Pages 1207-1215

Figure3. Areas of land use class areas in the Mitidja plain (1990-2020)



Urban growth was particularly concentrated around the metropolitan influence zone of Algiers and along the major transportation corridors connecting Blida, Boumerdes, and Tipaza. This spatial configuration reflects the increasing demographic concentration, economic polarization, and infrastructure development that characterized northern Algeria during recent decades. Similar spatial dynamics have been observed in several Mediterranean metropolitan regions, where low-density urban sprawl progressively consumes fertile peri-urban agricultural land (Salvati et al., 2012; Hegazy & Kaloop, 2015).

The results also demonstrate substantial transformations within agricultural land categories as a direct consequence of accelerated urban expansion. Between 1990 and 2020, fallow land decreased by approximately 19,868.16 ha, corresponding to a decline rate of −41.28%, while permanent agricultural areas represented by fruit tree orchards declined by nearly 9,464.28 ha, equivalent to a reduction rate of −44.01% (Table 3, fig4 &5). These changes reveal the progressive fragmentation, degradation, and reduction of agricultural systems under increasing urban pressure. The continuous conversion of fertile agricultural land into urbanized surfaces constitutes a major environmental sustainability challenge, particularly in Mediterranean regions characterized by limited cultivable land availability, increasing demographic pressure, and growing food security concerns.

Table 3. Net change in land-use classes (1990–2020)

Land Use Class	1990–2005		2005–2015		2015–2020		1990–2006	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Cultivated Land (A)	+2284.22	+4.21	+280.38	+0.5	-330.37	0.6	+2234.23	- 4.03
Fruit Trees (FT)	-12491.92	-58.1	+3228.62	+26.38	-200.00	1.36-	- 9464.28	- 44.01
Fallow Land (BR)	-12491.92	-3.11	+13375.42	-28.68	-4996.32	15.02-	- 19868.16	-41.28
Built-up Area (B)	+11705.10	+54.27	+9866.42	+31.38	+5526.69	14.95+	+ 27098.21	+73.31

Source: author's based on satellite imagery (1990, 2005, 2015, 2020).

Figure 4. Percentage Change in Land-Use Classes (1990–2020).

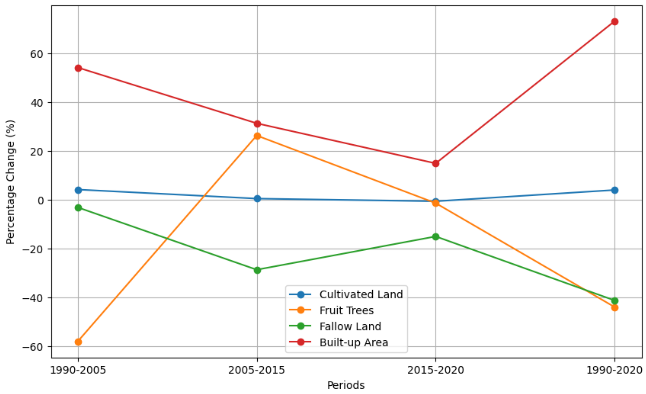
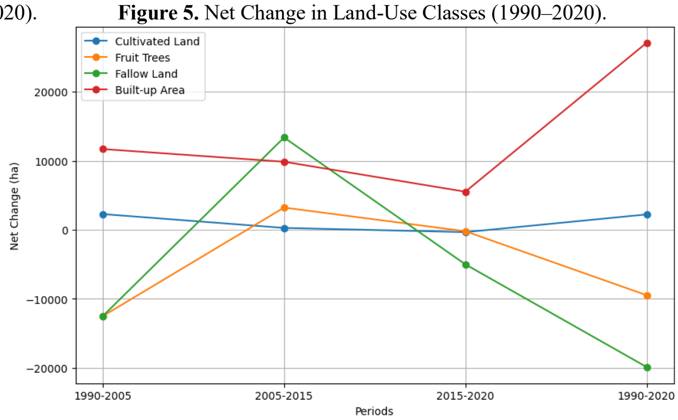


Figure 5. Net Change in Land-Use Classes (1990–2020).



The accelerated urban sprawl identified in the Mitidja Plain reflects broader socio-economic, demographic, and historical transformations that have reshaped the region since the 1990s. The first major phase of expansion coincided with the national security crisis during the 1990s, which generated intense rural-to-urban migration toward the relatively secure urban centers surrounding the Mitidja Plain. This demographic concentration stimulated spontaneous and frequently uncontrolled urban growth. A second phase emerged during the 2000s following major natural disasters, particularly the catastrophic Bab El Oued floods and the Boumerdes earthquake(photo 1.2**)**, which accelerated large-scale state-led housing and resettlement programs in peri-urban areas of eastern Mitidja. These successive crises exposed the limited capacity of territorial planning policies to regulate urban expansion and preserve agricultural boundaries during emergency development phases.

Photo 1. Bab El Oued floods2001

Photo 2. Boumerdes earthquake 2003

Source: Adapted and compiled by the authors from historical archives.

Beyond land conversion, the environmental implications of urban expansion extend to hydrological degradation and ecosystem instability. The replacement of permeable vegetated surfaces with concrete and asphalt infrastructures contributes to soil sealing, increased surface runoff, and declining groundwater recharge rates (Paul & Meyer, 2001; Berland et al., 2017). These transformations threaten the sustainability of the Mitidja aquifer system, already subjected to increasing water demand and pollution pressures associated with urban and industrial growth (Benali et al., 2020). Moreover, the progressive decline of vegetated surfaces reduces ecosystem resilience and contributes to biodiversity degradation and landscape fragmentation.

