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Spatio-Temporal Analysis by Remote Sensing of Crop Changes, between Global Warming and Urbanization in Semi-Arid Zones, What Adaptation? Case Study of the Setif Region, Algeria

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Abstract: This article aims at investigating the complex relationship between the local population and its natural and urban environment. The study of area which, is previously dominated by cereal cultivation, facing profitability challenges due to climate change, water scarcity Rapid urban expansion and overexploitation of aquifers, influenced by changes in agricultural practices, are disrupting the local ecosystem. The study relies on three interconnected indicators: population growth, climate change effects on agriculture, and the NDVI (Normalized Difference Vegetation Index) reveal the impact of these factors on agricultural practices. Google Earth Engine was employed to determine urbanization and greenness indices using scripts. Key findings include a shift towards intensive and protected agriculture, driven by individual and collective choices of official and unofficial actors, deviating from government directives. Additionally, the study highlights the unsustainability of this new agricultural direction, as the available water resources cannot meet the demands, potentially leading to recurrent agricultural shortages. The study underscores the importance of incorporating agricultural production into future urban planning and development programs to maintain a renewed balance between built environments and agriculture on the outskirts of cities.

Keywords: semi-arid regions; peri-urban agriculture; climate change; water stress; remote sensing; urban region of Setif

1. Introduction

Urbanization remains a powerful mega-trend of the twenty-first century. The world's urban population will grow by an additional 2.2 billion by 2050 [1],and will reach 68 per cent of the world's total population, despite the temporary delay experienced during the COVID-19 pandemic, according to the United Nations in its new report on habitat ,29 June 2022 [2].

The increase in population experienced by urban agglomerations in the four regions of the globe, especially in underdeveloped countries, has directly affected the increase in the phenomenon of urbanization, where the demand for various services increases in light of the weakness or scarcity of capacities 2 (institutional, human or financial) to deal with the pressures on urban areas [3,4].

As a result, the demand for urban development-oriented lands has increased, leading to a corresponding rise in the demand for food. This has a direct impact on the extent of agricultural lands, as urban expansion necessitates the direct acquisition of adjacent lands to meet housing, infrastructure, and economic activity requirements. On the other hand, it also affects the nature of agricultural land use, often leading to the restructuring of new production models in response to the needs of urban populations. Moreover, the pollution resulting from the process of urbanization, as

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indicated by [5], contributes to undermining agricultural productivity and the safety of food production due to the degradation of soil and water quality.

In the same vein, Africa's urban population can triple by 2030. About 80% of the world's loss of cropland can be attributed to urban expansion, which is believed to be concentrated in Asia [6]. Researchers in Africa see urbanization as a direct driver of changes in land use patterns [7,8]. Urbanization has both positive and negative consequences that conflict with one another, disrupting spatial and temporal balances and raising concerns for the future.

The Mediterranean basin stands out as the region of the world with the fewest agricultural spaces, situated in areas conducive to urbanization. Consequently, the primary challenges for nations revolve around the preservation of peri-urban agricultural land. This is especially pertinent for a country like Algeria, where economic and urban development dynamics are predominantly concentrated in the northern part of the country [9], further exacerbating the phenomenon of littoralization.

In Algeria, geographical research has long been centered on the city due to the phenomenon of urban sprawl. Only recently has it started addressing and continuing to grapple with the predicament of peri-urban land, leading to conflicts over land ownership [10].

As the population continues to increase in Algeria at a rapid pace, the population growth rate in 2021 was estimated at 1.7%, surpassing that of neighbouring countries such as Morocco with a rate of 1.1% and Tunisia with 0.8%,. Furthermore, the marriage rate in Algeria has surged to 7.79‰, in stark contrast to Tunisia's 2.1‰ in the year 2020 as reported by [11]. In light of this profound demographic shift, these indicators underscore the substantial latent demand for housing and sustenance by newly-formed households.

Consequently, this exerts mounting pressure on real estate resources whichs are earmarked for urban development at the expense of agricultural lands. This creates a complex equilibrium equation within the geographical realm, entailing a trinity of urbanization, arable land, and groundwater, each of which demands careful consideration and management to ensure a harmonious coexistence.

