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Promoting Peri-urban Agriculture: A Remedy for Climate Change. Case of the Town of Delly Brahim in Algiers

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Abstract

The issue of promoting peri-urban agriculture seems to be an important one in response to the various current concerns about the future of cities in the face of climate change. At first glance, these urban and peri-urban agricultural areas, which in the past served as a shelter for cities, are now threatened and increasingly losing their function of protecting urban areas from climatic hazards. This question is a priority when considering the future of agriculture in the context of urban expansion. We are therefore raising a number of concerns linked to multiple issues: significant reduction of land available for local agriculture, accelerated degradation of the city's natural environment, fragmentation of ecosystems, and deterioration of air and water quality.

Around these questions, this research is structured to provide theoretical and practical knowledge that will enable us to place urban and peri-urban agriculture at the heart of urban concerns, in a perspective of reaction to climate change. The interest of this work is reinforced in the case of peri-urban areas surrounding the capital of Algeria, Algiers, such as the commune of Delly Brahim: a concrete example of a territory concerned by the subject. On the one hand, this periphery boasts important agricultural production zones in close geographical proximity to the capital Algiers, and on the other, it plays a fundamental economic, environmental, and landscape role in relation to its region. Between its dense urban residential areas, agricultural lands, and natural areas rich in resources, this territory is today confronted with numerous environmental vulnerabilities. The aim is therefore to examine the issue of preserving the agricultural sector and its role in mitigating climate change. This study is based on data collected in 2020 to analyze the current and future dynamics of these territories.

Keywords

Climate change; Urban and peri-urban agriculture; Delly Brahim; Local Agricultural practices; adaptation strategies.

1. Introduction

Climate change is an inescapable reality affecting urban, peri-urban, and rural communities around the world. In this context, this topical research aims to study its impact and explore the potential of urban and peri-urban agriculture as an effective means of remedying its adverse effects and promoting sustainable food systems (FAO, 2021). Our motivation lies in the need to deepen our understanding of the interaction between climate change and urban and peri-urban agricultural practices, to strengthen their resilience by highlighting their often underestimated potential in this area.

The warming of the climate system, as highlighted by the Intergovernmental Panel on Climate Change IPCC observations in 2007, has direct implications for global weather conditions, with tangible consequences such as rising average temperatures, melting snow and ice, and rising sea levels. This reality is all the more worrying in

specific regions such as the city of Algiers, the capital of Algeria, where extreme climatic variations have become increasingly frequent (MATEV, 2013). In this context, the commune of Delly Brahim, on the outskirts of Algiers, is facing a double threat: climate change and the urban sprawl of the capital. This city is directly affected by the harmful consequences of this rapid urban expansion, which puts additional pressure on its natural environment, which has already been weakened by the effects of climate change.

The repercussions of this situation are manifold. Firstly, there is a significant reduction in the amount of land available for local agriculture, which is seriously compromising the local community's food security and jeopardizing the livelihoods of local farmers, thereby undermining the region's economy and social fabric. In addition, this rapid urbanization is leading to accelerated degradation of the city's natural environment, with the disappearance of green spaces, the fragmentation of ecosystems, and the deterioration of air and water quality. According to UN-Habitat (2020), "the rapid growth of cities puts considerable pressure on natural resources and often leads to negative environmental impacts such as air and water pollution and loss of biodiversity". Faced with these complex challenges, this research seeks to develop planning strategies adapted to the area to preserve both the natural resources and the agricultural activity of Delly Brahim. The results highlighted the potential benefits of promoting urban and peri-urban agriculture as a climate change mitigation and adaptation project. They propose strategies and incentives aimed at preserving and ensuring the continuity of existing agricultural activity, improving its production, and guaranteeing its sustainability in the face of increasing climatic hazards.

The literature review on this issue revealed updated data on the global phenomenon of global warming. By definition, this phenomenon corresponds to a lasting change in the statistical parameters of the Earth's global climate or its various regional climates (IPCC, 2021). These changes may be due to processes intrinsic to the Earth (El Nino), external influences (volcanoes, etc.), or, more recently, to human activities linked to the advent of the industrial era.

Recent studies (Smith et al., 2023; Brown et al., 2021) have highlighted a significant rise in global temperatures, accelerated melting of polar ice, more frequent extreme weather events, and acidification of the oceans. These phenomena have a direct impact on biodiversity, food security, human health, and economic stability. To address these challenges, scientific research is evaluating adaptation and mitigation strategies, including, for example, the identification of renewable energy sources, the development of clean technologies, the promotion of sustainable agricultural practices, and the implementation of environmental conservation policies (IPCC, 2021). The information and expertise generated by the scientific community are crucial for guiding political and personal choices, with the aim of shaping a safer future for generations to come.

In this context, the IPCC (2007) proposes a widely recognized theory of climate variability and its impacts. This theory states that global climate change is leading to an increase in average temperatures, greater variability in precipitation, and an increased frequency of extreme weather events such as heat waves, floods, and droughts. These studies, along with those of Müller et al (2011), also show that Mediterranean agricultural regions are among the most vulnerable to climate impacts, requiring urgent and effective mitigation and adaptation measures.

