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Cultivating Aloe Vera: An Economic and Environmental Asset in a Changing Climate

Saib Ibtissem, Zeggai Houaria, Nihad Abdelmalek, Nehar Benameur and Azzi Rachid

University of Abou Bekr Belkaid, Tlemcen, Algeria

Abstract

Aloe vera, a member of the Asphodelaceae family, is predominantly used for medicinal, pharmaceutical and cosmetic purposes, but its cultivation is now threatened by climate change. As global demand for this “green gold” keeps growing, extreme heat, unpredictable rainfall, and soil degradation threaten its sustainable expansion. This study examines the impact of climate change on *Aloe vera* production, while also evaluating its industrial consequences and exploring sustainable solutions. *Aloe vera* production is dominated by Mexico, which is the largest producer, and together with other major producers in the Americas, accounts for approximately 81% of the world's supply due to favorable climatic conditions. While nations such as India and China battle heat waves and unseasonal monsoons that reduce yield and quality of gel. The U.S. and Canada also rely on greenhouse technology to protect production from climate risk. Whereas Algeria, where this plant is known for its traditional use, shows potential as an untapped climate-resilient desert farming. As climate change triggers droughts and temperature fluctuations, the bioactive compounds are reduced in the *Aloe vera* resulting in altering the global supply chain that will affect pharmaceutical and cosmetic industries. The market analysis indicates an increasing demand, with the *Aloe vera* extract industry estimated at $2.99 billion by 2031. However, there are economic dangers associated with growing costs and unstable production. For these challenges, this study proposes sustainable alternatives like drought-resistant *Aloe vera* varieties, greenhouse farming, and advanced irrigation systems. Additionally, Algeria could use its vast desert regions to develop a climate-resilient *Aloe vera* industry.

Keywords: Algeria, *Aloe vera*, climate change, drought resistance, desert agriculture, greenhouse farming, sustainable solutions.

Introduction

Aloe vera L. (*syn*. *Aloe barbadensis Miller*), is a species from Asphodelaceae family, one of the most widely used medicinal plants, valued for its vast potential uses for the plant by the pharmaceutical, cosmetic, and nutraceutical industries. The gel or mucilage is greatly demanded due to its abundance in bioactive compounds such as polysaccharides, phenolic compounds and anthraquinones, and it was found to demonstrate promising wound-healing through antioxidant and anti-inflammatory activities (Eshun & He, 2004; Hamman, 2008). The *Aloe vera* global marketplace achieved USD 2.4 billion in 2019 and is expected to reach USD 3.2 billion by 2027, which demonstrates a fast-developing global marketplace (Majeed et al., 2024).

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Yet, as demand continues to expand, cultivation of *Aloe vera* is under increasing threats from climatic fluctuations. Rising temperatures, frequent droughts, unpredictable rainfall, and soil erosion pose risks not only to plant productivity but also to the composition and quality of the bioactive compounds that define the plant's industrial value (Delatorre-Castillo et al., 2022; González-Delgado et al., 2023; Kumar et al., 2017). Mexico and the Americas are among the world's key producers; other regions like India and China are projected to become more susceptible not only to heat waves but also unseasonal monsoons (López-Cervantes et al., 2018; Singh et al., 2021). This has raised concern over supply chain security and sustainability of *Aloe vera* production.

Such declines in productivity have real-time implications for cosmetics and drug industries from which *Aloe vera* is an essential raw material. Rising production expenses, declining gel quality, and fluctuations in marketplace conditions in several nations are already changing international trade regimes (Liontakis & Tzouramani, 2016; Sadiq et al., 2022; Thakur et al., 2023). They highlight the importance of sustainable agribusiness practices.

Against this backdrop of growing international and industrial demand for *Aloe vera*, this review addresses key knowledge and production gaps. Most of the earlier research has focused on the pharmacological activity and phytochemical composition of the plant, in particular its acemannan content and antioxidant activity (Hamman, 2008; Kumar et al., 2019). However, there have been few studies specifically connecting climate variability and *Aloe vera* productivity and stability in bioactive compounds, thus generating very wide knowledge gaps.