The findings of this study are consistent with previous research conducted in northern Algeria, which highlighted the rapid degradation of vegetative cover and the irreversible loss of fertile soils under uncontrolled urbanization processes (Houimli et al., 2022; Senadi et al., 2024). They also reflect broader regional patterns observed in Mediterranean and Arab peri-urban regions, including the Egyptian Delta and Italian coastal plains, where rapid urban growth increasingly exceeds institutional planning capacities (Salvati et al., 2012; Hegazy & Kaloop, 2015).

Future projections indicate that built-up areas may exceed 61,000 ha by 2050, suggesting a considerable intensification of environmental pressures if current urbanization trends persist. Such expansion represents a multidimensional sustainability challenge. First, the continued conversion of agricultural land directly threatens national food security by reducing the productive capacity of one of Algeria's most important agricultural regions (Seto & Ramankutty, 2016). Second, increasing impervious surfaces will likely aggravate groundwater depletion and reduce aquifer recharge potential, thereby intensifying water stress conditions (Benali et al., 2020). Finally, the expansion of artificial surfaces is expected to amplify Urban Heat Island (UHI) effects, increasing local temperatures, energy consumption, and environmental vulnerability in urban and peri-urban zones (Rimal et al., 2019).

Overall, the spatio-temporal analysis demonstrates that urban sprawl in the Mitidja Plain is not merely a demographic phenomenon but a multidimensional environmental management challenge affecting land resources, hydrological sustainability, agricultural resilience, and ecosystem stability. These findings emphasize the urgent need for integrated environmental management strategies based on GIS monitoring systems, sustainable territorial planning, stricter agricultural land protection policies, and long-term environmental sustainability objectives.

3.1.2. Prediction of Land Use and Environmental Sustainability Scenarios for 2050

Predicting future land-use dynamics has become a central component of environmental management and sustainable territorial planning, particularly in rapidly urbanizing Mediterranean regions where demographic pressure and uncontrolled urban sprawl increasingly threaten agricultural and hydrological systems. In this context, spatial simulation models provide essential decision-support tools capable of anticipating future environmental transformations and identifying vulnerable areas before irreversible degradation occurs (Seto et al., 2012; Verburg et al., 2015).

To simulate future urban growth patterns in the Mitidja Plain, this study adopted an integrated Cellular Automata–Markov (CA-Markov) modeling approach within the IDRISI TerrSet environment. The Markov chain model was initially employed to calculate transition probabilities between Land Use/Land Cover (LULC) classes based on historical land-use changes observed between 1990 and 2020. However, because Markov models are limited to temporal transition probabilities and do not explicitly account for spatial allocation processes, the Cellular Automata (CA) component was integrated to incorporate spatial neighborhood interactions, urban diffusion mechanisms, and land suitability conditions. This hybrid approach allows simultaneous simulation of temporal dynamics and spatial expansion patterns, thereby improving prediction accuracy and spatial realism.

The predictive simulation results indicate a continued and accelerated expansion of urbanized surfaces by 2050 (Table 4; Figure 6&7). Built-up areas are projected to increase from 36,960.87 ha in 2020 to approximately 61,404.87 ha in 2050, representing an additional increase exceeding 24,000 ha over three decades. In contrast, substantial declines are projected for agricultural and semi-natural land categories. Fallow land is expected to decrease dramatically from 28,252.99 ha to only 8,252.36 ha, while cultivated agricultural land may decline to approximately 51,334.90 ha by 2050. Fruit tree orchards are also projected to experience gradual decline due to increasing peri-urban encroachment and land fragmentation processes.

Table 4. Projected Land-Use Areas in the Mitidja Plain (2020–2050)

LULC Type	2020 Actual (ha)	2050 Projected (ha)	Net Change (ha)	Change (%)
Cultivated Land	55369.63	51334.90	-4034.73	-7.29
Fruit Trees	12036.70	11628.06	-408.64	-3.39
Fallow Land	28252.99	8252.36	-20000.63	-70.79
Built-up Area	36960.87	61404.87	+24444.00	+66.13

Source: author's using the CA-Markov model in IDRISI TerrSet based on Landsat-derived LULC maps.

Figure 6. Net Land-Use Changes in the Mitidja Plain (2020–2050)