On the other hand, the theory of climate resilience and adaptation, developed by C.S. Holling (1973) and other researchers (Gunderson, 2002), proposes that ecological and social systems must develop capacities for adaptation and resilience in order to cope with the impacts of climate change. This theory highlights the importance of strengthening infrastructure, natural resource management, and education to increase resilience to climate change.

Furthermore, the literature on urban and peri-urban agriculture (UPA) highlights its crucial role in adapting to climate change. The practice has a number of benefits for urban food systems, environmental management, and social well-being. For example, the study by Opitz et al (2016) demonstrates that AUP can improve the resilience of urban food systems by diversifying food sources and using sustainable agricultural practices such as agroecology, permaculture, and organic farming. In addition, Barthel and Isendahl (2013) point out that AUP enhances the resilience of cities by diversifying local food sources to mitigate the negative effects of climate change, such as the urban heat island. The practice also improves the health and well-being of residents by increasing access to fresh food and green spaces.

Another review of the literature on agricultural peri-urban towns in the face of urban sprawl and climate change highlights several crucial aspects. Anne-Marie Jouve et al (2007) examine the role played by peri-urban agriculture around the Mediterranean in supplying towns and cities, but it is under threat from rapid urbanization. This research shows that, although this agriculture is adapting by developing a variety of forms, it must rise to the challenge of multifunctionality to meet contemporary needs, by combining food production, landscape maintenance, and environmental protection. Paula Nahmias et al (2012), studying urban agriculture in Brittany, emphasize that professional practices in shared gardens and leisure agriculture are valued for their food, environmental and socio-political roles, thereby contributing to urban development. However, their diversity complicates the definition of "urban agriculture", which is characterized by its functionalities and its integration into urban projects rather than simply by its geographical proximity to the city.

In Algiers, according to the 2002 coastal development programme, uncontrolled urbanization since 1992 has swallowed up 1,400 km² of fertile land in the Mitidja plain, with more than 15,000 ha of agricultural land lost between 1987 and 1997, and more than a third of the useful agricultural area built between 1972 and 1999. The climate in Algiers is showing a warming trend of 0.5°C per decade for maximum temperatures and 0.2°C per decade for minimum temperatures, increasing the risk of flooding and water shortage, which has a negative impact on agriculture and the quality of irrigation water.

This literature review places our study of Algiers and Delly Brahim in the broader context of research into the impacts of climate change and adaptation strategies using urban and peri-urban agriculture (UPA), a subject that remains little explored in the existing literature. Overall, UPA is emerging as a promising solution to mitigate and adapt to these effects. So how can this practice strengthen the resilience of these cities in the face of current and future climate challenges?

2. Materials and Methods

The wilaya of Algiers, the capital of Algeria, covers an area of 809.22 km² and occupies a strategic position on the northern Mediterranean coast of Africa. With a population of over 3 million (3,309,896), the city has a high urban density of 4,090 inhabitants per square kilometre (Annuaire statistique de la wilaya d'Alger, 2020). Urban sprawl stretches for around 30 kilometers along the Mediterranean coast, exacerbating the pressure on natural resources such as water and land (Ministry of the Environment and Renewable Energies). With a rich history dating back to antiquity, the city now faces a number of challenges, including rapid urbanization, natural resource management, and adaptation to climate change.

2.1. Pre-climate change historical data for the capital of Algiers and the surrounding area

Prior to the impact of climate change, the climatic history of the Algiers capital region and its surroundings between 1961 and 1990 was mainly characterized by a Mediterranean climate, offering moderate weather conditions throughout the year. Summers were hot and dry, with average temperatures between 25°C and 30°C. Winters were mild and wet, with average temperatures between 10°C and 15°C. Precipitation was generally moderate to low during the summer season, but more abundant during the winter months, concentrated mainly between November and March (Fig. 1) (IPCC, 2007. BNEDER, 2009).

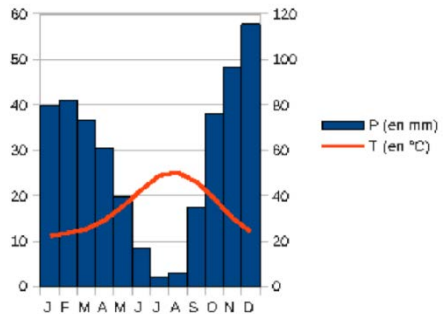

Figure 1 : Umbrothermal diagram based on historical data for the period 1961-1990.
The temperature scale is on the left, the precipitation scale on the right. (IPCC, 2007)

Algiers enjoyed plenty of sunshine throughout the year, particularly during the summer months. Sunny days were frequent, contributing to the overall mildness of the climate. Relative humidity showed significant seasonal variations, with the summer months characterized by relative dryness, while humidity increased during the winter months due to heavier rainfall. In terms of winds, the Algiers region experienced a variety of atmospheric currents, including the "sirocco", a hot, dry wind blowing from the desert to the north, and the "chergui", a hot, dry wind blowing from the east.