The Algerian natural space, particularly the agricultural one, has become a subject of multiple pressures resulting from human activities, including agricultural production and urbanization. These activities have been a subject of controversy among local farmers, investors, and urban operators. As a consequence, agricultural spaces have gradually undergone a process of "artificialization" due to rapid urbanization.

The urbanization rate has experienced a remarkable increase, representing less than a third of the total population with 31.4% in 1966 and rising to two-thirds (65.94%) in 2008, with projections of reaching 85% by 2050, as per the Population and Housing Census of 2008 [12]. Conversely, the Agricultural Land per capita (ALC) has shown a concerning decline from 0.63 hectares in 1967 to 0.27 hectares in 2000, and further to 0.19 hectares in 2018, according to [13]. Moreover, agricultural lands serve as land reserves for the ever-expanding urbanization, a trend that presents a growing concern [14]. The sustainability of peri-urban agriculture in semi-arid zones is in question, as it must address these multifaceted challenges while mitigating its adverse impacts on the environment [15].

Between 1998 and 2018, the total area of urbanized zones in the province of Sétif increased by over 38%, from 2,290 hectares to 3,172 hectares, with an average annual growth of 1.5%. The urbanization rate of the province was 29.3% in 1987 and reached 47.9% in 2018. In the urban area of Sétif, agricultural land has decreased by 5.8% between 1987 and 2018 [16], which could have detrimental effects on the region's food needs and local environmental sustainability.

The pressure on the surrounding agricultural lands of the city of Sétif is partly due to the city's own expansion, demographic growth, and the increased food demand in the Sétif region, where the demographic basin reached 1.9 million inhabitants in 2019, according to [17].

In addition to these factors, climate change and the perceived temperature rise have further exacerbated the ecosystem of the Sétif urban area, leading to large-scale wildfires in recent years, particularly in 2021 and 2022. This phenomenon raises questions about the need to revise agricultural practices and adopt new methods in the study area, despite the historical predominance of traditional agro-pastoral practices.

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In summary, reconciling urbanization, population growth, and agriculture in the urban area of Sétif is a critical challenge for ensuring sustainable regional development. The importance of this issue arises from the nature of the three structural elements, characterized by dualities and perpetual conflicts. The complex and vulnerable relationship between these elements emphasizes the significance of studying and monitoring the spatio-temporal evolution of these components within the local space, where environmental uncertainties are substantial, as depicted in (Figure 1).

The impact of urban dynamics on agricultural spaces, the overexploitation of groundwater, the conflicts arising from these phenomena and the potential these vital elements could represent for the city all currently seem to be neglected aspects in urban policies [18]. However, agriculture in peri-urban areas can hold strategic importance for the stability and environmental quality of the urban environment [19].

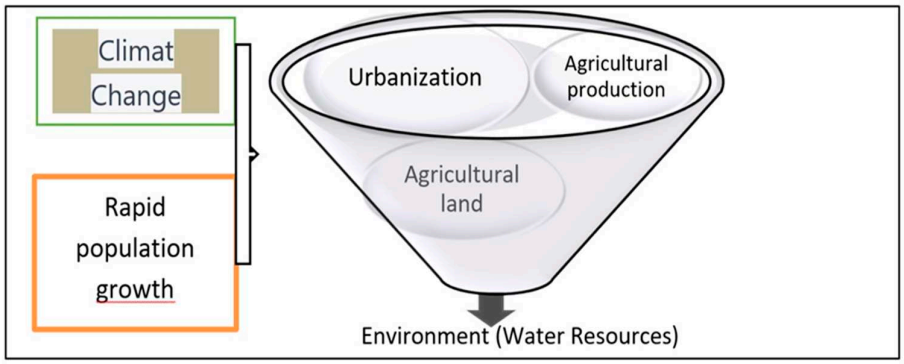

Figure 1. Perpetual Duality Between Structural Elements and the Environment .Source: Authors.

Developing a spatial representation would, therefore, enable the presentation of various perspectives and the identification of consensus regarding the sustainable use of peri-urban space and its natural resources.

Study Area

In order to investigate the impact of climate changes and urban expansion on Suburban agriculture in semi-arid regions, the city of Sétif and its southern outskirts were selected as the study area based on two primary factors. The first factor is its geo-climatic characteristics. The study area (see Figure X) is situated in the eastern highlands of Algeria and is distinguished by a semi-arid climate. The second factor is the rapid urban expansion of Sétif due to historical and economic considerations, which has directly influenced the regional dynamics of its territory. The study area extends over an area of approximately 1129, 69 km² and had a population of 671132 inhabitants in the year 2020 [20].

