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Embracing sustainability: Shade-grown coffee and avian ecology

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ABSTRACT

Coffee, a globally consumed commodity, exerts significant environmental impacts through its cultivation practices. Traditional shade-grown coffee, which supports biodiversity and provides various ecological benefits, is increasingly being replaced by sun-grown coffee that involves deforestation for higher yields. This study critically examines the ecological and economic dimensions of shade-grown coffee in South India, particularly Tamil Nadu, and compares it with sun-grown coffee systems. It also investigates the role of avian species in providing pest control services within these agroforestry systems. Avian species play a pivotal role in natural pest control, thereby reducing reliance on chemical inputs and fostering ecological equilibrium. Birds act as natural predators, reducing populations of insect pests that can damage coffee plants. By feeding on a variety of pests, including beetles, caterpillars, and aphids, birds help maintain a balanced ecosystem and reduce the need for chemical pesticides. This ecological service not only enhances coffee yield and quality but also promotes biodiversity and sustainability in coffee plantations. The study explores the importance of conserving avian habitats to support effective and natural pest management. integrating coffee cultivation with biodiversity conservation. biodiversity conservation. The unique agroforestry practices in Tamil Nadu may serve as exemplary models of integrating coffee cultivation with Sustainable coffee agroforestry could be crucial for environmental conservation and long-term agricultural productivity. Future research should focus on optimizing shade-grown coffee practices, understanding the dynamics of bird-pest interactions, and developing strategies to promote shade-grown coffee through financial incentives, certification programs, and community engagement. These measures will ensure economic benefits for farmers while preserving ecological integrity.

KEYWORDS

Shade-grown coffee; Agroforestry systems; Biodiversity conservation; Natural pest control

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Introduction

Coffee is one of the most popular beverages worldwide, and its cultivation significantly impacts the environment [1]. Traditionally, coffee is grown in shaded environments, promoting biodiversity and offering ecological benefits [2]. In recent times, however, sun-grown coffee, which involves deforestation and intensive farming practices, has become more prevalent due to its higher yield. Shade-grown coffee is cultivated under a canopy of trees, mimicking the natural habitat of wild coffee plants. This method has been practiced for centuries in coffee-producing regions such as Latin America, Africa, and Asia [2]. The primary advantage of shade-grown coffee is its promotion of biodiversity. The canopy trees provide a habitat for various species of birds, insects, and mammals, enhancing the ecological balance [3]. In India, coffee cultivation is primarily concentrated in the southern states of Karnataka, Kerala, and Tamil Nadu. Shade-grown coffee has been a traditional practice in these regions, particularly in the Western Ghats, a biodiversity hotspot [4]. The Indian coffee industry is diverse, with small-scale farmers coexisting with large plantations. Tamil Nadu, particularly the Nilgiri district, is known for its shade-grown coffee [5]. The region's unique topography and climate make it ideal for this cultivation method. However, like other parts of India, Tamil Nadu faces challenges such as deforestation, monoculture practices, and the impact of climate change on coffee production.

This review explores the ecology and economics of shade-grown coffee, with a particular focus on coffee plantations in South India, especially in the state of Tamil Nadu. It reviews the existing literature on agricultural practices involving forest-grown coffee, comparing its yield and profitability with conventional methods and analyzing how the sustainability of coffee agroforestry could explore the ecological services of birds that could, in turn, contribute to pest control. Additionally, it also proposes potential strategies to ensure the sustainability of coffee while minimally affecting the avian diversity in this region.

Sustainability of coffee plantations

Conventional coffee farming, often referred to as sun-grown coffee, has become popular due to its high-yield potential and quicker returns on investment [6]. In sun-grown systems, coffee plants are exposed to full sunlight, which accelerates growth and increases the density of coffee plants per hectare. This method also simplifies pest control and harvesting, making it an attractive option for farmers looking to maximize short-term profits. Additionally, the initial capital investment required for sun-grown coffee is generally lower compared to shade-grown systems, making it more accessible to small-scale farmers [7].

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Shade-grown coffee typically yields less per hectare compared to sun-grown coffee [2]. The shaded environment slows the growth rate of coffee plants and reduces the number of coffee cherries produced. While sun-grown coffee can produce up to 4,000 kilograms per hectare, shade-grown coffee often yields around 1,500 to 2,500 kilograms per hectare. This significant difference in yield is a primary reason many farmers opt for sun-grown methods.

Sun-grown coffee farming, while more productive in the short term, has several significant drawbacks [8]. The higher yield may fetch profit in the short term, but the longer harvest time of shade-grown coffee aids flavor development, and hence, conventional coffee lags in quality and profitability in the long run. The monoculture nature of sun-grown coffee farms makes them more susceptible to pests and diseases, which can result in higher costs and lower resilience over time. The intensive use of chemical fertilizers and pesticides required to maintain high yields can lead to soil degradation, water contamination, and loss of biodiversity [9]. Additionally, the removal of trees to create open fields for coffee plants contributes to deforestation and reduces carbon sequestration, exacerbating climate change.

