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Expanding Coffee Cultivation beyond Traditional Boundaries: Challenges, Innovations, and Sustainability in Non-Traditional Regions: A Review

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ABSTRACT

Coffee production has traditionally thrived within the confines of the equatorial Coffee Belt, yet recent climatic shifts and evolving market dynamics are pushing the boundaries of where coffee can be successfully cultivated. This review synthesizes current research on the expansion of coffee cultivation into non-traditional regions, highlighting the interrelated challenges and opportunities that accompany this transition. Climate change, manifested through rising temperatures and altered precipitation patterns, has necessitated the adoption of novel agronomic practices such as precision nutrient management, optimized irrigation systems, and the selection of drought and disease resilient cultivars to maintain crop quality in emerging areas. Additionally, integrating coffee cultivation with agroforestry systems has demonstrated significant benefits, including improved soil health, enhanced biodiversity, and microclimatic moderation, which collectively mitigate environmental risks and promote sustainability. The review also examines economic and market potentials, noting that non-traditional regions can access niche specialty coffee markets and diversify income sources, despite facing challenges such as infrastructural limitations, pest and disease pressures, and socio-economic barriers. Ultimately, this article underscores the urgency for interdisciplinary research and strategic policy support to develop resilient, sustainable coffee production models that leverage technological innovations and sustainable practices. By providing a comprehensive analysis of the environmental, agronomic, economic, and technological dimensions of coffee cultivation beyond traditional zones, this review offers critical insights and future directions to guide the global coffee industry toward a more diversified and sustainable future.

Keywords: Coffee cultivation, Non-traditional regions, Climate adaptation, Agroforestry, Precision agriculture, Sustainability, Specialty coffee, Emerging coffee markets.

INTRODUCTION

Coffee cultivation has traditionally been confined to well-established growing regions, primarily within the "Coffee Belt", the geographic zone between the Tropics of Cancer and Capricorn. This region offers the stable temperatures, high humidity, suitable altitudes, and nutrient-rich soils those coffee plants especially Arabica require for optimal growth (Bunn *et al*., 2015; Davis *et al*., 2012). Historically, these ideal climatic and edaphic conditions confined high quality coffee production to this narrow band. However, climate change, technological advancements, and shifting economic landscapes are driving the expansion of coffee farming into non-traditional regions, requiring new strategies for sustainable and efficient cultivation.

Rising global temperatures and unpredictable weather patterns are altering the viability of traditional coffee-growing regions, prompting researchers and farmers to explore higher-altitude locations and cooler climates for production (Bunn *et al*., 2015; Davis *et al*., 2019). These changes necessitate agronomic adaptations, including soil modifications, shade management, and irrigation innovations, to ensure crop resilience in these emerging regions (Rahn *et al*., 2018). Additionally, genetic improvements in coffee plant varieties such as drought-resistant and pest-tolerant cultivars are enhancing coffee's adaptability beyond traditional boundaries (Santos *et al*., 2020).

Integrating agroforestry systems has become a key approach to sustainable coffee expansion in non-traditional areas. By cultivating coffee alongside fruit trees and timber species, farmers can improve carbon sequestration, biodiversity conservation, and soil health while mitigating environmental risks (Perfecto *et al*., 2005; Jha *et al*., 2014). These systems also enhance climate resilience, allowing coffee plants to thrive despite shifting weather conditions.

Beyond environmental considerations, economic and market dynamics play a crucial role in shaping the feasibility of coffee expansion into new regions. Increasing global demand for specialty coffee has opened opportunities for non-traditional coffee producers, particularly in regions historically overlooked for cultivation (Pendergrast, 2010). However, challenges such as supply chain development, farmer training, and economic viability remain critical factors that must be addressed for successful integration into the global coffee market.

Despite the potential benefits, expanding coffee cultivation into new regions presents several challenges, including pest and disease management, deforestation risks, and high production costs (Avelino *et al*., 2015). Addressing these issues requires a multi-disciplinary approach, combining scientific research, technological advancements, and policy support to ensure sustainability.

This review will explore the environmental, agronomic, and economic implications of coffee production in non-traditional regions, assessing climate adaptation strategies, sustainable farming practices, market expansion opportunities, and emerging research directions. By understanding the broader landscape of coffee cultivation beyond its traditional zones, this study aims to provide insights into future trends and innovations that will shape the global coffee industry.