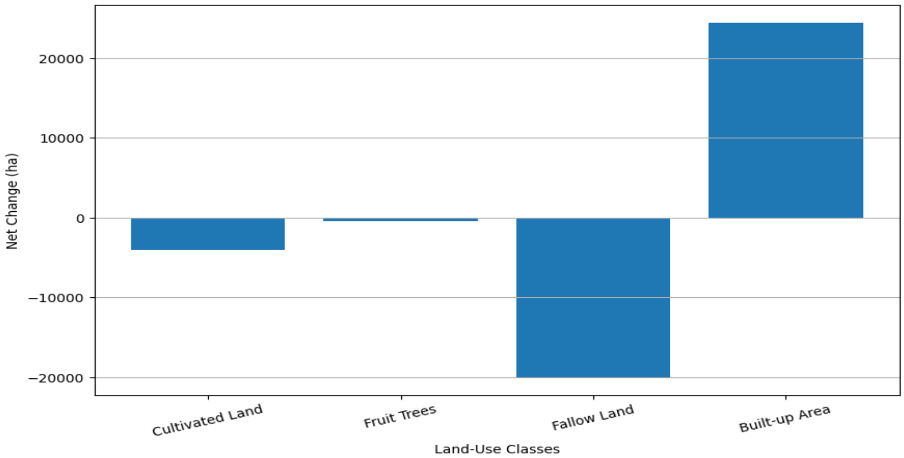
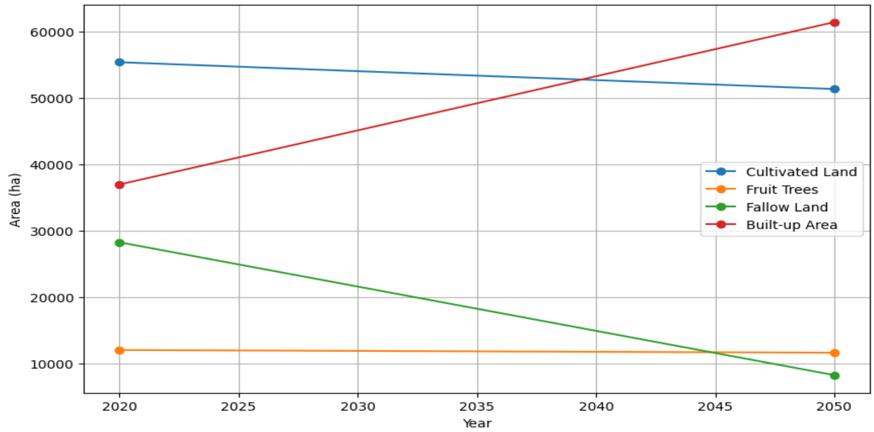


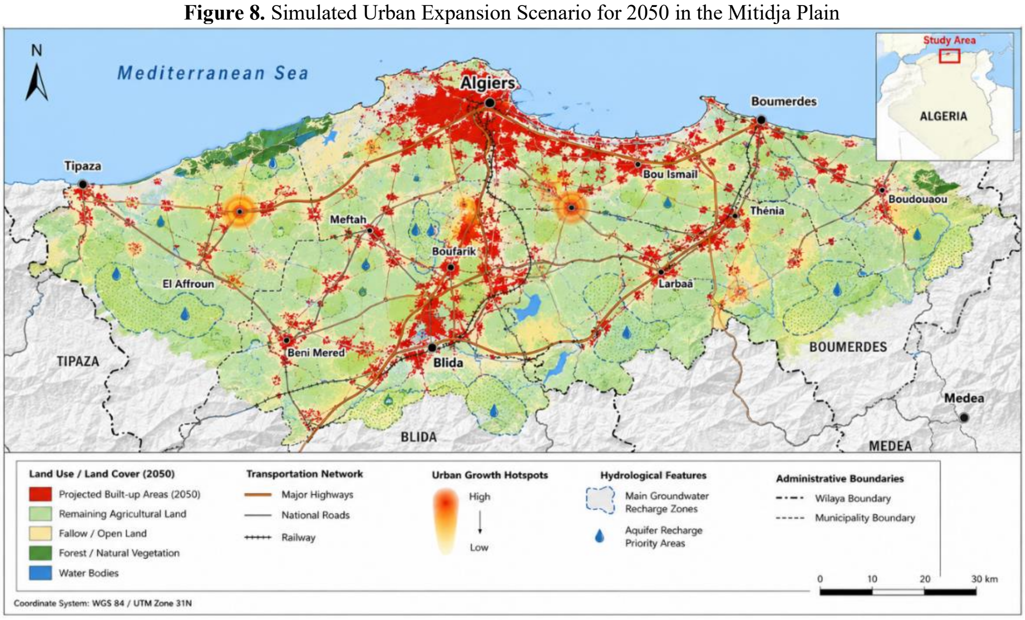
Figure 7. Predicted Evolution of Land-Use Classes in the Mitidja Plain (2020–2050)



The projected increase in artificial surfaces is strongly associated with future demographic growth and the continuous concentration of economic activities around the metropolitan area of Algiers. According to United Nations demographic projections, Algeria's urban population is expected to exceed 48 million inhabitants by 2050, representing more than 81% of the total population. This rapid urbanization is expected to intensify demographic and economic pressures within northern coastal regions, particularly in the Mitidja Plain, leading to increasing pressure on land resources, transportation infrastructure, housing demand, and water supply systems. These pressures are expected to reinforce existing urban corridors extending toward the provinces of Blida, Boumerdes, and Tipaza.

The simulated spatial distribution of future urban growth indicates that expansion will primarily follow historical urbanization trajectories already established between 1990 and 2020 (Figure 8). Rather than generating entirely new urban nuclei, future urbanization is expected to occur through densification, outward peri-urban diffusion, and the progressive coalescence of existing urban clusters. Urban growth corridors are particularly concentrated along transportation networks, industrial zones, and peri-urban municipalities surrounding the Algiers metropolitan area.

Figure 8. Simulated Urban Expansion Scenario for 2050 in the Mitidja Plain



Source: author's using GIS and CA-Markov outputs.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 2, 2026, Pages 1207-1215

The environmental implications of these projected transformations are considerable. The continued replacement of permeable agricultural and vegetated surfaces with impervious urban infrastructure will likely intensify soil sealing processes, reduce groundwater recharge capacity, and increase surface runoff and flood vulnerability (Paul & Meyer, 2001; Berland et al., 2017). Moreover, the progressive decline of agricultural land threatens regional food security and accelerates landscape fragmentation, biodiversity degradation, and ecosystem instability.

