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Climate Variability and Agricultural Yields in Semi-Arid Mediterranean Zones: A Case Study of Algeria's Cereal Sector

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Abstract

Algeria's cereal production plays a strategic role in ensuring national food security, given its centrality in the population's diet and its impact on import dependency, primarily centered on durum wheat, soft wheat, and barley production. Despite its strategic importance, this sector faces persistent challenges from climatic variability, particularly water scarcity, and structural inefficiencies such as land fragmentation and reliance on rain-fed agriculture. This study provides a comprehensive systemic analysis of Algeria's cereal production within the broader agricultural framework, evaluating the national strategies including heavy subsidies, import dependency, and ongoing efforts towards modernization and climate-smart agriculture. Drawing on recent production data, climatic assessments, and policy reviews, the analysis reveals the fragility of Algeria's cereal self-sufficiency goals amid increasing climate volatility. Key recommendations emphasize accelerating irrigation expansion, adopting drought-resistant seed varieties, and reforming land tenure systems to enhance productivity and resilience. This integrative approach aims to move Algeria from a subsidy-dependent cereal system towards a sustainable and resilient agricultural model, securing long-term food sovereignty in the face of mounting environmental and economic pressures.

Keywords: Algeria, cereal production, food security, climate variability, rain-fed agriculture, agricultural subsidies.

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Introduction

1. Food Security in the Context of Climate Volatility: Challenges, Impacts, and Adaptive Strategies

In a global context marked by increasing climate volatility, food security is becoming a priority and urgent issue for contemporary societies. Climate change is seriously disrupting all the pillars of food security availability, access, utilisation and stability of food resources,by affecting agricultural yields, livestock productivity and fisheries, while exacerbating the frequency and intensity of extreme weather events such as droughts and floods **(FAO, 2023).** These disruptions, which are often more pronounced in developing countries and particularly affect vulnerable populations, lead to food market instability, price increases, and a greater risk of malnutrition and chronic hunger worldwide. Furthermore, this food crisis is compounded by socio-economic and geopolitical factors, including conflicts, ecosystem degradation, and increased competition for natural resources **(Elkhalfi et al., 2025)**. To address these challenges, it is imperative to strengthen the resilience of agri-food systems through the adoption of sustainable agricultural practices, technological innovation, and integrated policies aimed at climate adaptation and reducing inequalities. This holistic framework is essential not only to achieve the Sustainable Development Goals related to zero hunger, but also to ensure global stability and security in a world where climate variability remains a growing threat.

2. Assessing the Vulnerability and Resilience of North Africa's Food Systems in the Face of Climate Variability and Change

Within the fragile ecosystem of North Africa, agricultural challenges are significantly magnified by the region's hyper-arid climate, heavy dependence on food imports, and susceptibility to climate-driven shocks such as prolonged droughts and advancing desertification. The 2022 World Bank report on "Climate and Development in the Middle East and North Africa"unequivocally identifies water scarcity as the most critical threat to the region's economic sustainability and social cohesion . Regional powers including Egypt and Morocco have long implemented comprehensive agricultural modernization and water management strategies to mitigate these pressures **(Affoh et al ., 2022).** Algeria, sharing similar biogeographical and climatic constraints, serves as a pivotal case study of a nation striving to harness its extensive yet limited agricultural potential to achieve greater food sovereignty within this complex regional context. This scenario highlights the urgent need for integrated approaches that address water resource management, climate adaptation, and food security to build resilient agro-ecosystems in North Africa **(Ahmad et al., 2020).**

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3. Strategic Agricultural Transformation in Algeria: Advancing Economic Diversification Beyond Hydrocarbon Dependence

At the national level, Algeria's agricultural sector is characterized by a history of profound structural transformation and significant contemporary strategic urgency. Following the dissolution of the state farm system (Domaines Agricoles Socialistes) in the 1980s and a subsequent liberalization phase, agriculture has been the focus of recurrent national revitalization efforts, notably the Plan National de Développement Agricole (PNDA) **(Mohamed , 2022)** . This initiative is instrumental in aligning the sector with the national imperative to diversify an economy overwhelmingly dependent on hydrocarbon revenues, which account for over 90% of export earnings **(IMF, 2023).** Situated within this post-oil strategic framework, agriculture is positioned as a cornerstone for economic diversification, rural employment generation, and the reduction of Algeria's substantial food import bill exceeding $10 billion annually. The government's strategy, strongly backed by public investments, aims to improve productivity across key crop categories—from staple cereals to high-value date production—to enhance self-sufficiency and buffer the country against international market volatilities. These efforts reflect a broader commitment to modernizing agricultural infrastructure, fostering sustainable resource management, and supporting rural livelihoods in pursuit of long-term economic resilience and food security **(Bertassello et al ., 2023).**