Climate Change and Its Role in Expanding Coffee Cultivation:

Global climate change is fundamentally reshaping agricultural production, and coffee is no exception. Traditionally confined to the "Coffee Belt," coffee cultivation has depended on stable temperature ranges and consistent precipitation patterns. However, rising global temperatures and irregular rainfall have disrupted traditional growing zones while simultaneously opening new possibilities for production in regions previously considered unsuitable. Studies by Bunn *et al*. (2015); Davis *et al*. (2019) highlight that warming trends are shifting optimal cultivation zones to higher altitudes and latitudes, expanding the geographical range of coffee production. Similarly, Davis *et al*. (2012) predicts future trends in Coffea arabica adaptability, emphasizing the importance of identifying climate-resilient strategies.

The expansion is driven primarily by climate change which alters temperature and precipitation patterns and technological advancements in precision agriculture, drought- and disease-resistant cultivars, and irrigation innovations. Additionally, evolving market dynamics, including increased global demand for specialty, sustainably produced coffee, are pushing producers to explore higher-altitude or previously unsuitable regions (Ngure & Watanabe, 2024). These climatic shifts necessitate adaptive agronomic practices tailored for emerging coffee-growing regions. Measures such as precision water management, the adoption of drought-tolerant and disease-resistant cultivars, and the integration of technological advancements like precision agriculture techniques have become essential (Santos *et al*., 2020). Research by Rahn *et al*. (2018) furthermore, supports that integrating these innovative strategies can enable non-traditional regions to achieve yields and quality comparable to or even surpassing traditional coffee zones. The adoption of agroforestry systems, as noted by Jha *et al*. (2014); Avelino *et al*. (2023), has proven beneficial by enhancing microclimatic stability and soil fertility while simultaneously mitigating environmental risks.

In addition, climate-driven shifts in disease patterns present further challenges. Studies by Avelino *et al*. (2012) and Avelino *et al*. (2018) report that increasing temperatures accelerate the spread of coffee rust and other pathogens, demanding new pest and disease management strategies. Similarly, Angelotti *et al*. (2024) provide insights into climate-induced changes in plant disease prevalence, reinforcing the importance of integrated crop protection techniques.

However, while these reviews rightly emphasize coffee rust, they often do not specify other common pathogens affecting coffee production, such as *Fusarium* spp., *Colletotrichum* spp., and bacterial pathogens linked to coffee wilt and leaf spot. This lack of specificity may lead to an underestimation of the overall disease pressure in non-traditional regions. In addition, the discussion of management strategies rarely moves beyond conventional integrated crop protection or general IPM (Integrated Pest Management) approaches. To strengthen this point, it is important to highlight several novel techniques that have shown promise in addressing these challenges such as Precision Disease Detection due to recent advances in remote sensing technologies and machine learning algorithms enable the early detection of disease symptoms. These precision tools allow growers to monitor disease progression in real time and apply targeted interventions before outbreaks become severe (Hareliman *et al*., 2022). Biocontrol Agents and The deployment of biocontrol agents, such as specific strains of *Trichoderma* and *Bacillus* spp., have demonstrated effectiveness in suppressing a range of fungal pathogens. These biological control methods offer an environmentally friendly alternative to chemical pesticides and have been successfully trialed under variable climatic conditions (Morales Peña *et al*., 2024). Molecular Approaches and Novel molecular techniques, including RNA interference (RNAi), are being explored to down regulate key virulence genes in coffee pathogens. This strategy could provide a highly specific tool to curb pathogen spread without the environmental drawbacks associated with traditional pesticides (Angelo *et al*., 2020). Moreover, Next-Generation Sequencing (NGS) for Surveillance with The application of NGS techniques enables comprehensive profiling of the coffee microbiome, facilitating the early identification of emerging pathogens. This genomic information can then be used to refine disease forecasting models and develop more tailored management strategies.

Beyond agronomic factors, climate change is increasingly influencing global coffee market dynamics. The evolving temperature profiles across coffee-growing regions have spurred investment in research and development to optimize coffee cultivation outside traditional zones (Ngure & Watanabe, 2024). As temperature patterns continue to shift, the economic rationale for expanding production into higher-altitude areas strengthens, driving interdisciplinary research efforts that address both environmental and commercial challenges.