Table 1. Population of the Study Area in 2020.

Municipalities	Bir- Haddada	Aïn El Hadjar	Guedjal	Guellal	AïnOulmene	Mezloug	Setif	Total Area (km²)
Area (km²)	114.04	224.64	231.43	125.6	171.08	135.55	127.3	114.04
Population 1998	2622	8185	1869	8496	48019	7781	235168	323,140
Population 2020	27340	48040	44389	29712	105244	22441	393966	671132

Source: The monograph of the Setif province, the civil registry records for 2020, and the General Population and Housing Census (RGPH 1998).

Naturally confined between Mount Mokrass at 1,737 meters to the north and the Harraanah Mountains to the south, represented by Mount Boutalib, which soars to an elevation of 1,886 meters (the summit of Afrajane), the study area stretches across a wide plain with an average elevation of 950 meters above sea level. This region is characterized by dispersed and detached mountain masses,

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appearing sporadically, such as Mount Youssef at 1,442 meters. Moreover, the area is punctuated by marshes and saline depressions, including the Mullah Marsh, Al-Hamiyat Salt Flat, and the Meloul Salt Flat.

2. Materials and Methods

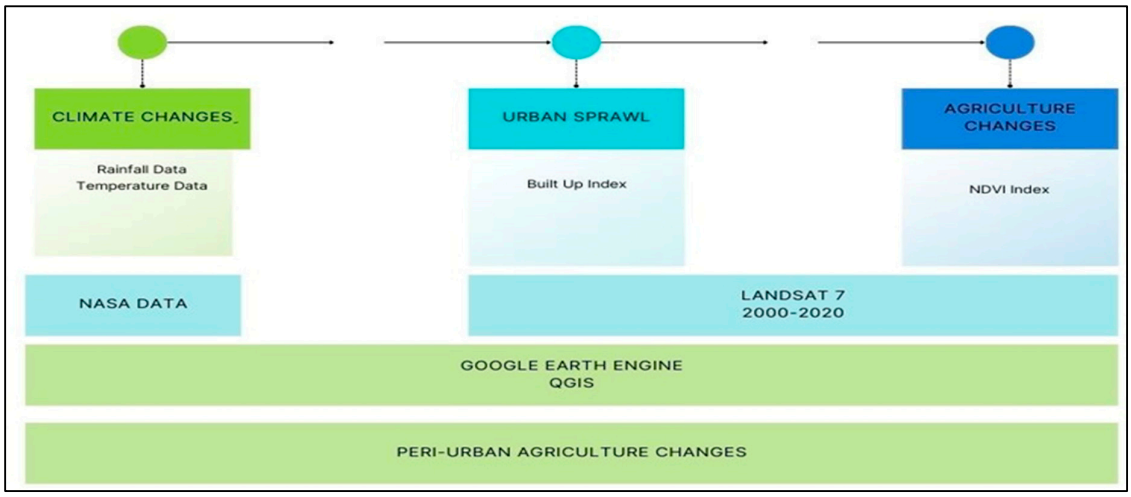

Figure 3. Research Methodology.

The study relied on three interconnected key indicators: population and urban growth, which is considered a significant element in controlling the demand for agricultural products and thus promoting semi-urban agriculture in the region. The second indicator is climatic changes, which also have a major impact on altering the agricultural pattern based on variations in precipitation levels. The third indicator is the Normalized Difference Vegetation Index (NDVI), which reveals the degree of influence of the aforementioned factors on changing the agricultural production pattern in the study area.

In our study, we utilized Google Earth Engine to determine the urbanization index (Build up index) and the vegetation index (NDVI) through the application of a script built upon the following characteristics:

Table 2. Characteristics of Landsat imagery.

	Filter			
index	**Periodstart**	**Period end**	**Satellite**	**cloud**
NDVI	01-06-2000	31-08-2000	LANDSAT_7	lowcloudiness
	01-06-2021	31-08-2021	LANDSAT_7	lowcloudiness

The study relied on three interconnected key indicators: population growth, urbanization, and an important element, initially choosing imagery from both Landsat 7 (L7) for the year 2000 and Landsat 8 (L8) for the year 2021. However, we observed variations in the specific pixel values of the Normalized Difference Vegetation Index (NDVI) in nearly the same area. Therefore, we resorted to utilizing Landsat 7 imagery for both years, 2000 and 2021, which allowed for significantly more accurate results.