According to this diagram, which is typical of a Mediterranean-type climate, annual temperatures and precipitation are clearly moderate, with the following climatic indicators:

- Annual minimum temperatures of 11.8 °C
- Annual maximum temperatures of 23.1°C
- Annual rainfall: 688.8 mm
- Number of days with heavy rainfall: 8.1
- Number of days with the longest drought period: 59.

Based on this data, before the impact of climate change, Algiers and its surroundings enjoyed a balanced Mediterranean climate, characterized by moderate temperatures and well-distributed seasonal rainfall. This climate offered pleasant and relatively stable living conditions throughout the year.

2.2. Peri-urban agriculture in Delly Brahim: Data and physical characteristics

Delly Brahim, a suburb located 10 km west of Algiers (Fig. 2), covers a total area of 7.72 km² and is home to a population of 39,036 (Annuaire Statistique de la Wilaya d'Alger 2020). This peri-urban location offers a diverse landscape potential, with ecological, natural, tourist, and recreational features. Delly Brahim's peri-urban environment is conducive to agriculture, which is essential to local food security and environmental preservation. Agriculture in Delly Brahim is influenced by a variety of factors, including climate, water resources, agricultural policies, and traditional farming practices (POS Delly Brahim, 2020).

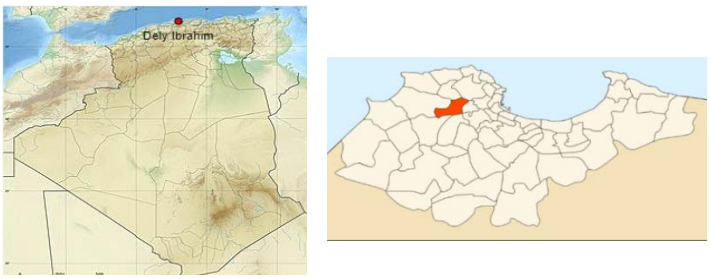

Figure 2: Location of the commune of Delly Brahim in the western suburbs of the capital Algiers. (POS Delly Brahim. 2020)

Thanks to its strategic location, the region has its own specific characteristics and significant potential for growth, thanks to its highly valuable resources (Fig. 3):
- Water resources, natural sites, agricultural potential.
- The exploitation of the "Bois des Cars" and "Caroubier" forests as an economic source.
- The presence of an agri-park "Dounia" as a strategic project for sustainable development.
- An area of trade and regional productivity (trade, tourism ....).

The spatial distribution of this potential is as follows (Fig. 4):
- Agricultural areas are mainly concentrated on the outskirts of the town, with a few scattered plots in residential areas.
- Green spaces are relatively evenly distributed throughout the city, providing breathing and recreational areas for residents.
- There are opportunities to develop urban agriculture in certain densely populated areas (POS Delly Brahim, 2020).

Figure 3: Natural sites and agricultural potential of Dely Brahim. (POS, 2020)

Figure 4: Spatial distribution of agricultural land in Delly Brahim. (POS, 2020)

The history of this former colonial village goes back to an agricultural estate known as the "Zaoui" estate, characterized by various plantations and livestock farms. It was one of the first colonial villages to have an instrument for controlling the regional space (centre), built on the site of the "Haouch Deli-Ibrahim" and officially recognized by a royal decree issued by the Duke of Rovigo on 21 December 1832. This extremely fertile area was renowned for its harvests of top-quality cereals and fodder.

According to our recent interviews detailed below in the methods section, the development of these activities, transmitted by the ancient “Fellahs” families, is currently classified into several categories:

- private urban farms, including the largest at "Ain Allah", which belongs to the former estate of the Zaoui settlers,

- gardens associated with individual or collective housing,

- wasteland gardens,

- agri-parks and forests combining production and leisure farming.

In conclusion, the history of Algiers' climate and the data on peri-urban agriculture in Delly Brahim show a significant dynamic of change over time, requiring in-depth analysis to better understand and optimize their potential. The evolution of agricultural practices, resources, and local policies must be continually assessed to ensure sustainable development and meet contemporary challenges.

2.3. Methods

The following methods have been adopted to explore our ideas and arrive at conclusions, combining agricultural, urban, and climatic data.

- A documentary study providing us with up-to-date data on climate change

- An analysis of climatic hazards in the capital of Algiers based on a reading of the document "Study on the vulnerability and adaptation of the Wilaya of Algiers to climate change and natural hazards" (IPCC, 2007).

- A survey of households, farmers, and local actors considered to be important stakeholders, to understand the attitudes, motivations, and behaviors related to the disasters that have occurred most frequently in the capital of Algiers and the town of Delly Brahim. The aim of this survey is to find ways of mitigating climate change, while at the same time raising awareness of the consequences of this phenomenon. The survey is qualitative in nature, using semi-structured interviews to gather data and understand people's perceptions, strategies, and needs in terms of adaptation.

- Analysis of the data to answer the research questions and meet the survey objectives.

- Communication of results to stakeholders to inform future decisions and actions.