This section synthesizes current evidence and case studies to outline a strategic path forward for sustainable, climate-resilient coffee cultivation in non-traditional regions. By leveraging technological innovations and ecological adaptations, the global coffee industry can navigate the challenges posed by climate change while seizing new opportunities for production and market expansion.

Agronomic Adaptations for Coffee in Non-Traditional Regions:

Expanding coffee cultivation beyond traditional areas requires a tailored set of agronomic practices to manage diverse edaphic and climatic conditions. In non-traditional regions, soils often vary in pH, texture, and organic matter content compared to the established coffee belt. Studies suggest that precision nutrient management and customized fertilization schemes, including organic amendments like compost and biochar, significantly improve soil structure and water retention (Gebisa & Regasa, 2024). For instance, Läderach *et al*. (2017) demonstrated that integrating organic matter not only enhances soil fertility but also promotes beneficial microbial activity, mitigating acidity and increasing nutrient availability. These practices are essential for robust seedling establishment and achieving high yields in suboptimal soil conditions. Despite the growing interest in expanding coffee cultivation beyond traditional boundaries, many review articles have yet to provide detailed, customized fertilization schemes or specific application rates tailored to non-traditional regions. In these emerging areas where factors such as lower altitudes, altered microclimates, and unique agroforestry systems prevail, precise nutrient management is critical for optimizing coffee yield and quality. The absence of such detailed recommendations constitutes a notable lack of depth in current horticultural reviews, which limits their practical utility for agronomists and practitioners.

Research has consistently demonstrated that fertilizer management strategies tailored to local soil and climatic conditions are essential. For instance, studies employing sustainability-driven fertilizer recommender systems using case-based reasoning approaches have shown the promise of delivering region-specific recommendations that account for variations in soil nutrient status and crop requirements (León Chilito *et al*., 2024). Similarly, investigations into agroforestry systems have emphasized that optimal application rates of nitrogen, phosphorus, and potassium are crucial for achieving maximum productivity in non-conventional settings (Morales Peña *et al*., 2024). These studies underscore the importance of integrating detailed fertilization schemes as part of comprehensive management practices for coffee cultivation in new regions.

Key agronomic adaptations for coffee cultivation in emerging regions in addition to the above, three essential agronomic adaptations have emerged as crucial for successful coffee production in non-traditional areas; precision nutrient management and customizing fertilization schemes using organic amendments such as compost or biochar tailored to local soil conditions improves soil structure and nutrient availability (León Chilito *et al*., 2024; Morales Peña *et al*., 2024). Optimized irrigation systems and how implementing drip irrigation alongside sensor-based moisture monitoring systems helps counteract water scarcity and variable precipitation, ensuring efficient water use (Santana *et al*., 2022; Santos *et al*., 2020). Finally, shade and canopy management with integrating agroforestry systems or employing controlled shading practices moderates microclimatic extremes, enhances photosynthetic efficiency, and fosters resilient plant growth (Jha *et al*., 2014; Perfecto *et al*., 2019).

Beyond soil management, water availability is a critical factor in coffee cultivation in new geographic areas. Modern irrigation strategies, such as drip irrigation and sensor-based moisture monitoring systems, allow for precise water distribution and efficient resource use (Santana *et al*., 2022; Santos *et al*., 2020). Research confirms that implementing these precision irrigation methods in non-traditional regions significantly reduces water stress and promotes uniform growth (Santana *et al*., 2021). Additionally, optimizing planting density and canopy management through controlled pruning and strategic shade introduction helps regulate microclimatic conditions. These methods enhance photo-assimilate distribution, buffer temperature fluctuations, and lower evapotranspiration rates, which is especially crucial in regions prone to heat or water scarcity (Perfecto & Vandermeer, 2015; Jha *et al*., 2014).

Varietal selection also plays a crucial role in adapting coffee production to non-traditional regions. With evolving climatic constraints, selecting drought-tolerant, disease-resistant coffee cultivars with adaptability to variable environmental conditions has become a priority (Ferrão *et al*., 2024; Ngure & Watanabe, 2024). Rahn *et al*. (2018) emphasized the importance of field trials and breeding programs aimed at identifying and promoting coffee genotypes suitable for these emerging coffee-growing zones. Complementing these genetic improvements, integrated pest management (IPM) strategies are necessary to mitigate new pest and disease pressures that may arise in these regions (Avelino *et a*l., 2015; Avelino *et al*., 2012).