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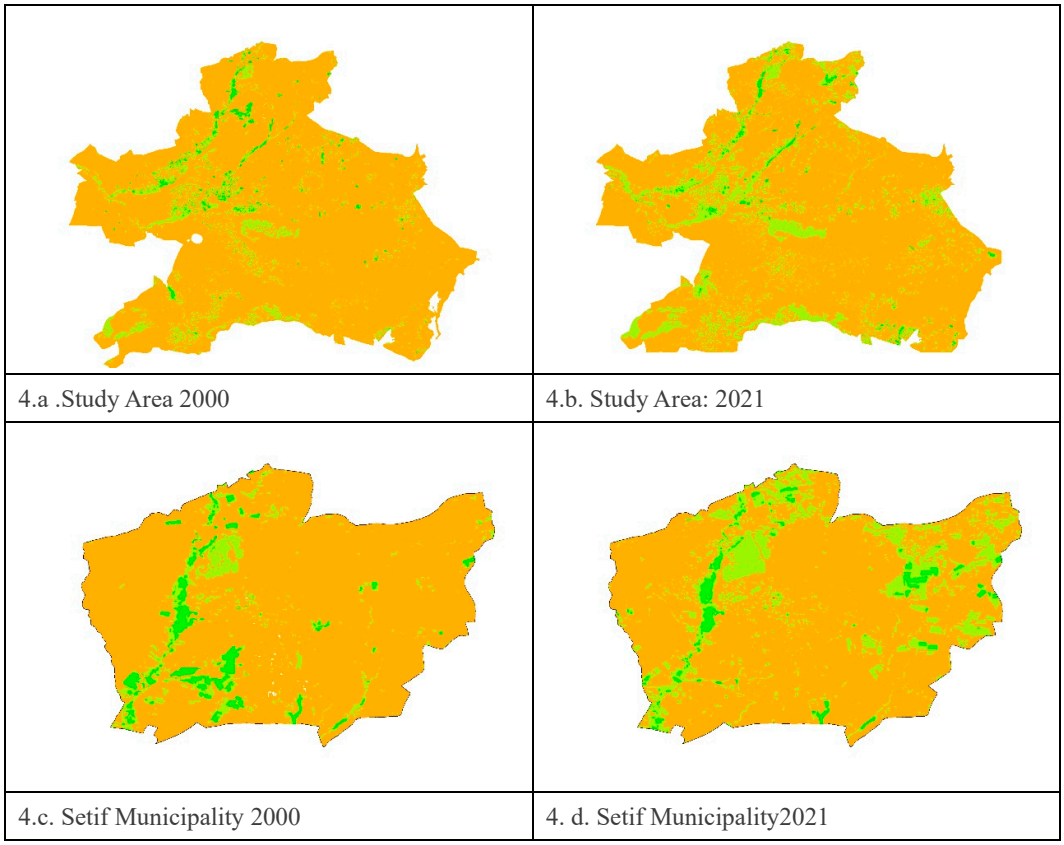


4.a .Study Area 2000 | 4.b. Study Area: 2021

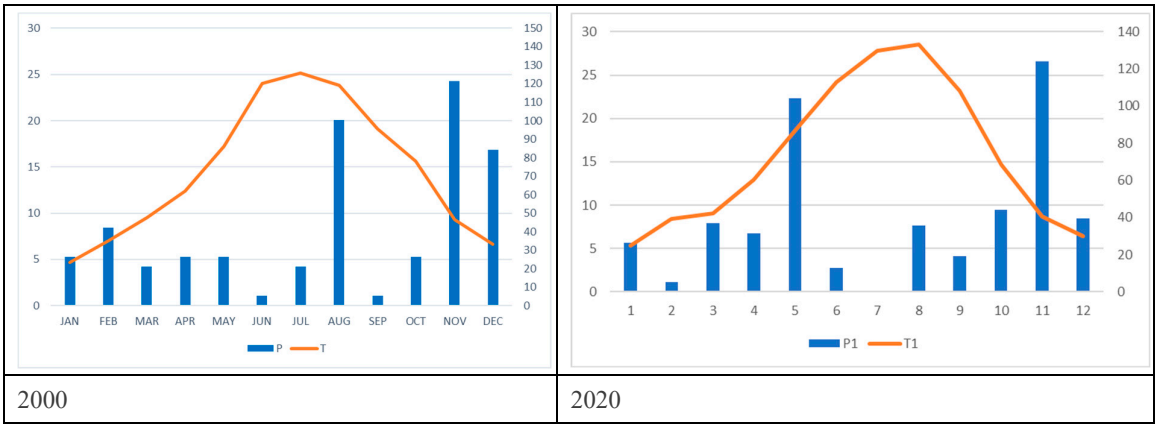
4.c. Setif Municipality 2000 | 4. d. Setif Municipality2021