3. Results

3.1. Dynamics of climate change in Algiers and its region

Like many other countries around the world, Algeria is regularly confronted with a variety of devastating climatic events, made even more unpredictable by climate change. As a Mediterranean country, designated by the IPCC as

one of the 24 'hot spots' most sensitive to climate change, the capital of Algiers regularly experiences extreme weather events such as floods, droughts, and forest fires. According to our analyses, the reasons include a variety of climatic, environmental, and socio-economic factors that make the region more susceptible to significant negative impacts as the climate changes.

- Sensitivity to climate change: Algiers is a region where even small variations in climate can have significant impacts on the environment and human societies. Recent experience shows that a slight increase in average temperature or changes in rainfall patterns lead to more frequent and intense droughts, floods, and storms.

- Exposure to climatic hazards: Algiers' geographical location, accentuated by its topography and rapid urbanization, predisposes the region to pronounced climatic variations (Wilaya d'Alger, 2016). The rugged terrain encourages rainwater to run off into low-lying areas, increasing the risk of flooding. Soil sealing due to urbanization reduces water infiltration, and the lack of adequate urban planning and effective drainage systems exacerbates this situation.

- Limited capacity to adapt: Algiers includes areas where the capacity of ecosystems and human societies to adapt to climate change is limited. This is due to insufficient economic resources, inadequate infrastructures, and weak governance systems.

As a result, average annual temperatures have risen over the last few decades, with summers becoming longer and hotter, with more frequent heatwaves, as witnessed by the recent heatwaves in July 2023. At the same time, greater variability in rainfall patterns has been noted, characterized by episodes of intense rainfall alternating with prolonged droughts. Storms, floods, and forest fires also appear to be becoming more frequent and intense in Algiers. In addition, winds such as the sirocco and chergui have been affected by climate change in recent years (MATEV, 2013).

These climatic developments have led to major environmental changes, profoundly affecting the daily lives of people living in urban areas in and around Algiers. Recent interviews with local people have revealed dramatic consequences for their daily lives. The findings highlight a series of devastating impacts, ranging from public health problems to infrastructural damage and growing environmental challenges. These impacts underline the urgent need for concerted action to mitigate these effects and strengthen the resilience of urban communities.

This dynamic climate in the Algiers region means that strategies need to be constantly adapted to meet the new challenges and maximize the region's potential in the face of these changes.

3.2. Lessons from Recent Meteorological Events (ONM) and Mitigation Measures

Faced with extreme weather events in recent decades, the city of Algiers reveals worrying trends in urban vulnerability to climate hazards. This sub-section examines these events to identify key lessons and strategies needed to strengthen the region's climate resilience. It presents a detailed analysis of four types of major climate hazards: intense rainfall, heat waves, droughts, and high winds accompanied by forest fires. Each table provides an overview of the key events, the causes linked to urban development, and the consequences for residents and farmers. Understanding and integrating these lessons into development policies is essential if we are to effectively anticipate and manage future climate risks.

3.2.1. Intense precipitation

Intense rainfall has become a recurring phenomenon in Algiers, leading to sudden and devastating floods. These events are often exacerbated by rapid urbanization and the lack of adequate drainage infrastructure. Flooding caused by heavy rain has a significant impact on urban infrastructure, disrupting transport and damaging homes. This table details the major incidents, their causes, and their effects on the urban population.

Table 1: Intense precipitation

Climate hazard	**Intense precipitation**
Event near Algiers	Flooding on November 9-10, 2001 in Bab-El-Oued (commune west of Algiers) with : - North-easterly flow

	- rainfall of 290 mm in less than 17 hours, well in excess of the cumulative total - 781 dead and 115 missing - 3,271 buildings destroyed or damaged The cost of the disaster is estimated at 5 billion dinars.
Causes linked to urban development (technical actor declarations)	Waterproofing of soils with excessive and inappropriate use of concrete and asphalt in urban areas. Faulty and poorly designed drainage systems Development in flood-prone areas prone to hazards High density and poorly managed urbanization, with 78% of the surface occupied by buildings. Lack of maintenance of stormwater filtration systems
Consequences (statements by citizens and farmers)	Loss of life and material damage Disruption of essential services (water, electricity, supplies, communications, health etc.) Health risks and spread of disease Impact on agricultural livelihoods. Emotional stress and trauma

These floods highlight the devastating impact of poor urban management and rapid urbanization without adequate infrastructure. Soil sealing combined with an inefficient drainage system has exacerbated the effects of intense rainfall, causing considerable loss of life and property. This situation highlights the need for better urban planning and more robust stormwater management systems to reduce vulnerability to flooding.

3.2.2. Heat waves

Heat waves in Algiers are becoming increasingly frequent and intense, putting a strain on public health and urban cooling systems. Prolonged periods of extreme heat increase energy demand for air conditioning, worsen outdoor working conditions, and pose increased risks to vulnerable people, particularly the elderly and children. The following table analyses recent events, their impacts, and possible mitigation measures.