Integrating coffee cultivation with agroforestry systems:

Integrating coffee cultivation with agroforestry systems presents a promising strategy for sustainable expansion in non-traditional regions. Agroforestry not only diversifies farm income but also enhances ecosystem services, mitigates climate risks, and improves soil fertility. Agroforestry systems offer multiple advantages, they improve soil fertility and moisture retention, moderate microclimates by reducing temperature extremes, enhance biodiversity, provide natural pest control, and create diversified income streams the latter also improving the overall sustainability of coffee production (Perfecto *et al*., 2005; Jha *et al*., 2014).

By intercropping coffee with native trees, fruit orchards, or timber species, farmers can create microclimates that reduce temperature extremes and buffer against erratic rainfall. Studies by Perfecto *et al*. (2005); Jha *et al*. (2014), and Perfecto *et al*. (2019) demonstrate that strategically incorporating shade trees into coffee plantations enhances water retention in soils, fosters beneficial microbial communities, and ultimately improves yield and fruit quality.

In non-traditional regions, where environmental conditions may be less predictable, agroforestry practices provide significant adaptive advantages. For example, canopy trees moderate temperature fluctuations and reduce evaporation rates, thereby conserving soil moisture a critical factor in regions with sporadic rainfall (Jha *et al*., 2014; Gebisa & Regasa, 2024). Additionally, diversified planting systems help control pests and diseases naturally, reducing reliance on chemical pesticides. The resulting biodiversity within these systems enhances ecological stability and resilience, as it creates habitats for beneficial insects and natural pest regulation mechanisms (Avelino *et al*., 2012; Avelino *et al*., 2023).

Beyond environmental benefits, economic advantages arise from agroforestry-based coffee production. Integrating multiple crops allows farmers to generate additional revenue streams, reducing overall economic risks associated with coffee farming (Ngure & Watanabe, 2024). In regions where market access poses challenges, diversified agroforestry systems enhance profitability for smallholder farms by providing stable and varied income sources (Sott *et al*., 2020; Perfecto & Vandermeer, 2015). Furthermore, agroforestry promotes carbon sequestration and improved soil organic matter, aligning with global sustainability initiatives and qualifying farms for climate finance or eco-certification programs (Santana *et al*., 2022; Angelotti *et al*., 2024).

Through the lens of sustainable development, agroforestry presents a holistic approach to coffee cultivation that transcends monoculture practices. This integrated framework not only enhances coffee quality by creating optimal microclimatic conditions but also supports long-term economic and environmental viability in non-traditional coffee-growing regions. Without diversification and sustainable practices, expanded coffee monocultures risk causing severe deforestation and soil degradation. Mono-cropping depletes soil nutrients, increases erosion, and reduces biodiversity, which in turn heightens vulnerability to pests and reduces ecosystem resilience (Jha *et al*., 2014; Gebisa & Regasa, 2024).

Continued research and field-level innovation in agroforestry practices will be crucial to maximizing these benefits and scaling up production responsibly, ensuring that the future of coffee remains both sustainable and resilient.

Economic and Market Potential of Coffee in New Regions:

Expanding coffee cultivation into non-traditional regions presents significant economic opportunities for both local communities and the global coffee market. As consumer preferences shift toward specialty and sustainably produced coffees, demand is rising for unique flavor profiles and ethically sourced products. Studies suggest that non-traditional coffee-growing regions can tap into niche markets that value quality and origin-specific characteristics (Pendergrast, 2010; Davis *et al*., 2012; Freitas *et al*., 2024). These regions may offer cost advantages due to lower land and labor costs, enabling producers to remain competitive while investing in quality-enhancing agronomic practices (Ngure & Watanabe, 2024).

Despite these promising prospects, integrating coffee from emerging regions into global supply chains presents challenges. Infrastructure limitations, reduced market integration, and extended logistics networks can increase production costs and complicate quality control (Sott *et al*., 2020; Gebisa & Regasa, 2024). However, with targeted investments in supply chain improvements, capacity building, and value chain diversification, these barriers can be overcome (Santana *et al*., 2021; Maspul, 2025). Economic incentives such as premium pricing for specialty coffees and potential access to eco-certification programs encourage local farmers to adopt sustainable cultivation practices (Avelino *et al*., 2015; Angelotti *et al*., 2024).