Figure 4. a.b NDVI results in Study area/ c.d. , NDVI results in Municipality of Setif.

3. Results and discussion

3.1. Climate changes in the study area are trending towards acidification

The data utilized in this study (Figure) confirm the semi-arid nature of the study area, consistent with previous research indicating that the Sétif region consistently maintains its status in the semi-arid bioclimatic zone, with a slight shift towards arid conditions [21]. Moreover, the semi-arid climatic zone has experienced an increased susceptibility to drought in recent years due to reduced precipitation and prolonged dry periods, exacerbated by the delayed arrival of the autumn season, a factor that is currently impacting and will further affect the nature of agricultural crops [22]**.** The crop cycle will accelerate, leading to consequences for early growth stages and cycle duration [23], which will ultimately influence the agricultural production in the study area known for cereal cultivation and livestock farming, characterized by a concurrent and integrated cycle.



2000 | 2020

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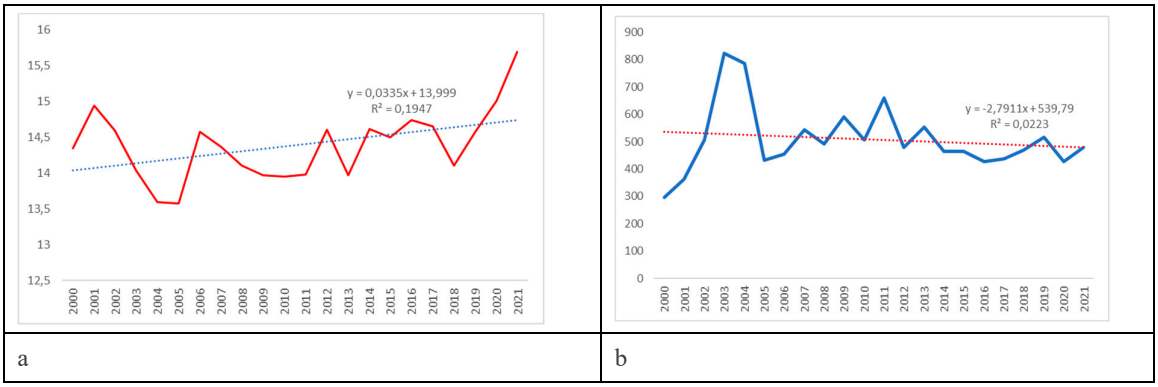


a b

Figure 5. a: annual changes of temperature and precipitation.b: annual changes of temperature and precipitation.

3.2. Urban changes in the study area in response to population pressure

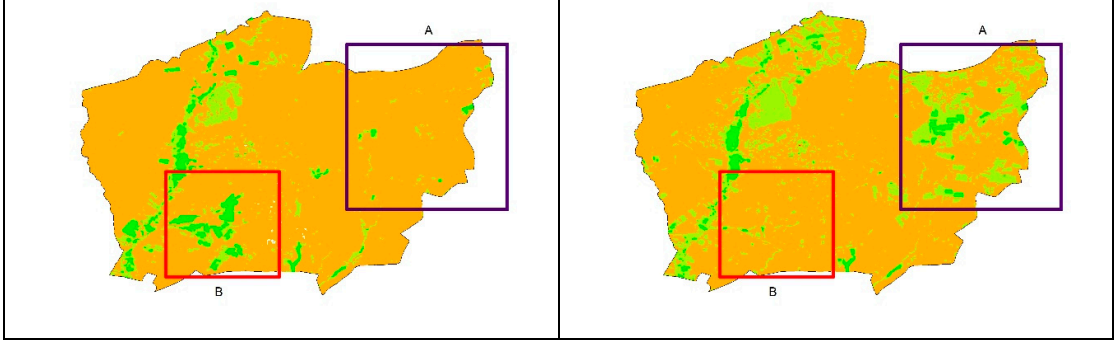
Similar to other major cities in Algeria, the population increase and other urbanization factors [24], that have been witnessed in the study area in general, and specifically in the city of Setif, underscores the rapid urban expansion. This urban sprawl is characterized by two fundamental properties: dispersion and increasing land consumption [25], particularly on agricultural lands to the east and south of the city.