Projected urban expansion is also expected to increase pressure on groundwater resources within the Mitidja aquifer system. Increased domestic, industrial, and commercial water demand combined with declining recharge potential may intensify groundwater overexploitation and water stress conditions by mid-century. Similar trends have already been documented in rapidly urbanizing Mediterranean basins, where urban sprawl significantly contributes to hydrological imbalance and environmental vulnerability (Benali et al., 2020).

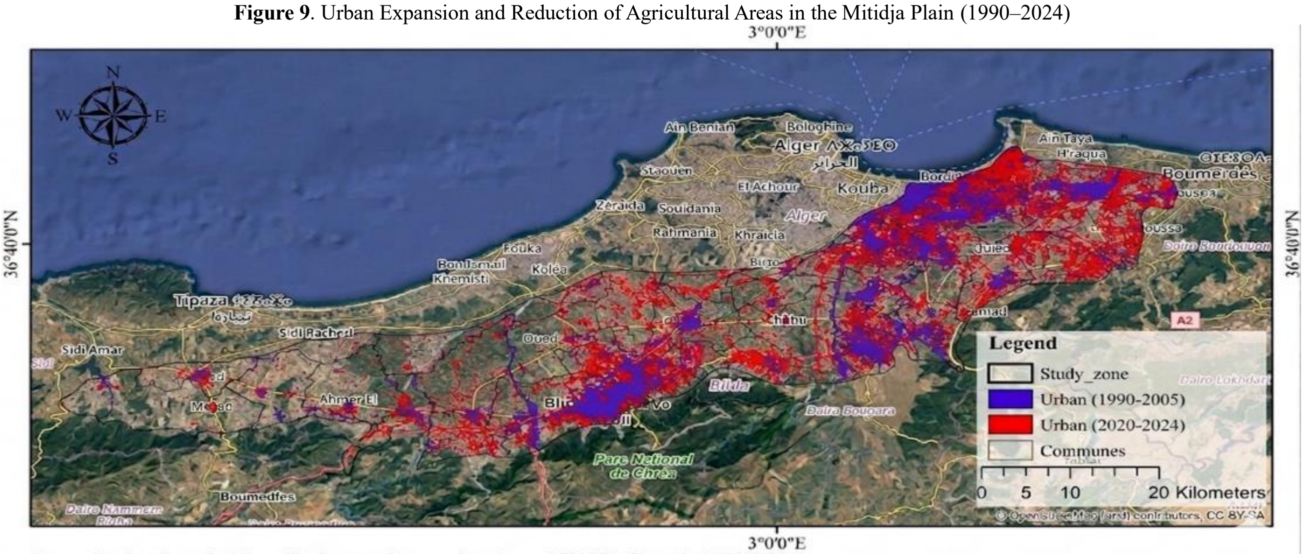
In addition, the expansion of artificial surfaces is likely to amplify Urban Heat Island (UHI) effects, particularly in densely urbanized peri-urban zones. The reduction of vegetated surfaces and agricultural areas may contribute to increasing local temperatures, deteriorating air quality, and rising energy consumption associated with cooling demands (Rimal et al., 2019). These projected climatic and environmental changes may further reduce the resilience of the Mitidja Plain under future climate change conditions characterized by increasing drought frequency and precipitation variability.

The predictive analysis demonstrates that if current urbanization trends continue without effective territorial regulation, the Mitidja Plain may experience severe environmental degradation by 2050. Consequently, integrated environmental management strategies are urgently required to preserve agricultural land, protect groundwater recharge zones, and regulate future urban growth. Such strategies should include stricter land-use planning regulations, reinforcement of GIS-based environmental monitoring systems, promotion of sustainable housing policies, and the integration of climate resilience measures into future territorial planning frameworks.The findings also highlight the importance of adopting sustainability-oriented urban development policies capable of balancing demographic growth with natural resource conservation. In rapidly urbanizing Mediterranean regions such as the Mitidja Plain, predictive spatial modeling constitutes a valuable scientific tool for anticipating environmental risks and supporting evidence-based territorial governance.

3.2.Environmental Impacts and Natural Resource Management

The accelerated urban expansion occurring in the Mitidja Plain during recent decades has generated severe environmental pressures on groundwater resources and the overall hydrological balance of the region. Water resources in Mediterranean environments are particularly vulnerable due to irregular rainfall patterns, increasing demographic pressure, climate variability, and uncontrolled urbanization. In the Mitidja Basin, urban growth has progressively transformed agricultural and natural landscapes into impermeable artificial surfaces, thereby altering groundwater recharge processes and increasing environmental degradation risks (Bouderbala, 2019).According to recent land-use analyses conducted in the Mitidja Plain, built-up areas increased dramatically from approximately 9,862 ha in 1990 to more than 36,960 ha in 2020, representing an increase exceeding 73% over three decades. Simultaneously, large portions of agricultural and permeable lands were converted into urban infrastructure, roads, and industrial zones. This rapid transformation has considerably reduced rainwater infiltration capacities and increased surface runoff rates (Senadi et al., 2024).