Table 2: Heat waves

Climate hazard	**Heat waves**
Events in and around Algiers	The heat wave of June 2003, lasting 20 consecutive days, was exceptional in terms of its intensity and geographical extent over the entire wilaya of Algiers, with maximum temperatures in excess of 38.7°C, well above normal for more than... The exceptional heat wave of July 2023, with temperatures exceeding 48°C and humidity 80%. Electricity consumption peaks on three consecutive days: 17,508 megawatts (MW) (Sunday 9), 17,905 MW (Monday 10), and 18,377 MW (Tuesday 11) (Sonelgaz, Algiers).
Causes linked to urban development Technical actor declarations	Urban heat islands and excessive accumulation of concrete, asphalt, and other heat-absorbing materials in urban areas Building design without consideration for natural ventilation, adequate shading, and energy efficiency Insufficient green spaces in urban areas
Consequences (statements by citizens and farmers)	Anxiety, exasperation, and a new awareness of climate change Food poisoning and environmental pollution Threats to water supplies and food security for local residents

Recent heatwaves have demonstrated the impact of urban development on the intensity of temperatures in urban areas. The heat islands created by high building density and a lack of green spaces exacerbate already severe conditions, increasing risks to public health and energy consumption. More sustainable urban development strategies, including green spaces and appropriate architectural designs, are needed to mitigate the effects of heat waves.

3.2.3. Drought

Drought is another major climate risk for Algiers, seriously affecting water supplies and agriculture. Prolonged periods without rain reduce the availability of water for irrigation and human consumption, threatening food and economic security. This table explores historical droughts, their underlying causes, and the water management strategies needed to mitigate their effects.

Table 3: Drought

Climate hazard	Drought
Events in and around Algiers	The drought of 1985, when daily precipitation remained below 0.2 mm from June 1 to September 16 inclusive, i.e. 108 days. The drought of 2000, was the driest year on record, with no precipitation greater than or equal to 1 mm from May 26 to September 28 inclusive (126 days). During this period, only two days recorded precipitation between 0.5 and 0.9 mm: July 11 (0.9 mm) and August 4 (0.7 mm).
Causes linked to urban development Technical actor declarations	Inadequate management of water resources aggravates the effects of drought. Some urban developments aggravate drought by altering the water cycle, increasing water demand, and modifying local environmental conditions such as temperature and humidity.
Consequences (statements by citizens and farmers)	Water shortages and crop failure in large parts of the city. Soil degradation, including erosion, salinization, and desertification, reducing the fertility of agricultural land and compromising crop productivity.

The droughts of 1985 and 2000 highlight the impact of climate change on water resources and agriculture. Inefficient water management and certain urban planning practices exacerbated the effects of these droughts, leading to water shortages and a drop in agricultural productivity. Implementing more efficient water management systems and promoting resilient agricultural practices are crucial to mitigating these impacts.

3.2.4. High winds and forest fires

High winds, often accompanied by forest fires, pose a serious threat to the region. Fires, fuelled by windy and dry conditions, can spread rapidly, destroying homes, infrastructure and natural ecosystems. The vulnerability of urban areas adjacent to forests and shortcomings in fire risk management are critical points examined in this table.

Table 4: High winds and forest fires

Climate hazard	High winds and forest fires
Evènement Alger	Several hectares of vegetation spared by the forest fires of the previous two summers were damaged.
Causes linked to urban planning declarations technical actors	Deforestation increases the risk of forest fires by making areas drier and reducing the natural barriers that could limit the spread of fires. These fires have resulted in loss of life, significant material damage, and long-term socio-economic disruption in the affected regions.
Consequences (statements by citizens and farmers)	Destruction of fertile farmland Devastating impacts on local populations, infrastructures, and the economy. Deterioration of air quality and negative impact on respiratory health, Increased levels of air pollution.

These recurring forest fires highlight the consequences of deforestation and poorly planned urbanization. Reduced vegetation cover increases the susceptibility of regions to fire, with severe impacts on agricultural land, air quality, and public health. Reforestation and sustainable land management measures are essential to reduce the risk of fire and protect local communities.

These recent extreme weather events in and around Algiers have revealed a number of alarming trends. Inadequate urban management, including soil sealing and a lack of effective drainage infrastructure, has exacerbated the impacts of intense rainfall and urban heat islands. In addition, recurrent droughts have increased pressure on water resources and compromised agricultural productivity. Forest fires, amplified by deforestation and unplanned urbanization, have also caused considerable economic and environmental losses, affecting local communities and their livelihoods. It is therefore essential to learn from these disasters in order to improve climate risk prevention and management strategies and to strengthen urban infrastructures and natural resource management systems.

3.3. Peri-urban agriculture in Delly Brahim: A solution to mitigate climate hazards

3.3.1. Climate change dynamics and the role of AUP

Compared with historical climate data for the Algiers region before the impact of climate change indicated in section 2.1, the current dynamics at Delly Brahim are characterized by:

- Irregular rainfall and a clearer alternation between two contrasting seasons. The relatively short wet season runs from September to February, with monthly rainfall of between 60 and 140 mm.