Therefore, the present review attempts to analyze worldwide trends and geographical variations in *Aloe vera* production, to evaluate climate change effects on its productivity and growth, and to analyze the potential industrial and economic consequences of decreased production. Furthermore, it addresses sustainable measures to minimize climate-related risks, with particular emphasis on Algeria's potential as a future climate-resilient producer.

Global Aloe Vera Production and Regional Variations

Average annual *Aloe vera* production globally is calculated to be roughly 60,720,400 kg (Planetoscope, 2015), and global consumption was 60,720 tons in 2015 (~1.92 kg/s) (Planetoscope, 2015). Consumption continues to rise due to application in pharmaceuticals, cosmetics, and food industries. Table 1 summarizes the main producing regions, cultivated areas, and production challenges.

Table 1

Global Aloe vera production, cultivated area, and regional challenges

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Region	Country	Production (tons/year)	Area (ha)	Key Notes/Challenges
Americas	Mexico	158,000 (ActuLatino, 2021)	12,500	Semi-arid climate favorable; risks from recurrent droughts and heat waves above 35 °C
	United States	>32,000,000 (Forever Living, 2023)	>1,000	Industrial-scale, advanced processing; water shortages require greenhouse production
	Dominican Republic	Large-scale plantations (>2,000 ha) (Forever Living, 2023)	n/a	Export-oriented production
Asia	India	~100,000 (Interfresh, 2023)	50,000	Organic growth; vulnerable to unusual monsoons and heat waves
	China	~80,000 (Interfresh, 2023)	30,000	Concentrated in Yunnan, Guangdong, Fujian; humidity fosters fungal disease
	Thailand	~25,000 (Interfresh, 2023)	12,000	Warm, humid climate promotes growth but also fungal infections
Europe	Spain	~20,000 (Interfresh, 2023)	10,000	Canary Islands & Andalusia; niche, high-quality production
	Italy	n/a	160	Small-scale, focus on quality
Africa	Morocco	n/a (~120,000 ha) (ADA-ChababAgri, 2023)	120,000	Sidi Ifni ~30% production, mainly for cosmetics
	Algeria	n/a (author's estimate, based on climatic similarity with Mexico)	n/a	High potential in Sahara; limited by data, investment, and stress
	South Africa	15,000 (Interfresh, 2023)	8,000	Favorable warm climate; erratic rainfall reduces yield

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Region	Country	Production (tons/year)	Area (ha)	Key Notes/Challenges
Other	Canada	n/a	n/a	Greenhouse production only; small-scale, pharmaceutical-grade

Note. Data compiled from Planetoscope (2015), ActuLatino (2021), Aranda Cuevas et al. (2016), Interfresh (2023), Forever Living (2023), and ADA-ChababAgri (2023).

Regional Distribution

Americas. The Americas generate almost 81% of all *Aloe vera* grown in the world (ActuLatino, 2021).

Mexico. Leading producer with 12,500 ha under cultivation, yielding 158,000 tons/year. Main producing states are Veracruz, Yucatán, and Tamaulipas (4,250 ha) (ActuLatino, 2021). The semi-arid climate (18–35 °C) and sandy-calcareous soils favor growth, though recurrent droughts and heat waves above 35 °C pose risks (ActuLatino, 2021). In Yucatán specifically, 1,019 ha of plantations produced 3,944.06 tons in 2007 (Aranda Cuevas et al., 2016). Average yields reach 21–22 tons/ha (ActuLatino, 2021).

United States. Mainly in Texas and California, via industrial-scale production and advanced processing technology. Forever Living Products has >1,000 ha in Texas and produces >32 million kg *Aloe vera* annually (Forever Living, 2023). Water shortage determines greenhouse agriculture and precision irrigation.

Dominican Republic. Big plantations by Forever Living Products (larger than 2,000 ha), exporting (Forever Living, 2023).

Asia

India. Rapidly increasing organic *Aloe vera* production with ~100,000 tons from 50,000 ha. Unusual monsoons and strong heat waves (>40 °C) can reduce gel content in leaves and medicinal grade (Interfresh, 2023).