Figure 9. Urban Expansion and Reduction of Agricultural Areas in the Mitidja Plain (1990–2024)



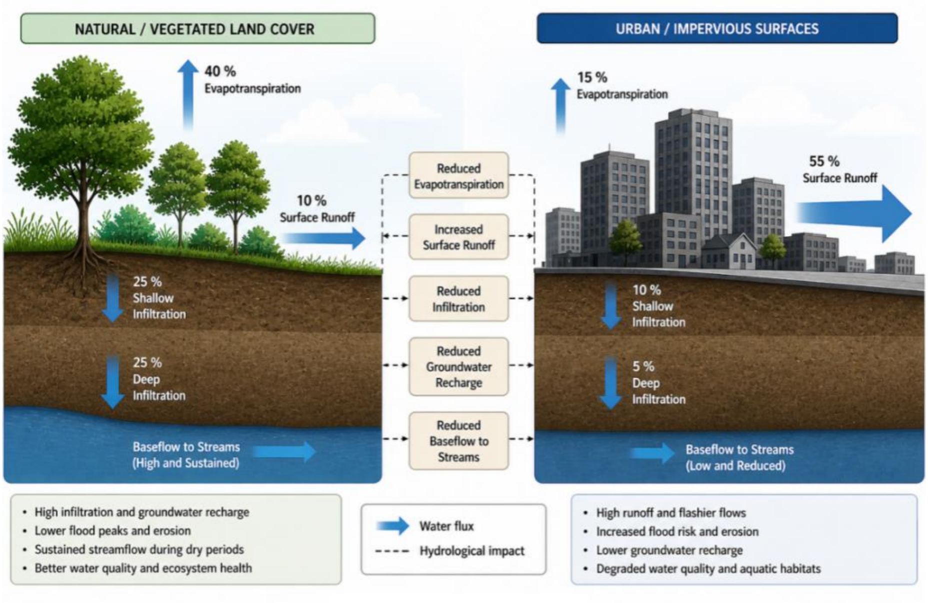
Source :Landsat & sentinel 2 satellite images_Cartographer : Imene SENADI_Created : 20/02/2024.

One of the most significant hydrological consequences of urbanization is the reduction of groundwater recharge caused by the proliferation of impermeable concrete and asphalt surfaces. Impervious surfaces prevent natural infiltration of precipitation into the soil and consequently reduce aquifer replenishment rates. Several studies conducted in northern Algeria demonstrated that urban sealing substantially modifies hydrological cycles by increasing runoff coefficients while decreasing infiltration capacities (Benali et al., 2020)

In the Mitidja Plain, groundwater constitutes one of the most strategic natural resources for domestic supply, agricultural irrigation, and industrial activities. However, the continuous expansion of urbanized zones has severely affected recharge areas. Benali et al. (2020, pp. 9–12) reported that increasing urban density around Algiers and Blida contributed to declining groundwater quality and increased pressure on aquifer systems. The authors observed strong correlations between urban land-use change and deterioration in several physicochemical water parameters.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 2, 2026, Pages 1207-1215

Figure 10. Simplified Hydrological Impact of Urban Impervious Surfaces



Source: Author's elaboration based on hydrological literature (e.g., Foley et al., 2005; Shuster et al., 2005)

Groundwater pollution has also emerged as a major environmental issue in the Mitidja Basin. Urban wastewater, uncontrolled sewage discharge, industrial effluents, and solid waste disposal represent the principal sources of contamination. Rapid population growth combined with insufficient wastewater treatment infrastructure has intensified the discharge of pollutants into rivers, drainage channels, and infiltration zones connected to the shallow aquifer system (Talbi et al. 2020, pp. 5–10) demonstrated that groundwater quality in the Mitidja aquifer has deteriorated significantly due to urban and industrial pollution. Their analysis revealed elevated concentrations of nitrates, phosphates, ammonium, and organic pollutants in several groundwater monitoring stations. The study further indicated that contamination levels were particularly high near industrial areas and densely populated urban centers(Table 5).

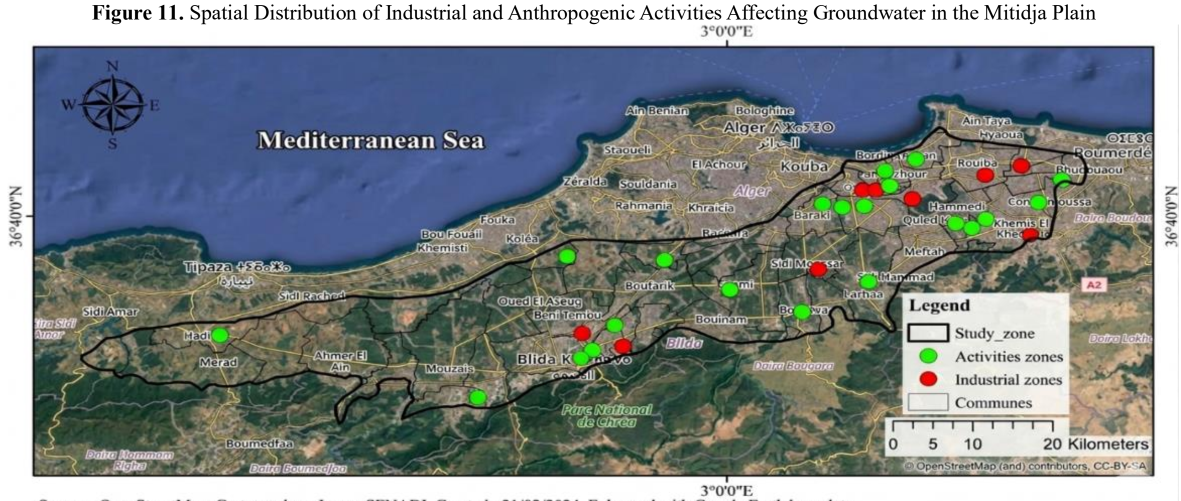
Table 5. Main Sources of Groundwater Pollution in the Mitidja Plain