4.Comprehensive Review of Agricultural Policy Evolution and Development Challenges in Algeria

The academic discourse on Algerian agriculture is well-established, encompassing critical analyses of agrarian reforms, institutional evolution, and sectoral performance. Foundational studies by **Boudjelkha & amamra , (2018)** and **Medjagdaoui & Tabet aouel ,(2022)** meticulously document the political economy underlying agricultural transformations since independence. More recent research, often published in journals such as New Medit, delves into key sub-sectors including cereals—highlighted for their persistent import dependency—and the date palm sector, with particular emphasis on the export potential of the Deglet Nour variety. Water resource management emerges as a recurrent theme, with extensive examination of the National Water Plan (Plan National de l'Eau) and the development of desalination infrastructure to address the region's chronic water scarcity. Despite Algeria's significant agricultural potential, the literature converges on the view that structural inefficiencies, such as land fragmentation, climatic variability, and limited technological adoption, continue to constrain sectoral productivity and sustainability. These insights underscore the urgency of policy frameworks that integrate climate resilience, resource optimization, and market diversification to support sustainable agricultural development in Algeria.

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5.Critical Knowledge Gaps and Emerging Research Priorities in Algerian Agricultural Development

Despite substantial existing research on Algerian agriculture, a significant gap remains in the integration of disparate analyses into a cohesive, systemic framework. Most studies tend to isolate specific crop sectors or singular challenges such as water resource management, without sufficiently addressing the interdependencies among key agricultural "corps" within a unified national system **(Lambarraa-Lehnhardt et al ., 2025)**. The literature rarely juxtaposes the state's subsidy-heavy approach aimed at staple cereal self-sufficiency against the market-driven, export-oriented policies supporting horticulture and arboriculture. This fragmented approach obscures the complex synergies, trade-offs, and conflicts that arise from pursuing simultaneously food security and export-led economic growth **(Irfan & Hatice, 2023).** Addressing this gap requires a holistic, interdisciplinary research agenda that reconciles sectoral policy tensions to optimize resource allocation, enhance resilience, and advance sustainable agricultural development in Algeria.

6. Assessing the Persistent Cereal Deficit in Algeria: Structural Challenges and Policy Implications for National Food Security

Algeria continues to face a significant cereal deficit, highlighting persistent vulnerabilities within its agricultural sector. Recent reports indicate that cereal import requirements for the 2024/25 marketing year are projected at approximately 14 million tonnes, representing an 8% increase above previous estimates and underscoring structural insufficiencies in domestic production **(GIEWS, 2025).** Despite efforts to enhance cereal yields,currently averaging 1.8 metric tons per hectare, well below the global average,domestic production remains insufficient to meet national demand, compelling reliance on imports that constitute a critical component of food security strategies **(Eskander&Fankhauser, 2020).** Structural constraints, including limited irrigation coverage, inadequate storage capacity, and the impacts of chronic drought exacerbated by climate change, continue to impede productivity growth. Furthermore, recent land use data reveal that land under cereal cultivation has stagnated around 2.9 million hectares, while yield declines persist, particularly in the western regions affected by recurrent drought **(World Bank, 2024)**. To address these challenges, the government has authorized substantial investment,in excess of 5.8 billion USD for 2026,to modernize the sector, improve yield efficiency, and reduce dependency on imports, yet significant institutional and environmental barriers remain dominant obstacles. Consequently, Algeria's cereal sector exemplifies a broader structural fragility that constrains national food self-sufficiency and resilience amid climate pressures.

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7. Objective of this Article

Therefore, this article aims to fill this gap by providing a comprehensive, systemic analysis of Algeria's five principal crop corps:

a) The Cereal Corps (Strategic Reserve)

b) The Arboriculture Corps (Long-Term Investment)

c) The Market Garden Corps (Domestic Frontline)

d) The Industrial Crop Corps (Economic Diversification)

e) The Forage Crop Corps (Livestock Foundation)

By examining these corps not in isolation but as interconnected components of a national agricultural system, this study will offer a nuanced critique of current policies and propose a more integrated pathway for achieving sustainable food security and economic resilience in Algeria.