China. These yields ~80,000 tons from 30,000 ha, and it is highly concentrated in Yunnan, Guangdong, and Fujian. Both domestic and export use are rising, although high humidity fosters fungal disease and excess summer heat affects gel stability. Planting investments include controlled watering and heat tolerance (Interfresh, 2023).

Thailand. Produces ~25,000 tons from 12,000 ha, largely in central and north areas. The tropical environment with warm weather and high humidity promotes development but intensifies disease susceptibility to fungal infections (Interfresh, 2023).

Europe

Spain. Produces ~20,000 tons from 10,000 ha, largely in Canary Islands and Andalusia. Subtropical in Canary Islands and Mediterranean climate in Andalusia support niche, high-quality production (Interfresh, 2023).

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Italy. ~100 farm (160 ha), quality over large quantities (Interfresh, 2023).

Africa

Morocco: Over 120,000 ha, Sidi Ifni contributing about 30% production, mostly for cosmetics and spa exports (ADA-ChababAgri, 2023).

Algeria: Good prospects, especially in Sahara where climatic conditions and soils resemble Mexico. Underdeveloped production due to limited data, insufficient investment, and climatic stress. Greenhouses and sprinkler or drip irrigation can open industrial production prospects (author's estimate, on climatic similarity with Mexico).

South Africa: Estimated to produce ~15,000 tons from 8,000 ha, principally in Eastern Cape and KwaZulu-Natal. The climate is warmer than typically would be assumed but low rain fall creates variation in yields; however, sunny and/or warm provides good drainage and production potential (Interfresh, 2023).

Canada

Aloe vera is a subtropical and tropical species, and its large-scale cultivation is typically concentrated in warmer regions. While innovative uses of *Aloe vera*, such as its application as a scaffold in tissue engineering and food products, are being explored internationally, there is no evidence in the current literature of significant commercial *Aloe vera* farming or industrial-scale production in Canada (Gome et al., 2025). This suggests that, in Canada, *Aloe vera* is likely produced on a small scale, possibly in greenhouses or as specialty crops, rather than as a major agricultural commodity.

Table 2

Aloe vera research focus and production context in Canada.

Focus Area	Key Insights	Citations
Medicinal/Biomedical Use	Extensive research on health and therapeutic applications	Kumar et al., 2019; Gao et al., 2018; Sánchez et al., 2020
Agricultural Production	No direct evidence of large-scale production in Canada	Gome et al., 2025
Industrial Applications	Innovative uses in food and tissue engineering, not specific to Canada	Gome et al., 2025

Note. These papers were sourced and synthesized using Consensus, an AI-powered search engine for research. Try it at https://consensus.app

Climate Change Impacts on Growth and Phytochemistry

Physiological and Agronomic Effects

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Optimal Growth Conditions. *Aloe vera* prefers in warm conditions with humidity and temperatures between 20–38 °C. Growth is impaired below 20 °C, stops near 10 °C, and tissue harm occurs below 0 °C. Well-draining soils and moderate rainfall are preferred by the plant (Rodríguez-García et al., 2007).

Increased Temperatures (>40 °C). Reduce gel content and inhibit phytochemical compounds by directly lowering medicinal and phytochemical activity (Rodríguez-García et al., 2007).

Drought Stress. Limits the size of leaves, moisture levels, and polysaccharide production resulting in poorer gel quality and fewer antioxidant compounds (Rodríguez-García et al., 2007).

Desertification & Rainfall Irregularities. Defoliation, plus irregular rainfall patterns are impediments to phytochemical production and leaf renewal (González-Hernández et al., 2022).

Phytochemical Composition and Antioxidant Potential

Impact of Climate Zone. *Aloe vera* methanolic extracts from highland and semi-arid climatic zones consistently showed higher antioxidant activity and total phenolic content (TPC) than temperate climatic zones with tropical circumstances. This would suggest that stress effects are responsible for increased phytochemical synthesis, for example, phenols, flavonoids, saponins, alkaloids, and terpenes (Kumar et al., 2017).

Correlation of TPC to Antioxidant Activity. There were positive high relationships of TPC with good antioxidant activity in several assays (DPPH, metal chelating, hydrogen peroxide scavenging, reducing power and β-carotene-linoleic acid assay) (Kumar et al., 2017).