Pollution Source	**Main Pollutants**	**Environmental Impacts**
Urban wastewater	Nitrates, phosphates, bacteria	Groundwater contamination
Industrial discharge	Heavy metals, hydrocarbons	Aquifer degradation
Agricultural fertilizers	Nitrates, pesticides	Soil and water pollution
Solid waste disposal	Organic and chemical leachates	Water quality deterioration

Source: Prepared based on Talbi et al. (2020) and Benali et al. (2020).

The spatial distribution of anthropogenic activities and potential sources of groundwater contamination in the Mitidja Plain is illustrated in Figure 11. The map provides a geographic overview of industrial zones and activity areas, highlighting the intensity and spatial concentration of human pressures across the region(This map shows potential sources of groundwater contamination).

Figure 11. Spatial Distribution of Industrial and Anthropogenic Activities Affecting Groundwater in the Mitidja Plain



Source : OpenStreetMap_Cartographer : Imene SENADI_Created : 21/02/2024. Enhanced with Google Earth base data.

As shown in Figure 11, industrial zones (represented in red) are highly concentrated in the eastern and central parts of the Mitidja Plain, particularly around Rouiba, Reghaïa, and the metropolitan outskirts of Algiers. These areas correspond to major industrial hubs characterized by high levels of economic activity and urban density.

In contrast, activity zones (green) are more spatially distributed but still exhibit significant clustering along major urban corridors and transportation networks. This spatial configuration reveals a strong overlap between urban-industrial development and areas of hydrogeological vulnerability, increasing the likelihood of groundwater contamination.

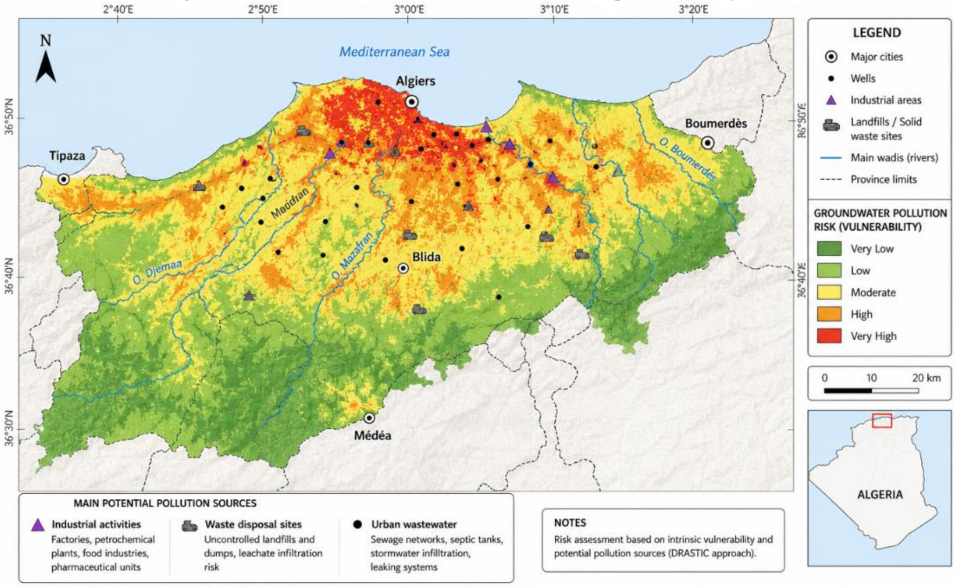
The proximity of these zones to agricultural lands and recharge areas further exacerbates environmental risks, as pollutants from industrial discharge, urban wastewater, and diffuse sources may infiltrate into the aquifer system. These findings are consistent with previous studies highlighting the role of land use patterns in influencing groundwater quality in the Mitidja Basin (Benali et al., 2020; Talbi et al., 2020).

This spatial evidence confirms that groundwater degradation in the Mitidja Plain is not only a result of diffuse processes but is also strongly linked to the spatial organization of anthropogenic activities.

Industrial activities located in the metropolitan region surrounding Algiers and Blida further aggravate groundwater degradation. Industrial zones associated with petrochemical, pharmaceutical, metallurgical, and manufacturing activities generate substantial quantities of untreated or partially treated wastewater. In many cases, these pollutants infiltrate through permeable soils or are discharged directly into watercourses connected to the Mitidja aquifer. Such practices threaten not only water quality but also public health and agricultural sustainability(Figure 12).

Furthermore, agricultural intensification contributes significantly to groundwater contamination in the region. The excessive use of fertilizers and pesticides in highly productive agricultural zones has increased nitrate concentrations within the aquifer system. Previous hydrochemical studies revealed that nitrate levels in several parts of the Mitidja aquifer exceeded World Health Organization (WHO) recommended thresholds for drinking water quality (Talbi et al., 2020).

Figure 12. Potential Groundwater Pollution Risk Map in the Mitidja Plain.