Additionally, agroforestry and sustainable farming methods in non-traditional regions generate additional revenue streams. These practices support ecosystem services such as carbon sequestration credits and the production of high-value byproducts from agricultural waste (Perfecto *et al*., 2019; Jha *et al*., 2014). Such diversification not only stabilizes farmer incomes but also contributes to rural development and environmental protection (Perfecto & Vandermeer, 2015; Ferrão *et al*., 2024).

As international markets evolve, emerging producers will likely play an increasingly influential role, reshaping the global coffee industry and advancing sustainable economic growth. With proper investment, market accessibility, and technological support, these regions have the potential to enhance coffee production while meeting rising global demand for sustainability-driven products.

Non-traditional regions can tap into niche specialty coffee markets where premium prices and consumer demand for sustainable, unique flavor profiles prevail. Lower production costs (in terms of land and labor) combined with successful adaptation practices can lead to increased export potential and the development of local processing and manufacturing industries, thereby diversifying income sources (Pendergrast, 2010; Ngure & Watanabe, 2024).

Challenges and Risks in Expanding Coffee Cultivation:

Expanding coffee cultivation into non-traditional regions presents a range of challenges and risks that must be carefully managed to ensure sustainability and economic viability. One of the foremost concerns is increased vulnerability to pests and diseases. In regions where coffee has not been traditionally grown, the local biotic environment lacks natural suppressive factors, which can lead to a higher incidence of coffee berry borer and coffee rust (Avelino *et al*., 2015; Avelino *et al*., 2012). Additionally, variations in climate conditions across these new zones can further complicate disease dynamics, potentially causing unpredictable outbreaks (Angelotti *et al*., 2024).

Environmental risks are another critical challenge. The expansion of coffee monocultures without proper management can lead to deforestation, biodiversity loss, and soil degradation (Jha *et al*., 2014; Perfecto *et al*., 2019). Studies indicate that unsustainable land-use practices in emerging coffee regions deplete soil organic matter and compromise water resources, particularly in areas where natural ecosystem services have not been fully integrated into farming methods (Gebisa & Regasa, 2024; Santana *et al*., 2022). To mitigate these impacts, adopting sustainable agronomic practices such as agroforestry, soil conservation techniques, and precision agriculture is essential for maintaining environmental resilience and productive yields (Perfecto & Vandermeer, 2015; Rahn *et al*., 2018).

Economic and infrastructural challenges further pose risks in the expansion process. Establishing coffee production in non-traditional regions often requires high initial investments for infrastructure development, supply chain enhancement, and technical training (Davis *et al*., 2019; Sott *et al*., 2020). Fluctuations in global market prices and transportation costs can further strain profitability, making long-term sustainability more difficult (Ngure & Watanabe, 2024; Ferrão *et al*., 2024). Additionally, the lack of extension services and localized research support can hinder farmers' ability to implement proven agronomic innovations, increasing the risk of crop failure or suboptimal production (Santana *et al*., 2021).

Socio-economic challenges are equally important. Farmers in non-traditional coffee regions often encounter limited extension services and a lack of traditional knowledge about coffee cultivation, infrastructural deficits (such as insufficient processing and market-access facilities), and high initial investment costs. These challenges can hinder effective adoption of improved agronomic practices and reduce long-term profitability (Maspul, 2025; McCook, 2024). As a result, significant investment in training, capacity-building initiatives, and government-supported extension services will be critical for ensuring successful transitions to coffee cultivation (Avelino *et al*., 2018; Santana *et al*., 2021). Collaborative efforts between researchers, policymakers, and local communities are essential to build robust support systems that facilitate adaptation and long-term sustainability.

In summary, while expanding coffee cultivation into non-traditional regions offers promising economic and social benefits, it requires a comprehensive risk management strategy. Addressing pest and disease pressures, environmental degradation, infrastructural constraints, and knowledge gaps through science-based policies and sustainable practices will be essential for ensuring the long-term viability of coffee production in emerging regions.