1. The Pillars of the Algerian Diet: Cultural Significance and Nutritional Foundations Beyond Mere Sustenance

The Algerian diet is fundamentally based on three primary cereals,durum wheat, bread wheat, and barley,each playing a crucial role that extends beyond nutrition to embed cultural and economic significance **(Chemache et al.,2018)** . These grains serve as essential sources of sustenance while symbolizing historical traditions and regional identity. Durum wheat, central to traditional dishes like couscous, holds economic importance due to its export potential. Bread wheat and barley complement dietary requirements and maintain significant cultural value, particularly in social and familial contexts. Consequently, national agricultural policies reflect the need to balance preservation of traditional consumption with efforts to enhance domestic production and reduce import reliance, ensuring food security and economic resilience **(Hammami et al ., 2022).**

Durum Wheat (Blé Dur): The Cultural Cornerstone : Durum wheat is the undisputed king of Algerian cereals, forming the very bedrock of the national cuisine. It is almost exclusively milled into semolina, which is then transformed into **couscous**, the iconic Friday dish and a powerful symbol of Algerian identity recognized by UNESCO as an Intangible Cultural Heritage of Humanity **(UNESCO, 2020)**. Beyond couscous, durum wheat semolina is essential for making traditional flatbreads like *kesra* and *harcha*, staples in both rural and urban households. This profound cultural significance elevates its production to a matter of strategic national interest. The government's focus on durum wheat is evident in its subsidy programs and procurement strategies. For instance, the Office Interprofessionnel des Céréales (OAIC),

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the state cereals agency, sets guaranteed purchase prices for local durum to incentivize farmers, a policy detailed in **the Ministry of Agriculture's (2022)** Annual Report. Despite these efforts, domestic production, which hovered around 2.1 million tonnes of durum in the 2021/22 season according to USDA **Foreign Agricultural Service (2022)** estimates, fails to meet demand, forcing the OAIC to supplement with imports to ensure a stable supply of semolina for the population.

Soft Wheat (Blé Tendre): The Import-Dependent Staple : In parallel, soft wheat serves as the engine of urban consumption, primarily in the form of the ubiquitous French-style baguette. The consumption of bread is exceptionally high in Algeria, with estimates from the **World Bank (2018)** suggesting it accounts for a significant portion of daily caloric intake. This creates a massive and consistent demand that the domestic agricultural sector has historically been unable to satisfy. Algerian soft wheat production is plagued by lower yields compared to durum, often due to its greater sensitivity to local climatic and soil conditions. Consequently, Algeria consistently ranks among the world's top wheat importers. For example, in the 2022/23 marketing year, Algeria was projected to import 5.5 million tonnes of wheat, predominantly soft wheat, according to **the International Grains Council (2022)**. This heavy reliance on the international market makes the country's food security vulnerable to price shocks and supply chain disruptions, as witnessed during the Ukraine-Russia conflict, which prompted the government to accelerate tenders and seek alternative suppliers.

Barley (Orge): The Dual-Purpose Backbone of Pastoralism : Barley, the third pillar, plays a critical but often overlooked dual role, underpinning both the livestock sector and certain culinary traditions. Its primary function is as a key fodder crop for Algeria's massive sheep population, estimated at over 22 million head **(FAOSTAT, 2020)**. The demand for barley spikes dramatically during periods of drought when natural pastures fail and in the lead-up to major festivals, most notably Eid al-Adha, when millions of sheep are sacrificed. This creates a direct link between barley availability, livestock health, and social stability. While also used in some traditional foods like *bsissa* (a roasted flour mix) and soups, its strategic importance is as an input for the meat and dairy industries. **The Algerian Ministry of Agriculture (2021)** has acknowledged this dependency, with programs aimed at increasing barley yields to reduce fodder imports. The delicate balance was highlighted in 2021 when poor harvests led to increased import volumes for barley, as reported by **Reuters (2021)** in an article on Algeria's tender for animal feed, demonstrating how the barley market is a key indicator of pressure on the national agricultural system.

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2. The Geographic and Climatic Battlefield: Spatial Inequalities and Environmental Pressures in North Africa

Algeria's cereal productivity is fundamentally constrained by ongoing geographic and climatic challenges. The country's most fertile agricultural zones are paradoxically located in areas marked by significant climatic variability. Moreover, entrenched historical land-use practices continue to impose structural obstacles that hinder optimal production efficiency. These combined factors create a complex environment for cereal cultivation that affects yield stability and overall sector performance.