Source: Author's elaboration based on GIS modelling and previous studies on groundwater vulnerability in the Mitidja Plain.

In addition to water quality degradation, increasing demographic growth has intensified quantitative pressure on groundwater resources. The population of the greater Mitidja region continues to increase rapidly due to urban concentration around Algiers and surrounding provinces. This demographic growth has substantially increased domestic, industrial, and agricultural water demand.According to the Algerian Ministry of Water Resources, groundwater extraction rates in northern Algeria have increased considerably during the last two decades, particularly in highly urbanized coastal basins(Table 6). In the Mitidja Plain, overexploitation of aquifers has contributed to declining groundwater levels and increased vulnerability to seasonal water shortages (Bouderbala, 2019).

Table 6. Evolution of Urbanization and Pressure on Water Resources in the Mitidja Plain

Indicator	1990	2020	Projected 2050
Built-up area (ha)	9,862	36,960	61,404
Agricultural land (ha)	53,135	55,369	51,334
Estimated population (millions)	4.2	6.7	8.7
Water demand (Mm³/year)	580	910	1,250

Source: Prepared based on Talbi et al. (2020) and Benali et al. (2020).

Climate change further intensifies water stress conditions within the Mitidja Basin. Mediterranean regions are expected to experience increasing temperatures, prolonged drought periods, and declining precipitation rates during the coming decades. Such climatic changes may significantly reduce groundwater recharge capacities while increasing evapotranspiration and urban water consumption. Consequently, the combination of urbanization and climate change creates a multidimensional threat to the sustainability of water resources in northern Algeria.

Geographic Information Systems (GIS) and Remote Sensing technologies represent essential tools for monitoring and managing water resources in the Mitidja Plain. Spatial technologies allow the production of groundwater vulnerability maps, well distribution maps, pollution risk maps, runoff simulation models, and aquifer recharge maps. Integrating hydrogeological data with satellite imagery provides valuable information for environmental monitoring and sustainable urban planning.

To strengthen sustainable water management strategies in the Mitidja Plain, several environmental indicators should be systematically monitored. These indicators include groundwater level fluctuations, annual groundwater abstraction rates, nitrate concentration trends, urban water consumption, and water stress indices. Continuous environmental monitoring would enable decision-makers to identify vulnerable zones and implement preventive measures before irreversible environmental degradation occurs.

Ultimately, protecting the hydrological sustainability of the Mitidja Plain requires integrated land-use planning policies capable of balancing urban growth with environmental conservation. Strict regulation of urban expansion, modernization of wastewater treatment infrastructure, protection of groundwater recharge zones, and promotion of sustainable agricultural practices are fundamental priorities for preserving strategic water resources in the region.

4. Conclusions and Recommendations

The present study analyzed the spatial and temporal dynamics of urban sprawl in the Mitidja Plain between 1990 and 2020 and simulated future land-use scenarios up to 2050 using GIS, Remote Sensing, and CA-Markov spatial modeling techniques. The findings reveal a significant acceleration of urban expansion over recent decades, accompanied by substantial agricultural land loss and increasing environmental pressure on natural resources.

The results demonstrate that built-up areas increased dramatically between 1990 and 2020, primarily at the expense of fallow land and productive agricultural areas. Urban expansion progressively transformed large portions of fertile land into artificial surfaces, reflecting the combined influence of demographic growth, socio-economic transformation, infrastructure development, peri-urbanization processes, and historical crisis-related urbanization dynamics.

The predictive simulation for 2050 indicates that urbanized areas may continue expanding aggressively if current territorial trends persist. The projected increase in built-up surfaces is expected to intensify environmental degradation processes, including soil sealing, landscape fragmentation, groundwater recharge reduction, hydrological imbalance, and increasing vulnerability to climate-related risks.

The study also highlights the growing pressure exerted on groundwater resources within the Mitidja aquifer system. Increasing impervious surfaces combined with rising domestic, industrial, and agricultural water demand may considerably aggravate future water stress conditions in the region. Moreover, the continued decline of agricultural land threatens long-term food security and environmental sustainability in one of Algeria's most productive agricultural basins.

From a methodological perspective, the integration of GIS, Remote Sensing, and CA-Markov modeling proved highly effective for monitoring urban dynamics, analyzing LUCC processes, and simulating future environmental scenarios. Predictive spatial modeling constitutes a valuable decision-support tool capable of assisting policymakers in identifying environmentally vulnerable zones and anticipating future territorial pressures.

Based on these findings, several recommendations are proposed:

- Strengthen territorial planning regulations to limit uncontrolled urban sprawl and protect fertile agricultural land.
- Establish protected zones for strategic groundwater recharge areas and environmentally sensitive ecosystems.
- Reinforce GIS-based environmental monitoring systems for continuous land-use and hydrological assessment.
- Promote sustainable urban development policies integrating environmental resilience and climate adaptation measures.
- Encourage vertical urban densification strategies to reduce peri-urban agricultural land consumption.
- Modernize wastewater treatment infrastructure to minimize groundwater pollution risks.
- Integrate environmental sustainability criteria into future housing and infrastructure development programs.
- Develop regional databases and geospatial decision-support systems to improve environmental governance and territorial planning efficiency.

Ultimately, the future sustainability of the Mitidja Plain depends on the implementation of integrated environmental management strategies capable of balancing urban growth with natural resource conservation. Without effective intervention, continued urban expansion may irreversibly compromise agricultural productivity, groundwater sustainability, and ecosystem resilience within one of the most strategically important regions of northern Algeria.