The study area has experienced a significant population increase, as indicated in the table. Additionally, the urbanized area in Setif has multiplied tenfold, increasing from 338 hectares in 1966 to 3,377 hectares in 2008 [26] .

According to [27], urban expansions can take two forms. They can either be connected to existing urban structures, in which case they involve collective or individual residential structures. The areas near existing urban structures are suitable for development, and as a result, land parcels are easily sold at high values. The second type of expansion occurs in dispersed areas within agricultural regions and near roads. In this case, various commercial and craft activities (such as workshops, car wash stations, and small units for manufacturing construction materials) typically start, often initiated by investors or even farmers themselves.

3.3. Suburban Agriculture

The Gradual Transition In this study, we relied on pixels with values ranging from 0.4 to 0.8 to accurately determine vegetative cover, especially densely cultivated areas that are irrigated in the summer. This is due to the region's semi-arid nature, where green areas are generally absent during the summer, except for forested areas or irrigated crops. Harvesting is typically complete, as the primary agricultural activity in the region has traditionally been cereal cultivation, as previously mentioned.



2000 2021

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Figure 6. Suburban Agriculture changes in Setif Municipality.

The use of NDVI (Normalized Difference Vegetation Index) changes allowed us to understand the transformations in agricultural vegetative cover between the years 2000 and 2021 within the study area. Substantial changes in land use patterns became evident, particularly in the northeastern (A) and southwestern (B) regions of Setif city. In these areas, the shift in land use has transitioned from cereal cultivation to more intensive open-field agriculture and the construction of plastic greenhouses, particularly in the southern part of the study region.

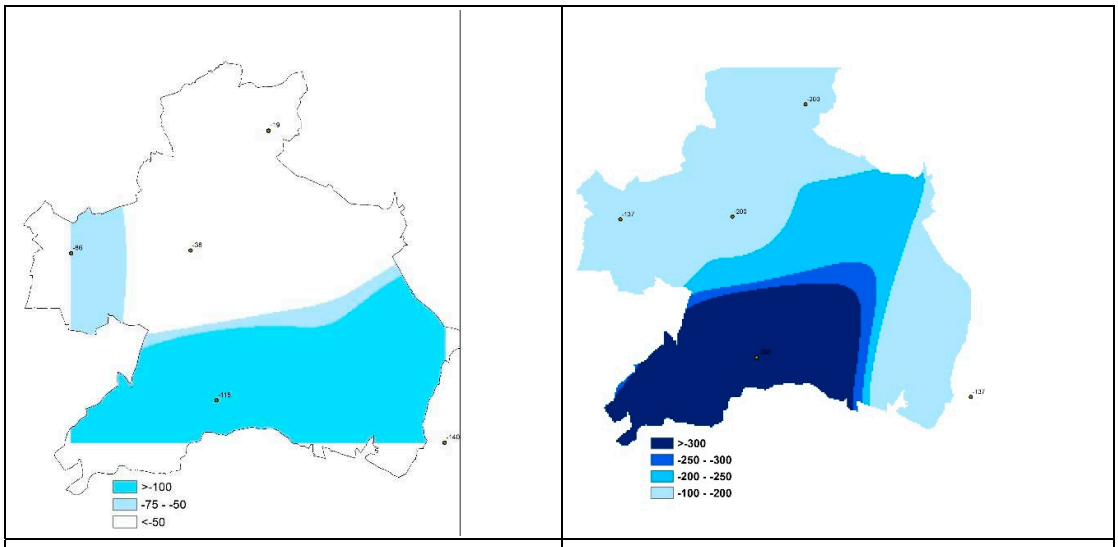
As previously noted, the region has historically been renowned for cereal cultivation. However, two key factors have contributed to this shift. First, the region has experienced climate changes resulting in decreased precipitation, which was the primary source of support for cereal cultivation. Second, the expansion of urban areas due to population growth has significantly increased the demand for food, particularly the products of intensive agriculture, such as tomatoes, peppers, beetroots, salad, and carrots.