- The dry season, which corresponds to summer, is characterized by maximum temperatures in excess of 35°C and relative humidity of 60%.
- Winters, although drier, maintain a relative humidity of 75% and minimum temperatures of around 5°C.
- Current average monthly temperatures vary between 15°C and 27°C, indicating an overall increase and greater variability in rainfall than in past decades (POS Delly Brahim, 2020).

Faced with these changes affecting Delly Brahim, introducing and strengthening urban and peri-urban agriculture is an effective solution as deduced in the discussion in subsection 3.2.3 above. In response to irregular rainfall patterns, rising temperatures, drought, and increased climate variability, AUP offers a number of adaptive advantages as mentioned in the literature review and affirmed by the interviews with the technical actors involved:

- Microclimate regulation: Reduction of heat islands and local temperatures.

- Water management: Improving rainwater infiltration and reducing flooding.

- Carbon sequestration: Absorption of CO2 by plants, reducing greenhouse gases.

- Local production: Reduced food dependency and carbon footprint due to transport.

It is clear from these results that current climate changes are having a significant impact on the region, and introducing and strengthening urban and peri-urban agriculture is proving to be an effective solution.

3.3.2. Socio-economic and environmental concerns of the AUP at Delly Brahim

Our various interviews with the municipality's agricultural services and with the farmers themselves highlighted the importance of the town's agricultural production at three levels: at the municipal level, at the level of the entire wilaya of Algiers, and at the level of the Maghreb. The breakdown of this production by activity is shown in the table below:

Table 5: Types of agricultural activity in Delly Brahim

Activity	Type of Activity	No. of participants
Breeding	Fellah	Family Groups (5 to 7 members/family)
Olive growing	Sales and production	Unemployed youth group (3 to 5 boys/group)
Arboriculture	Additional activity	2 to 3 families per apartment block or 1 to 2 members per family in single-family homes
Plantation	Leisure and production activities	2 to 3 families per apartment block or 1 to 2 members per family in single-family homes
Commercial	Distributeur. Vendeur Transporteur.	25 employers

This data underlines the diversity of agricultural activities and their socio-economic importance, which can take several forms, according to the interview with the agricultural services of the municipality of Delly Brahim:

- Main source of income: For the heir families of the former "Fellahs", these activities represent the main source of income.

- Secondary activities: These provide around 30% of additional income for middle-income families.

- Leisure opportunities: These are particularly popular with pensioners and families for leisure and relaxation.

- Exploitation of natural resources: Young farmers exploit the carob and olive trees, producing 7 tonnes of carob for the international market and 500 liters of olive oil sold locally each season (POS Delly Brahim, 2020).

These activities are not only economic but also make a significant contribution to the landscape, environment, climate, and social aspects of the region. As well as mitigating the effects of climate change, peri-urban agriculture in Delly Brahim enriches the local community by providing jobs, increasing food security, and improving quality of life through a greener, healthier environment showed the study by Barthel and Isendahl (2013) cited above in the literature review in the Introduction chapter.

However, according to the farmers interviewed, climate change is threatening these benefits. Unpredictable variations, such as frequent droughts and erratic rainfall, are jeopardizing the locality's agricultural production. Crops are facing increased water stress, leading to lower yields and reduced crop quality. In addition, extreme weather events such as flash floods damage crops and agricultural infrastructure, jeopardizing food security and the local economy. It is becoming crucial for Delly Brahim to adopt adaptive practices to meet the challenges of climate change and preserve its agriculture, which is vital to the community.

3.4. Strategies for adapting peri-urban agriculture to climate change

To adapt to the effects of climate change, our analysis in the previous chapter on peri-urban agricultural potential in Delly Brahim indicates that several strategies can be implemented. These strategies focus on three main areas:

- Ensuring the preservation and continuity of agricultural activity,

- Improving this activity,

- And ensuring its sustainability.

These measures, in continuity with those presented in section 3.2, offer more specific adaptive proposals and apply to the three types of peri-urban areas of Delly Brahim: the “Bois des Cars” and “Caroubier” forest sites, the Agri-“Dounia” park, as well as the various farms and gardens associated with housing.

3.4.1. The "Bois des Cars" and "Caroubier" forest sites

These forest sites are natural areas characterized by dense and varied vegetation, dominated by tree species such as carob, pine, eucalyptus, and various local species. They play a crucial role in regulating the local climate, preserving biodiversity, and providing essential ecosystem services "In Algeria, as in several Mediterranean countries, the carob tree grows in natural conditions in the wild under bioclimates of sub-humid, semiarid, and arid type It is generally in association with the olive tree and the mastic tree" (Benmahioul et al, 2011). They also provide recreational spaces for the inhabitants of Dely Brahim and the surrounding area, fostering the connection between the urban population and nature. As peri-urban spaces, the two forests are also involved in initiatives to redevelop urban agriculture, helping to adapt to climate change.