REFERENCES

1- Benali, A., Khanchoul, K., & Bouanani, A. (2020). Assessment of water quality and land use impacts in semi-arid Mediterranean environments using GIS techniques. Environmental Monitoring and Assessment, 192(8), 1–17. https://doi.org/10.1007/s10661-020-08462-3
2- Bellout, A., Bousbaine, A., Akkari, C., & Bryant, C. (2020a). Action research: An essential approach to the development of the agricultural field of the Mitidja Plain, North of Algeria, and comparisons with other territories in developed countries. In E. Vaz (Ed.), Regional Intelligence (pp. 191–204). Springer. https://doi.org/10.1007/978-3-030-36479-3_10
3- Bellout, A., Vaz, E., & Penfound, E. (2020b). Rethinking agricultural land use in Algiers: A spatial analysis of the Eastern Mitidja Plain. Habitat International, 104, 102239. https://doi.org/10.1016/j.habitatint.2020.102239
4- Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. Landscape and Urban Planning, 162, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017
5- Bouderbala, A. (2019). The impact of climate change on groundwater resources in coastal aquifers: Case of the alluvial aquifer of Mitidja in Algeria. Environmental Earth Sciences, 78(24), 698. https://doi.org/10.1007/s12665-019-8702-5
6- Deep, S., & Saklani, A. (2014). Urban sprawl modeling using cellular automata. The Egyptian Journal of Remote Sensing and Space Science, 17(2), 179–187. https://doi.org/10.1016/j.ejrs.2014.03.002
7- Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder, P. K. (2005). Global consequences of land use. Science, 309(5734), 570–574. https://doi.org/10.1126/science.1111772
8- Guan, D., Li, H., Inohae, T., Su, W., Nagaie, T., & Hokao, K. (2011). Modeling urban land use change by the integration of cellular automaton and Markov model. Ecological Modelling, 222(20–22), 3761–3772. https://doi.org/10.1016/j.ecolmodel.2011.09.009
9- Hegazy, I. R., & Kaloop, M. R. (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. International Journal of Sustainable Built Environment, 4(1), 117–124. https://doi.org/10.1016/j.ijsbe.2015.02.005
10- Hind, B., Azzeddine, B., & Mohamed, S. (2022). Urban expansion and agricultural land degradation in northern Algeria using GIS and remote sensing techniques. GeoJournal, 87(4), 2451–2468. https://doi.org/10.1007/s10708-021-10508-4
11- Houimli, Y., Bensaid, A., & Khélifi, N. (2022). Monitoring urban sprawl and agricultural land conversion using GIS and remote sensing techniques in northern Algeria. Applied Geomatics, 14(3), 421–438. https://doi.org/10.1007/s12518-022-00434-7
12- Koomen, E., Stillwell, J., Bakema, A., & Scholten, H. J. (2011). Modelling land-use change: Progress and applications. Springer. https://doi.org/10.1007/978-90-481-8924-3
13- Lambin, E. F., & Geist, H. J. (2006). Land-use and land-cover change: Local processes and global impacts. Springer. https://doi.org/10.1007/3-540-32202-7
14- Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. Annual Review of Ecology and Systematics, 32, 333–365. https://doi.org/10.1146/annurev.ecolsys.32.081501.114040
15- Rimal, B., Zhang, L., Keshtkar, H., Wang, N., & Lin, Y. (2019). Monitoring and modeling of urban expansion and land-use/land-cover change using integrated Markov chain cellular automata model. ISPRS International Journal of Geo-Information, 8(6), 288. https://doi.org/10.3390/ijgi8060288
16- Salvati, L., Sabbi, A., Smiraglia, D., & Zitti, M. (2012). Soil sealing and urban sprawl in Mediterranean urban regions. Ecological Indicators, 23, 160–166. https://doi.org/10.1016/j.ecolind.2012.03.019
17- Senadi, I., Bellout, A., & Kherraz, K. (2024). Urban sprawl and environmental sustainability challenges in the Mitidja Plain using GIS and CA-Markov modeling. Journal of Environmental Management Studies, 15(1), 45–67.
18- Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences, 109(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109
19- Seto, K. C., & Ramankutty, N. (2016). Hidden linkages between urbanization and food systems. Science, 352(6288), 943–945. https://doi.org/10.1126/science.aaf7439
20- Talbi, A., Chitsazan, M., & Meddi, M. (2020). Groundwater vulnerability assessment using GIS-based models in northern Algeria. Arabian Journal of Geosciences, 13(18), 1–15. https://doi.org/10.1007/s12517-020-05876-0
21- Verburg, P. H., Crossman, N., Ellis, E. C., & Heinimann, A. (2015). Land system science and sustainable development of the Earth system: A global land project perspective. Anthropocene, 12, 29–41. https://doi.org/10.1016/j.ancene.2015.09.004
22- Wang, F. (2001). GIS and remote sensing applications in urban growth analysis. CRC Press.
23- Weng, Q. (2001). A remote sensing–GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. International Journal of Remote Sensing, 22(10), 1999–2014. https://doi.org/10.1080/01431160118847
24- Zhu, Z., Woodcock, C. E., Olofsson, P., & Vogelmann, J. E. (2019). Continuous monitoring of land disturbance based on Landsat time series. Remote Sensing of Environment, 238, 111116. https://doi.org/10.1016/j.rse.2019.111116