The "Tell" Heartland: A Precarious Breadbasket : Cereal cultivation is overwhelmingly concentrated in the northern regions, specifically the plains of the Tell Atlas and the Hauts Plateaux. This includes the agriculturally critical *wilayas* (provinces) of Sétif, Tiaret, Relizane, and Bordj Bou Arréridj, which are traditionally considered the nation's breadbasket. This zone benefits from a Mediterranean climate, receiving the highest and most reliable rainfall in the country, with average annual precipitation ranging from 400 to 600 mm. However, this reliability is relative. As noted in a **World Bank (2021)** Climate Risk Country Profile for Algeria, the rainfall is highly seasonal and exhibits significant inter-annual variability. The success of the cereal campaign is therefore a direct gamble on the timing and quantity of autumn and spring rains. The National Office of Meteorology (ONM) frequently issues reports on rainfall deficits, such as the one highlighted for the 2020-2021 season, which directly contributed to a harvest of only 2.3 million tonnes, far below government targets.

The Rainfall Dilemma: The High Stakes of Rain-Fed Agriculture : The core vulnerability of the sector stems from the fact that over 95% of Algeria's cereal surface is rain-fed (dépendante de la pluie), as consistently reported in the **Ministry of Agriculture's (2022) Agricultural Statistics.** This lack of irrigation infrastructure leaves the harvest exceptionally vulnerable to climatic shocks. A direct correlation exists between rainfall levels and yield. For instance, the severe drought of 2018-2019 led to a catastrophic harvest of just 1.3 million tonnes, forcing a sharp increase in import spending to over $3 billion that year, according to International Trade Centre data. This event starkly illustrated the direct link between a poor rainy season and national food security. Climate change projections cited by the **FAO (2020)** in its report on "Climate Change and the Cereal Sector in Algeria" suggest an increasing frequency of such droughts and heatwaves, threatening to further depress yields and heighten import dependency.

Soil and Land Fragmentation: The Invisible Constraint : Beyond climate, structural challenges rooted in land tenure severely limit productivity gains. Soil degradation, including erosion and loss of organic matter, is a widespread issue, reducing the inherent fertility of the land **(Renard et al ., 2023).** More critically, land fragmentation is a major impediment.

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Following the dissolution of state farms, land was often divided among heirs through inheritance, leading to a patchwork of small, scattered plots. A study by the Centre de Recherche en Economie Appliquée pour le Développement **(CREAD, 2019)** found that the average farm size in the cereal-growing regions is often less than 15 hectares and fragmented into several non-contiguous parcels. This structure hinders large-scale mechanization, as operating combine harvesters and other efficient machinery on small plots is economically unviable and logistically challenging **(Masud & Khan, 2024)**. It also complicates the adoption of unified soil management practices and precision agriculture, locking many farmers into a cycle of low-input, low-output subsistence farming, despite their proximity to the nation's most productive lands **(Mohseni-Cheraghlou & Evans, 2023)** .

3. National Strategy for Economic Modernization in Algeria: The Role of Subsidies and Import Policies

Facing persistent geographic and climatic challenges, the Algerian state has implemented a comprehensive national strategy. This strategy involves substantial financial support to farmers, a strategic reliance on international markets to offset domestic deficits, and an intensified emphasis on technological modernization to enhance future agricultural production. This multi-faceted approach aims to ensure agricultural resilience, food security, and sustainable development amid environmental constraints.

The Pursuit of Self-Sufficiency: A Strategic Imperative :The overarching goal of Algeria's cereal policy is to achieve a high degree of self-sufficiency, thereby reducing a massive import bill and insulating the country from global market volatilities **(Yahi & Yahyaoui ,2023)**. This objective is formally enshrined in the National Agricultural Plan (Plan Agricole National - PAN), which has been iterated over decades, with the current version aiming to increase domestic cereal production to over 5 million tonnes annually. As stated in a **Ministry of Agriculture (2021)** progress report, this goal is "strategic for national food security." The drive was intensified following the 2007-2008 global food price crisis and the more recent supply chain disruptions from the war in Ukraine, which highlighted the geopolitical risks of import dependency **(Le Mouël et al ., 2023)**.