Mechanisms of Actions. Antioxidant activity serves to protect against oxidative stress due to free radical scavenging by reactive oxygen species (ROS), electron donation of free radicals, and metal chelation (Kumar et al., 2017).

Global Biodiversity and Distribution Risks

Habitat loss. MaxEnt modeling in Ethiopia indicates that suitable habitats for *Aloe vera* will shrink considerably from 2050–2070 with increased fragmentation (Hussein & Workeneh, 2021).

Major Climatic Variables. Reduced maximum monthly temperatures and less annual rainfall are most vital variables determining *Aloe vera* distribution (Hussein & Workeneh, 2021).

Regional Extinction Threat. If climate change intensifies, *Aloe vera* could suffer regional extinction in East Africa's vulnerable areas (Hussein & Workeneh, 2021).

Climate Role of Aloe Vera

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Aloe vera provides benefit to CO² absorption with ability to increase humidity in closed areas and outperformed many species (Rodríguez-García et al., 2007; Shishegaran et al., 2020).

Demonstrated ability to decrease CO² concentration by ~487 ppm across 8- hour cycles with little secondary release (Rodríguez-García et al., 2007; Shishegaran et al., 2020).

Therefore, *Aloe vera* shows to be both negatively impacted by climate change (stress and habitat loss) and utilized as remediation to offset climate change (carbon sequestration capacity).

Industrial and Economic Consequences of Declining Aloe Vera Yields:
Decreasing *Aloe vera* production has both short-run and longer-run implications for industrial markets that are dependent upon this produce—primarily cosmetics, pharmaceuticals, and nutritional supplements. Two interrelated themes are of highest relevance to understand: (a) market size and trend patterns regulating demand as well as price setting, and (b) economic risks involved whenever production becomes uncertain or becomes costlier.

Market Size and Trends

Global *Aloe vera* extract and finished-product demand has continued increasing during the last several years, influenced by rising interest in natural products. In 2019, *Aloe vera* leaf processors generated about USD 2.4 billion, projected to surpass USD 3.2 billion in the near future (Majeed et al., 2024). the most recently reported estimates of the global *Aloe vera* extract market value at USD 2.06 billion in 2023 and is projected to grow to USD 3.79 billion by 2030 (Grand View Research, 2023). Similarly, Mordor Intelligence (2023) stated that the *Aloe* extract market would reach USD 3.14 billion by 2025, growing at ~8.9% CAGR. An academic study reported the global market valuation of *Aloe* at USD 2.65 billion in 2023, and forecasts USD 2.86 billion in 2024 (Krupa et al., 2025). These forecasts emphasize the economic importance of maintaining a stable and quality-uniform raw material supply base for processors and end-product owners.

Risks of Unstable Production and Rising Costs

When *Aloe vera* is made intermittently—due to drought, heat, too much rain, or soil erosion—industries that depend on its face a number of associated risks:

Supply shortages and volatility. Unforeseen or lower yields lead to raw material deficits in certain regions or periods. These deficits increase prices in spot markets and force processors to find substitute suppliers or mix lots of varying quality. Field observations (Mittal, 2024; Thakur et al., 2023) demonstrate how rising input costs and falling yields reduce farmers' profit margins and decrease local supply guarantee.

Reduced quality and higher processing cost. Climate stresses do not only decrease the crop yield but also modify the chemical composition of the plant (e.g., phenolic composition or polysaccharide content). These changes lead to degraded gel quality as

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well as pharmaceutically or high-end cosmetic product acceptability (Liontakis & Tzouramani, 2016).

Vulnerability in the value chain and concentration risks. Due to the fact that global *Aloe vera* supply is focused in some regions, regional climate shocks have disproportionate effects on global supply chains. Profitability and field studies (e.g., Saiyem, 2020; Mittal, 2024) shows that many farmers lack access to reliable storage, processing, and markets, making them vulnerable to both climate and market risks.

Socio-economic impacts. Fluctuating and declining agricultural revenues have spillover consequences into wider community effects—reduced farm investment and impaired total supply resilience. Local studies show that many farmers face limited margins and are challenged by structural constraints (e.g., costly inputs, limited availability of planting material, and lack of marketing infrastructure), which increase producers' and supply chains' vulnerability (Thakur et al., 2023; Mittal, 2024).