A noteworthy observation, equally important, is the proliferation of poultry farming in the southern part of the study region. Extensive areas and livestock stables for poultry and cattle have been observed on lands previously allocated for cereal crops. This reflects farmers' attempts to compensate for the decline in income from cereal cultivation.

Furthermore, the sub-urban agriculture practiced in the study area provides seasonal employment opportunities. This is due to the unique nature of this form of agriculture, which requires the involvement of a significant workforce during the sowing, harvesting, and collection phases. The scarcity of jobs in the industrial and service sectors, especially in less-developed countries, motivates the population to engage in agricultural activities [28].

3.4. Excessive Exploitation of underground water Levels

The levels of regular and artesian wells have been affected due to the decline in underground water levels, primarily supplied by seasonal precipitation. The underground water levels have dropped from less than 50 meters in the northern areas before 2015 to over 150 meters by the end of 2022. In contrast, in the southern region, the depth of groundwater levels has surpassed 300 meters in 2022, as observed in the Ain Oulmene area, while previously it did not exceed 100 meters in extreme cases [29].



a b

Figure 7. Underground water depth (a) befor 2015. (b) 2022.

This can be explained by two main factors:

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The first is climate change, resulting from decreased precipitation and increased demand for groundwater resources, particularly in intensive summer agriculture.

The second factor is the demand arising from urban expansion and associated human activities.

With the continued phenomenon of drought and reduced precipitation, almost all wells have dried up completely or nearly so (4 out of 5 wells). This has prompted investors to seek permission from the Administrative and Technical Authority for Groundwater Resources to drill deeper wells, reaching depths of up to -350 meters in certain areas, such as (Ain Oulman). This situation reflects a state of groundwater depletion in the study area and creates difficulties in restoring balance to groundwater levels, especially given the non-harmonious hydrogeological structure of the region.

5. Conclusions

The relationship between urban populations and the natural environment remains a vital and fragile issue, as ensuring a comprehensive balance among the environmental elements in which they reside, especially between urban expansion and neighbouring farmlands, proves to be challenging. This duality has long been based on a struggle for control over one another.

The local natural space of the city of Setif and its suburbs is subjected to continuous and dual pressures, especially on farmlands, in terms of urban land use. Agricultural lands are receding in the face of urban expansion, particularly in the suburbs (périphérie), in addition to the demographic weight of the city and its region. Setif is the second-most populous province in Algeria with 1.9 million inhabitants. In recent decades, the city has transformed into a true regional metropolis.

What further complicates this duality is the continued response of the state to social housing needs in an urgent manner.

The notable result of this research is a shift in the agricultural production pattern in the study area. It has long been known for grain cultivation and cattle farming, but now it is witnessing the spread of intensive and protected agriculture (greenhouses) along with poultry farming. This new pattern is unintentional and not specified in the state's major goals and directions; rather, it results from spontaneous, individual, and collective choices made by both official and non-official actors seeking quick profits. This is because, despite state support and incentives, the financial return on grain cultivation remains modest compared to other seasonal crops.

This new trend in agricultural production, favoring intensive and protected cultivation, raises unknown consequences in a changing climate marked by drought periods, fluctuating and reduced precipitation, as well as declining groundwater levels in the study area. In contrast, local and regional urban planning schemes and tools do not address the food needs of the population.

Therefore, the water resources in the study area (the city of Setif and its suburbs) will not suffice to support this new agricultural trend, which is heading towards the depletion of local undergroundwater. This situation presents a challenge and calls for a shift in water resources allocation from the more rainfall-endowed northern coastal regions to the semi-arid inland areas as a first step. However, it is our belief that seawater desalination, located 80 kilometers away, should be pursued to meet the water demand for both the population and agriculture. This is the direction outlined by the Algerian government through future seawater desalination projects.

In the future, the issue of food must be integrated into local and regional urban planning programs and tools to ensure a renewed balance between housing and agriculture in the suburbs of cities.

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