Heavy-Handed Support: The Subsidy Shield :To incentivize domestic production, the government employs a robust system of subsidies and price supports. The state, primarily through the Office Interprofessionnel des Céréales (OAIC), provides substantial financial support for inputs, including certified seeds, fertilizers, and diesel fuel for agricultural machinery**(Eisenstadt et al ., 2021)**. Crucially, the OAIC acts as a buyer of last resort, guaranteeing a prix d'achat garanti (guaranteed purchase price) for local durum and soft wheat that is often set above international market rates. This system was notably expanded in the 2020 Finance Law, which allocated significant funds to maintain these subsidies despite fiscal

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pressures. While this policy successfully encourages farmer participation and ensures a baseline domestic supply, it places a considerable and recurring burden on the state budget.

The Reliance on Imports: A Structural Dependency : Despite these substantial investments, Algeria consistently imports between 40% and 60% of its cereal consumption, a fact routinely documented in USDA **Foreign Agricultural Service (2023)** Grain Reports. The country is a perennial top-ten global wheat importer, with purchases of soft wheat alone often exceeding 5 million tonnes per year. This dependency was starkly evident in 2022, when, according to Reuters market reports, Algerian state buyers were forced to navigate record-high global prices following the invasion of Ukraine, significantly increasing the national food import bill. This structural reliance means that international price shocks and supply crises directly and immediately impact Algeria's economy and food security posture.

The Modernization Push: A Path to Resilience : Recognizing the limitations of subsidies alone, national strategy is increasingly pivoting towards modernization to build long-term resilience. Key focuses include:

- Expanding Irrigation: The government is actively working to channel water to cereal plains through large-scale projects, such as the transfer of water from the Beni Haroun dam to farming areas in the Setif region. The goal, as per the National Water Plan (2020), is to increase the irrigated cereal area, thereby insulating a portion of the harvest from rainfall variability.
- Improved Seed Varieties: The Institut Technique des Grandes Cultures (ITGC) is central to efforts in developing and distributing drought-resistant and higher-yielding seed varieties. A notable example is the promotion of the "Hiddab" and "Boussalam" durum wheat varieties, bred specifically for better performance under Algerian dryland conditions.
- Conservation Agriculture: There is a growing, though still limited, push for conservation agriculture practices. Supported by **FAO (2022)** pilot projects in areas like Tiaret, these practices—including minimal tillage, soil cover, and crop rotation—are promoted to preserve soil moisture, improve soil health, and enhance water infiltration, making rain-fed farming more sustainable in the face of climate change.

Conclusion

The strategic dynamics shaping Algeria’s cereal production system encapsulates a protracted and multifaceted struggle, defined by a persistent paradox: the critical strategic importance of wheat and barley for national food security is continuously challenged by immutable environmental constraints and entrenched structural inefficiencies. Analytical observations depict a sector founded on tenuous grounds. The Cereal Corps, responsible for providing staple

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dietary components such as couscous, bread, and animal feed, primarily operates within the vulnerable "Tell" region, where reliance on rain-fed agriculture renders production highly susceptible to increasing climatic unpredictability. This geographic and climatic battleground manifests directly in fluctuating rainfall patterns, which are integrally linked to national food security indicators through significant year-to-year yield variability.

In response, the Algerian government has instituted a National Strategy marked by substantial subsidies and guaranteed pricing mechanisms, functioning as essential yet provisional fiscal measures to sustain baseline domestic production and motivate agricultural stakeholders. Nevertheless, this approach has proved to be a temporary palliative rather than a structural reform, as evidenced by the persistent dependency on cereal imports,constituting 40-60% of national requirements, predominantly soft wheat,thereby exposing the country to vulnerabilities arising from global market volatilities and geopolitical disruptions, notably during crises such as the Ukraine conflict.

Consequently, future sectoral resilience and productivity demand a paradigm shift beyond the expansion of subsidy frameworks toward sustained modernization efforts. Key strategic imperatives include:

1.Accelerating the transition from rain-fed to resilient irrigated agriculture by expanding irrigation coverage, completing water transfer projects, and prioritizing water-efficient technologies like drip irrigation for high-value seed cultivation;

2.Scaling the implementation of climate-smart agricultural practices, including drought-resistant cultivars, conservation agriculture, and soil health management—from pilot initiatives to nationwide adoption, supported by strengthened extension services;

3. Addressing structural inefficiencies by promoting land consolidation and cooperative farming models to overcome fragmentation, thereby enabling mechanization and technological integration.

Ultimately, Algeria's pursuit of cereal self-sufficiency transcends agricultural production, intersecting critically with water resource management, economic policy, and climate adaptation. The success of the Cereal Corps hinges on transitioning from subsidy-dependent vulnerability to engineered resilience, ensuring the sustainability and stability of the nation's breadbasket amid escalating environmental and socioeconomic uncertainties.

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