Table 3

Industrial and economic effects of reduced Aloe vera yields in selected regions.

Region / Country	Main Issue Reported	Industrial / Market Effect	Reference
India	Rising input costs and water scarcity reduce profitability at farm level	Lower supply reliability for processors; increased spot-market prices	Saiyem, 2020 ; Mittal, 2024
Mexico	Climate extremes (heat waves, drought) disrupt large-scale production	Volatility in gel exports; risk of global price shocks	Thakur et al., 2023
Greece (EU)	Climate-induced gel quality reduction (polysaccharides, phenolics)	Higher processing costs to meet cosmetic/pharma standards	Liontakis & Tzouramani, 2016
Global (Industry forecast)	Rising demand vs. unstable supply	Increased risk of concentration, vertical integration by large firms	Grand View Research, 2023; Fortune Business Insights, 2025

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Industry and Policy Implications

For businesses, declining yields justify investments in geographical diversification of supplies, traceability, and supplier support programs. Governments can reduce risks by subsidizing irrigation, greenhouse deployment, and processing plants. Certification systems such as organic or fair-trade and market differentiation (premium extracts vs commodity gel) can enhance resilience and sustainability of *Aloe vera* supply chains (Grand View Research, 2023; Liontakis & Tzouramani, 2016; Mordor Intelligence, 2023).

Sustainable Cultivation Strategies for Climate-Resilient Aloe Vera Production

To guarantee the long-term sustainability of production, a combination of climate-resilient agronomic techniques, innovative technologies, and socio-economic initiatives has to be adopted. Many of these methods were suggested and validated as a means of reducing the negative effects of climate change while enhancing yield, gel quality, and general resilience.

Genetic and Physiological Adaptability

Genomic studies discovered that *Aloe vera* possesses specific mechanisms of withstanding drought stress through CAM (Crassulacean Acid Metabolism) photosynthesis and high-level production of osmoprotectants (Jaiswal, 2021). These findings highlight the potential of developing better cultivars with high-levels of drought and salt tolerance through breeding and biotechnology techniques involving marker-assisted breeding and tissue culture techniques of mass-scale multiplication.

Water Management and Irrigation

Optimized irrigation is crucial for productivity. Recent studies have demonstrated that controlled deficit irrigation with optimum planting geometry significantly enhances water-use efficiency and yield (Singh 2021). Similarly, utilization of saline water during irrigation has produced a high volume of the material of bioactive compounds with a slight yield deterioration, revealing that *Aloe vera* may tolerate non-conventional water sources such as brackish water (Souguir, 2015).

Propagation and Agronomic Practices

Methods of propagation are paramount in obtaining bulk and sustainable production of *Aloe* (Cristiano, 2016) also highlighted sucker propagation, planting layout and distance, and land preparation, in initiating improved establishment and ultimate long-term productivity. Micropropagation and tissue culture are also effective alternatives towards obtaining standardized and pathogen-free planting materials, particularly during bulk production at a business level.

Controlled Environments and Protected Cultivation

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Integration of controlled environments such as greenhouses can buffer *Aloe vera* from climatic fluctuations. Integration of photovoltaic systems at the time of greenhouse establishment has been elaborated upon by (Kavga, 2024) as raising energy efficiency besides offering good microclimatic conditions suitable for *Aloe* production. Inexpensive shading nets and hydroponic or semi-hydroponic systems could also offer alternatives under heat-stress or desert conditions, particularly among emerging producers such as Algeria.