Future Directions and Research Needs:

The future of coffee cultivation in non-traditional regions hinges on a multifaceted, interdisciplinary research approach that integrates advancements in plant breeding, digital agriculture, and sustainable farming practices. Continued research is essential for developing new coffee varieties that are resilient to emerging climatic stresses, pests, and diseases. Breeding programs leveraging genomics and advanced phenotyping are crucial in identifying and promoting cultivars with enhanced drought tolerance, pest resistance, and adaptability to variable soil conditions (Rahn *et al*., 2018; Santos *et al*., 2020; Ferrão *et al*., 2024). Research focused on genetic improvement ever aging genomics, advanced phenotyping, and molecular techniques (such as RNA interference and next-generation sequencing) are critical. These efforts aim to breed new cultivars that are more tolerant to drought, temperature fluctuations, and disease, thereby enhancing the long-term resilience of coffee production (Rahn *et al*., 2018; Santos *et al*., 2020).

Advancements in precision agriculture hold great promise for optimizing coffee cultivation beyond traditional zones. The integration of sensor-based soil monitoring, remote sensing, and machine learning algorithms can offer real-time insights into microclimatic conditions, soil moisture levels, and plant health (Santana *et al*., 2021; Sott *et al*., 2020). These digital tools enable farmers to fine-tune irrigation, fertilization, and pest management practices, ultimately reducing input costs and environmental impacts, while improving yield outcomes (Santana *et al*., 2022; Santos *et al*., 2020). Future research should focus on validating these technologies under diverse environmental conditions to ensure their robustness and scalability in non-traditional regions (Sharma, 2023; Gebisa & Regasa, 2024). In addition, digital agriculture tools including remote sensing, real-time sensor monitoring, machine learning for predictive analytics, and IoT-based systems enable precise management of water, nutrients, and pest interventions. These technologies help farmers make data-driven decisions, optimize resource use, and improve overall yield and quality under variable climatic conditions, thus enhancing the viability of coffee cultivation in non-traditional regions (Santana *et al*., 2021; Nguyen *et al*., 2023).

In tandem with technological innovation, establishing strong extension services and capacity-building programs is vital. Research efforts must include socio-economic studies and participatory approaches that actively involve local communities, extension officers, and policymakers. Collaborative projects focusing on farmer training, technology transfer, and supportive policy frameworks will help facilitate the transition of innovative practices from research to commercial application (Ngure & Watanabe, 2024; Maspul, 2025). These measures are critical to empower local farmers and integrate emerging coffee producers into global supply chains, thereby enhancing market viability (Avelino *et al*., 2015; Davis *et al*., 2019).

Moreover, interdisciplinary research that connects agronomic practices with market and environmental data will provide a holistic understanding of the sustainability challenges and opportunities associated with non-traditional coffee cultivation. Studies should investigate how agroforestry integration, zero-waste approaches, and diversified income strategies can further improve environmental performance and economic resilience (Jha *et al*., 2014; Perfecto & Vandermeer, 2015; Perfecto *et al*., 2019). By addressing these interconnected issues through a comprehensive research agenda, the coffee sector can develop more resilient production systems, ensuring long-term sustainability and high-quality yields in an increasingly unpredictable climate.

Conclusion

Expanding coffee cultivation into non-traditional regions presents a mix of challenges and opportunities in today's dynamic agricultural landscape. As climate change reshapes the areas where coffee can prosper, new frontiers emerge that call for innovative agronomic practices, sustainable farming methods, and robust market integration. Emerging coffee regions can benefit from precision nutrient management, advanced irrigation techniques, and the use of resilient cultivars—all essential for sustaining high-quality yields in unconventional environments. Moreover, integrating coffee cultivation with agroforestry and other sustainable practices not only improves microclimatic conditions and enhances soil health but also supports biodiversity conservation and diversifies economic opportunities. These integrated systems play a critical role in mitigating environmental risks and ensuring that ecosystem services are fully leveraged. At the same time, challenges such as pest and disease management, infrastructural constraints, and socio-economic barriers necessitate a strategic, interdisciplinary approach that actively involves researchers, policymakers, and local communities. Looking ahead, the future of coffee production in emerging regions hinges on robust research in genetic improvement, the adoption of precision agriculture technologies, and the establishment of comprehensive capacity-building programs. Such initiatives will empower farmers to transition from traditional methods to innovative, climate-adaptive production systems, thereby reducing environmental impacts and boosting long-term economic viability. In summary, this review underscores the urgent need for a collaborative, multi-disciplinary strategy to unlock the full potential of non-traditional coffee cultivation. By embracing technological innovations, sustainability-driven practices, and market-oriented adaptations, coffee producers can overcome existing hurdles while paving the way for a more resilient, diversified, and environmentally conscious global coffee industry.

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