As shown in Figure 5, forest sites such as Bois des Cars and Caroubier at Dely Brahim play a crucial role in adaptation to climate problems. The following table details the adaptive measures needed to cope with climate change, highlighting specific strategies and incentives for various crops, including carob, citrus, and olive, as well as for small-scale farming. These initiatives are designed to ensure the preservation, continuity, and sustainability of agriculture, incorporating innovative forest conservation and agroforestry practices.

Figure 5: The Bois des Cars and Caroubier forest sites. (by the Authors)

Table 6: Adaptive measures to climate change: Bois des Cars and Caroubier

Growing	Adaptation strategies	Incentive measures
Carob Citrus Olive trees, Small-scale farming (production of milk and by-products and livestock rearing)	Ensure the preservation and continuity of agricultural activity,	**Define and delimit zones** to protect farmland from urban pressures. **Encourage agroforestry practices** (agriculture and forestry). **Encourage public-private partnerships.**
	Améliorer l'activité agricole	**New innovative forest conservation measures** **Community participation.**
	Ensuring the sustainability of farming	**Development of regenerative agriculture** **Biodiversity protection** to maintain biodiversity zones in and around agricultural areas. **Integration of renewable energy sources.**

This table of adaptive measures for climate change, focusing on the Bois des Cars and Caroubier sites, highlights the importance of targeted strategies to diversify and strengthen agricultural resilience. The combined measures help not only adapt to the impacts of climate change but also promote sustainable and resilient agricultural development.

3.4.2. Agri-Parc « Dounia »

The 165-hectare Agri-parc "Dounia" is a multifunctional space located in Dely Brahim, "the “Dounia Parc” space chosen to house the pilot farm project adopted by the Wilaya of Algiers, saw the launch of the planned development of leisure areas and planting of citrus and olive trees" (BNEDER, 2017). The park combines agricultural, educational, and recreational activities, providing a valuable green zone in the city's peri-urban landscape. This space represents a model of urban and peri-urban agriculture, designed to offer environmental, educational, and social benefits. It represents a key initiative for the city's sustainable development in the face of the challenges of climate change (BNEDER, 2017).

According to the photos, the "Dounia" agricultural park in Delly Brahim illustrates an innovative model of urban and peri-urban agriculture. By combining various agricultural activities, it is a major green space in Algiers' peri-urban landscape. However, to ensure the preservation, continuity, and sustainability of its varied crops, the park requires appropriate adaptive measures. These measures, presented in the table below, represent a proactive response to the challenges posed by climate change.

Figure 6: The "Dounia" Agri-Park or pilot farm. (By the Authors)

Table 7: Adaptive measures to climate change: Agri-Parc « Dounia »

Growing	Adaptation strategies	Incentive measures
Citrus Olive trees, Small-scale farming (production of milk and by-products and livestock rearing)	Ensure the preservation and continuity of agricultural activity,	**Definition and delimitation of zones** to protect farmland from urban pressures.
	Improving agricultural activity	**Choosing climate-resistant crops** **Crop rotation and plant cover** to maintain soil fertility and prevent erosion **Adoption of modern agricultural techniques** (irrigation) **Improved infrastructure** (warehouses, etc.)
	Ensuring the sustainability of farming	**Adoption of agro-ecological practices** that respect the environment **Protection of biodiversity** to maintain biodiversity zones in and around agricultural areas. **Integration of renewable energy sources.**

This table of adaptive measures for climate change within the "Dounia" Agri-Park illustrates the commitment to sustainable urban and peri-urban agriculture in Delly Brahim. By integrating strategies such as protecting farmland, choosing climate-resistant crops, and adopting agroecological practices, the park aims to ensure the preservation and continuity of agricultural activities while enhancing their sustainability in the face of current and future climate challenges.

3.4.3. Farms and gardens associated with housing

The farms and private gardens associated with housing in Dely Brahim date back to the colonial period and are key elements in the region's urban and peri-urban agriculture. They play a crucial role in local food security. By integrating agricultural production and living spaces, they offer a model of urban development adapted to the fertility of the region.

Figure 7: Farming activities on farms and gardens associated with housing. (By the Authors)

By integrating these agricultural practices into the residential environment, the farms and agricultural gardens of Delly Brahim offer a promising model to be encouraged and improved. Table 8 presents adaptive measures for coping with climate change, highlighting specific strategies and incentives for strengthening this type of local agricultural activity.

Table 8: Adaptive measures to climate change: Farms and gardens associated with housing

Growing	Adaptation strategies	Incentive measures
Citrus Olive trees, Small-scale farming (production of milk and by-products and livestock rearing)	Ensure the preservation and continuity of agricultural activity,	**Motivating farmers** with subsidies and low-interest loans. **Tax incentives** to support farmers. **Ongoing training** in sustainable farming practices and land management. **Awareness-raising and communication measures**
	Improving agricultural activity	**Promoting local products** **Facilitating market access**
	Ensuring the sustainability of farming	**Conservation of natural resources** **Efficient use of water** **Crop diversification (mixed farming)**

By integrating agricultural practices into the living environment, the farms and agricultural gardens in Delly Brahim present a model for urban development that is in harmony with the fertility of the region. The strategies proposed, such as financial support, improving agricultural skills, enhancing the value of local products, and promoting sustainable practices, aim to strengthen this agricultural activity in the face of climate challenges. These agricultural zones, characterized by almost permanent land use and extensive and sustainable agricultural activity, complement the agro-forestry production zones and urban interstitial zones. Conservation agriculture in these areas can contribute to a balanced and sustainable development of the urban structure of the city of Delly Brahim.