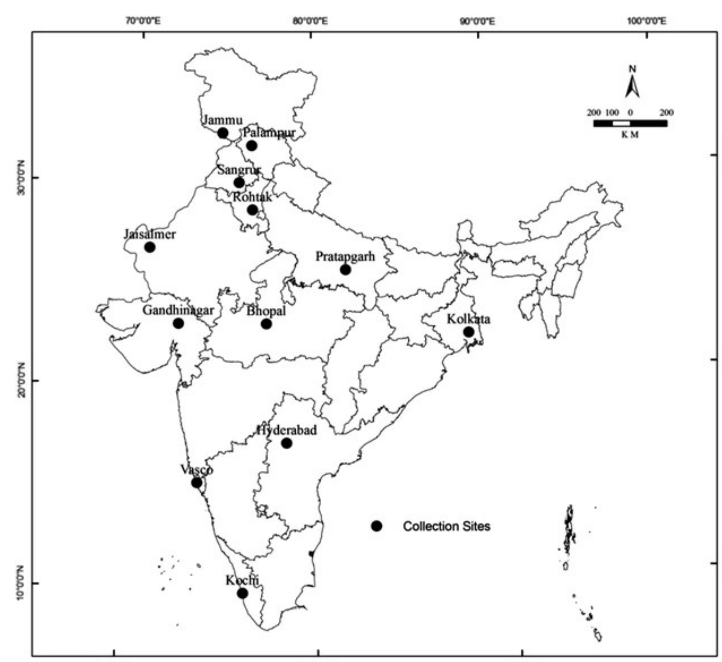
Socio-Economic and Policy Perspectives

Apart from agronomic practices, sustainable production of *Aloe vera* requires favorable socio-economic systems. Value-creating certification schemes such as organic or fair-trade labeling can improve *Aloe* commodities and promote responsible sourcing (Lee, 2025). Government initiatives toward promoting desert agriculture, particularly in North Africa, could improve the resilience of value chains and present new opportunities for rural livelihoods (Hssaisoune et al., 2020).

Integratively, sustainable *Aloe vera* cultivation requires genetic improvement, efficient use of water, innovative production systems, and socio-economic programs. Only with an integrated approach will future productivity under climatic changes as well as the sustainability of the cosmetic, pharmaceutical, and nutraceutical industries dependent upon this "green gold" also become secured (Cristiano, 2016; Jaiswal, 2021; Lee, 2025).

Figure 1

Showing different collection sites from 6 agro-climatic zones of India



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Note. Adapted from Effect of climate change on phytochemical diversity, total phenolic content and in vitro antioxidant activity of *Aloe vera (L.) Burm.f*, by Yadav, P., Singh, A., & Kumar, R., 2017, Journal of Applied Research on Medicinal and Aromatic Plants, 5(3), 45–52.

Algeria as a Potential Climate-Resilient Producer

Algeria is characterized by semi-arid conditions with high temperatures and low, irregular rainfall, conditions not ideally suited for most native crops (Hssaisoune et al., 2020; Meddi et al., 2013). Therefore, *Aloe vera* emerges as a strategic and ideal crop due to its drought resilience and low watering requirements, making it naturally apt to flourish in Algerian conditions (Hamman, 2008; Surjushe et al., 2008). Recent studies in western Algeria confirm that *Aloe vera* performs well under semi-arid conditions, producing high gel yields (≈40.4%) with good quality and antimicrobial activity (Fedoul et al., 2022).

Availability of Marginal Land

Algeria contains extensive areas of marginal land that cannot compete with food crops for high-quality agricultural ground due to soil suitability or salinity. These lands present a guaranteed opportunity to cultivate *Aloe vera* without competing with staple crops, transforming underutilized resources into valuable economic potential (Fedoul et al., 2022).

Economic Opportunities

Aloe vera has the potential for increased economic activity because of escalating global interest in it, a result of its commercial applications and many value-added uses as a food, pharmaceutical, and cosmetic product (Fedoul et al., 2022; Liontakis & Tzouramani, 2016). Thus, Algeria stands to invest in developing small and medium-scale processing units with opportunities in domestic marketing and exporting to international markets. Moreover, successful greenhouse expansion in Biskra—enabled by government policy support and PNDA financing—illustrates that Algeria can leverage marginal and arid lands for profitable agribusiness ventures (Aidat et al., 2023).

Sustainable Practices for Long-Term Viability

For achieving the sustainability and survival of this business, it is critical to take intelligent choices based on modern methods (Aidat et al., 2023; Hu, 2020). They include water-efficient drip irrigation systems, promotion of agricultural cooperatives to build pools for joint use of resources, and promotion of scientific studies in the region for developing *Aloe vera* varieties best suited for Algeria's specific climatic conditions.