4. Discussion

This study of strategies for adapting agriculture in urban and peri-urban areas such as Delly Brahim to climate change can help mitigate the environmental and socio-economic impacts caused by this growing global phenomenon. The information generated is crucial for guiding political and personal choices, based on case analyses that take account of the specific features of each region.

Based on the results of the climate change dynamics of Algiers and its region, the discussions highlighted the urgency of adopting a multi-dimensional approach to dealing with the impacts of climate change. Several points specific to Algiers, such as its high population density, difficult topography, and rapid urbanization, require particular attention in the development of mitigation and adaptation strategies:

- Raising awareness and educating local populations about the impacts of climate change is essential if they are to adopt more appropriate behavior. Education can also encourage active participation in mitigation and adaptation initiatives.

- With a high urban density of 4,090 inhabitants per square kilometer, Algiers needs to invest in efficient drainage systems and green spaces to encourage water infiltration. Measures such as soil rehabilitation and the creation of buffer zones could also reduce the city's vulnerability to flooding.

- In the presence of fertile land (Mitidja) around Algiers, our results are leading to the development of a local food policy that supports urban and peri-urban agriculture by encouraging short distribution circuits, farmers' markets, and the consumption of local produce.

To take advantage of recent meteorological events, our results highlight mitigation strategies for better planning and management of existing infrastructures. This includes increasing urban green spaces and adopting pre-existing agricultural practices. At the same time, policy reforms are needed to integrate the climate factor into urban policies in the Algiers region, which is densely populated, with a considerable influx of people from neighboring regions and the rest of Algeria, attracted by its status as the capital. The results of these examples in Algiers confirm the recognized theories of the IPCC and Holling on climate variability and resilience. Nevertheless, our study provides additional details on the measures to be taken and the types of intervention required to meet current and future climate challenges.

One such measure concerns the improvement of peri-urban agriculture, exemplified by the town of Delly Brahim, a suburb of Algiers threatened by climate change. The adaptation strategies and incentive measures resulting from our analyses adopt a series of sustainable agricultural practices to preserve agriculture that is vital to the local community. Depending on the type of site studied, the recommended strategies focus on three main areas: preserving agricultural activity; improving this activity; and ensuring its sustainability through a series of incentives that will increase agricultural resilience and bring lasting benefits to the local community.

A comparison of our results with existing literature confirms that the trends observed in Delly Brahim are representative of regional and global climate dynamics. The proposed adaptation strategies are in line with scientific recommendations for improving the resilience of urban and peri-urban agricultural systems. This integration of the literature review and the dynamics of climate change strengthens the relevance and credibility of our study, providing additional contributions in terms of local empirical data, socio-economic and cultural integration, and proposals for innovative adaptation strategies. These contributions enrich our understanding of the dynamics of climate change and the possible responses in specific contexts, offering applicable and concrete solutions for other regions facing similar challenges.

For example, exploring the socio-economic and cultural dimensions of peri-urban agriculture highlights the importance of the farming traditions inherited from the old 'Fellahs' families. This aspect, little explored in the literature, which focuses mainly on technical and environmental aspects, gives this study a more global perspective on agricultural dynamics.

Similarly, the incentives implemented, such as the promotion of agroforestry practices and the conservation of existing forests and parks, are aligned with the recommendations of the Barthel and Isendahl (2013) study, which suggests that integrated natural resource management and the promotion of agroforestry can strengthen urban resilience in the face of climate change. Our proposals for the demarcation of agricultural zones and the development of regenerative agriculture fit perfectly into this framework. In addition, the promotion of public-private partnerships and the encouragement of agroforestry practices specific to Delly Brahim demonstrate how innovative solutions can be adapted to specific local contexts.

Finally, in line with the scientific literature, this study has immersed itself deeply in the Delly Brahim context, providing a more nuanced and granular understanding of the challenges and opportunities unique to the area. It incorporates empirical data collected directly from farmers and local agricultural services. This qualitative approach enriches the understanding of the real impacts of climate change on farming practices and livelihoods in Delly Brahim.

This compares with the study by Opitz et al (2016), which highlights the importance of urban agriculture for food security and climate change adaptation. Our study enriches this framework by illustrating how traditional agricultural practices and modern innovations can be combined to improve resilience in Delly Brahim. For

example, the establishment of private urban farms and agri-parks shows how specific initiatives can be developed to meet local needs.

To take this further, future research could focus on the requalification of the AUP in Delly Brahim, the effectiveness of agroforestry practices, comparative analysis with Saharan regions, local climate modeling, participatory studies, and the optimization of public policies and partnerships to support sustainable peri-urban agriculture.

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Conflict of interest

The authors declare that there is no competing interest.

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