Aloe vera (*Aloe barbadensis Miller*) is cultivated in Algeria, particularly in regions such as Ghardaïa, where the plant is valued for its medicinal and biological properties. Studies of *Aloe vera* grown in Berriane (Ghardaïa) have demonstrated that the gel extract contains a variety of phytochemicals, including phenols, flavonoids, tannins, alkaloids, saponins,

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and terpenoids, which contribute to its antioxidant and antimicrobial activities. These findings highlight the potential of locally produced *Aloe vera* as a source of natural bioactive compounds for therapeutic use and suggest that the plant is well-adapted to Algerian agro-climatic conditions. Ethnobotanical surveys in northeastern Algeria (Constantine and Mila) further confirm the traditional use of *Aloe* species, especially for treating skin diseases, reflecting both the cultural significance and the practical value of *Aloe vera* production in the country. The high fidelity level reported for *Aloe* sp. in these regions underscores its importance in local folk medicine and supports ongoing interest in its cultivation and utilization for health-related applications (Khane et al., 2022; Ouelbani et al., 2016).

Discussion

A Critical Perspective

The synthesis of findings across subsections suggests that *Aloe vera* is an exceptionally resilient plant when exposed to climate stress, through CAM photosynthesis and osmoprotectant production (Souguir, 2015). Although controlled environments using water-efficient cropping practices show promise (Mittal, 2024), the socio-economic and policy aspects remain underexplored. Most of the research has focused primarily on physiological and agronomic aspects with relatively few addressing long-term scaling or sustainability (Saiyem, 2020).

Regional Differences

Evidence from the literature demonstrates that there are pronounced regional differences in *Aloe vera* production practice and resilience. In India, controlled irrigation and optimized planting geometry significantly improved yields (Singh, 2021), while in Greece, climate-induced changes in gel phytochemistry required higher-priced processing adjustments (Liontakis & Tzouramani, 2016). Mexico, with its large-scale export orientation, remains highly exposed to price volatility during drought years (Pedroza-Sandoval et al., 2022). Algeria's semi-arid environments offer unique opportunity to produce *Aloe vera* with high value phytochemical characteristics (Fedoul et al., 2022). By contrast, tropical producers with higher rainfall would struggle to achieve high quality gel production. These differing regional challenges highlight localized contexts and strategies needed for sustainable production (Fedoul et al., 2022; Thakur et al., 2023; Surjushe et al., 2008).

Strengths and Weaknesses

The existing studies provide valuable evidence on *Aloe vera*'s physiological resilience and associated phytochemical diversity (Souguir, 2015), highlighting its potential contribution to carbon sequestration at scale. However, limitations remain, including the lack of long-term resilience assessments, insufficient socio-economic data from North Africa, and limited integration of biotechnology into practice (Jaiswal, 2021). Moreover, there is a lack of multi-disciplinary approaches (agronomy, economics and climate

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modelling) that would enable enough collective knowledge in understanding *Aloe vera* as a crop (Saiyem, 2020).

Future Research Directions

Future research should prioritize biotechnology options including marker-assisted selection and tissue culture for drought- and salt-tolerant cultivars (Jaiswal, 2021). The study of controlled-environment systems will yield practical local enhancements, including greenhouse-photovoltaic systems, particularly in arid regions of North Africa (Hssaisoune et al., 2020). Socio-economic studies on cooperative models, certification systems, and equitable policy distribution could strengthen value-chain resilience (Saiyem, 2020). In conclusion, *Aloe vera* should not be viewed as one common plant but as one exciting agribusiness opportunity. It presents a practical model for climate-resilient agriculture that would greatly benefit Algeria's agricultural and economic security by transforming environmental constraints into authentic developmental opportunities (Aidat et al., 2023; Hssaisoune et al., 2020).

Conclusion

Aloe vera stands out as a unique crop that embodies both sensitivity and resilience in the face of climate stressors. Its ability to endure drought, coupled with its economic significance in the global bioproduct market, positions *Aloe vera* as a valuable asset for sustainable land management, particularly in regions like Algeria. This plant not only exemplifies how environmental challenges can be transformed into opportunities for economic and ecological resilience, but it also serves as a model for sustainable agriculture.

Aloe vera's adaptive mechanisms, including the increased production of bioactive compounds and its genetic traits that confer drought tolerance, enhance its survival under challenging conditions. These traits allow the plant to thrive despite the adverse effects of salinity and temperature extremes. However, it is essential to recognize that severe or combined stresses can still hinder its growth and photosynthesis, underscoring the crop's vulnerability amidst escalating climate pressures.

Ultimately, *Aloe vera* represents a promising pathway for developing resilient agricultural systems that can withstand climate variability while contributing to economic sustainability. Its cultivation could play a crucial role in promoting environmental stewardship and improving livelihoods in regions facing significant climate challenges.

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Author Notes

Saib Ibtissem is affiliated with the Department of Biology, Faculty of Natural Sciences, Life, Earth and Universe Sciences, University of Tlemcen, Algeria. She is a Master's

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student in Applied Biochemistry at University of Tlemcen, Algeria – Faculty of Natural and Life Sciences, Department of Biology. Her current research focuses on medicinal plants, with particular emphasis on the biochemical characterization of Aloe vera and the impact of climate variability on its antioxidant and antimicrobial properties. Her work explores how environmental stress influences the stability of bioactive compounds, with the aim of contributing to sustainable industrial applications in the pharmaceutical, cosmetic, and food industry.

Zeggai Houaria is affiliated with the Department of Biology, Faculty of Natural Sciences, Life, Earth and Universe Sciences, University of Tlemcen, Algeria. She is a Master's student in Applied Biochemistry at the University of Tlemcen, Algeria – Faculty of Natural and Life Sciences, Department of Biology. Her research is centered on medicinal plants, with a focus on Aloe vera. She investigates how climate variability influences its biochemical composition, particularly its antioxidant and antimicrobial properties. Through this work, she aims to contribute to the sustainable development of Aloe vera applications in the pharmaceutical and cosmetic sectors.

Abdelmalek Nihad is affiliated with the Department of Biology, Faculty of Natural Sciences, Life, Earth and Universe Sciences, University of Tlemcen, Algeria. She is a Master's student in Applied Biochemistry at the University of Tlemcen, Algeria – Faculty of Natural and Life Sciences, Department of Biology. Her research explores the resilience of medicinal plants under environmental stress, with a specific focus on how climate variability alters the phytochemical profile and bioactivity of Aloe vera gel. She aims to contribute to developing sustainable sourcing strategies for the plant's valuable compounds in the cosmetic and pharmaceutical industries.

Azzi Rachid is affiliated with Laboratory of Antibiotics Antifungal Laboratory, Physical-Chemistry, Synthesis and Biological Activity, Department of Biology, Faculty of Natural Sciences, Life, Earth and Universe Sciences, University of Tlemcen, Algeria. He is a holder of a Doctorate in Biochemistry, he conducts his research in the field of medical biochemistry and medicinal plants, with a particular interest in bioactive molecules and their therapeutic applications. Currently Professor and Teacher-Researcher in biology, Biochemistry option, at University of Tlemcen. He leads Team 4 of Laboratory, which focuses on research into the biological activity of local flora. His scientific interests encompass biochemistry and medical biochemistry, with a particular focus on medicinal plants and bioactive molecules. His work is part of an interdisciplinary approach that combines chemical, biological, and pharmaceutical aspects to evaluate the therapeutic potential of natural compounds.

Nehar Benameur is affiliated with the Laboratory of Functional Agroecosystems and Agronomic Sector Technologies, Department of Biology, Faculty of Natural Sciences, Life, Earth and Universe Sciences, University of Tlemcen, Algeria. Associate professor actively involved in international research collaborations, including The Global environmental exchange program in partnership with East Carolina University (USA). His work focuses on environmental management and biological studies of water systems, with ongoing interests in aquatic ecosystems, database integration, and sustainable

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environmental practices SDGs. Over 14 years of experience with companies, universities in teaching and researching topics related to natural resources, ecology, green skills, sustainability, and renewable energy. His mission is to educate the next generation on environmental sustainability and equip them with the knowledge and skills needed to build a more sustainable future.