Shifting to shade-grown coffee is essential for sustainable agriculture and environmental conservation [2,3]. Shade-grown coffee farming promotes biodiversity by providing habitats for various plant and animal species. It also supports soil health and water conservation, which are critical for long-term agricultural productivity [10]. With the increasing consumer demand for ethically produced and environmentally friendly products, shade-grown coffee offers a viable alternative that aligns with global sustainability goals [7]. Additionally, shade-grown coffee farms can serve as carbon sinks, helping to mitigate the effects of climate change [11,12].

Sustainable coffee agroforestry in Tamil Nadu

South India, particularly Tamil Nadu, offers ideal conditions for shade-grown coffee [13]. The region's tropical climate, characterized by consistent rainfall and warm temperatures, is conducive to growing coffee under the canopy of native shade trees. The Western Ghats, a biodiversity hotspot, provide a rich ecosystem that supports various flora and fauna, enhancing the ecological benefits of shade-grown coffee [4].

Coffee plantations primarily span the Nilgiris, Coimbatore, and Theni districts [14,15]. This area forms part of the agroforestry belt where coffee thrives under the shade of trees like Silver Oak, Grevillea, and various native species. These plantations benefit from the region's moderate climate and elevation, which are ideal for coffee cultivation. The traditional agroforestry practices in these regions not only sustain the coffee crop but also contribute to the preservation of biodiversity and natural resources [10,12].

Traditional coffee farming in South India has historically utilized shade trees, making it easier to integrate modern shade-grown practices [16]. Sustainable coffee agroforestry in Tamil Nadu, represents a significant approach to farming that balances ecological health with economic viability. This method involves cultivating coffee plants under a canopy of trees, which not only supports biodiversity but also enhances soil health and conserves water [10]. By providing habitat for various species and improving soil fertility through natural processes like leaf litter decomposition, shade-grown coffee farms contribute to the overall ecological balance. This practice also helps mitigate climate change by sequestering carbon dioxide and improving water retention in the soil [4].

Farmers in Tamil Nadu benefit from diversified income streams by intercropping coffee with spices, fruits, and other crops [17]. This diversification reduces economic risks and dependency on a single crop while promoting sustainable agricultural practices. Reduced input costs, such as those for chemical fertilizers and pesticides, further enhance the economic feasibility of sustainable coffee agroforestry. Pepper, another important crop in Tamil Nadu, is typically grown alongside coffee and other shade-loving plants [18]. Known for its robust flavor and medicinal properties, pepper vines are often trained on trees within coffee plantations, utilizing vertical space effectively. Coffee and pepper farming in Tamil Nadu are integral parts of the state's agricultural landscape, particularly in the hilly regions of the Western Ghats. Known for its robust flavor and medicinal properties, pepper vines are often trained on trees within coffee plantations, utilizing vertical space effectively [17]. Pepper farming in Tamil Nadu benefits from similar agroclimatic conditions as coffee, thriving in the Western Ghats' moderate climate and well-drained soils [13].

These crops are traditionally cultivated under agroforestry systems that promote biodiversity and sustainable land use practices. This intercropping not only maximizes land use but also enhances the biodiversity of the agroforestry system [18].

Ecological services of birds in pest control

Forest-grown coffee, also known as shade-grown coffee, is cultivated under a canopy of trees, mimicking the natural conditions of coffee's native habitat in the understory of tropical forests [2]. This method of cultivation offers significant ecological benefits. The canopy trees provide habitat for a wide range of wildlife, contribute to soil health, and enhance the water cycle [19]. The organic matter from falling leaves and branches enriches the soil, improving its fertility and structure [15,17]. Moreover, the shade from the canopy trees reduces the need for chemical inputs by maintaining soil moisture and suppressing weeds.

Globally, birds are integral to the health of coffee plantations. In regions like Latin America, Africa, and Asia, numerous studies have documented the positive impact of birds on coffee farms [20]. Birds play a crucial role in pest control within coffee plantations, offering a natural and sustainable alternative to chemical pesticides [21]. Many bird species feed on insects and other pests that can damage coffee plants. This ecological service is particularly valuable as it helps maintain the health of the coffee crop without harming the environment. For example, in Costa Rica, research has shown that birds significantly reduce the population of coffee berry borers, a major pest, by preying on the larvae [22]. Similarly, in Ethiopia, birds help control pests and contribute to the overall biodiversity of the coffee ecosystem [23].

The relationship between birds and pest control in coffee plantations is well-documented worldwide [21,22,23]. Birds such as warblers, flycatchers, and tanagers are known to consume large quantities of insects, thus reducing pest populations. This not only protects the coffee plants but also decreases the reliance on chemical pesticides, which can have

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harmful environmental and health effects. The presence of a diverse bird population can create a balanced ecosystem where pests are kept in check naturally.

South India is home to a rich diversity of bird species, many of which play a role in the ecosystem services of pest control [24]. Notable bird species include the Malabar whistling thrush, the Nilgiri flycatcher, and the Indian pitta. These birds, along with others, contribute to the ecological balance by controlling insect populations, dispersing seeds, and pollinating plants. The diverse habitats of South India, ranging from tropical forests to wetlands, provide suitable environments for these birds [25].

In India, particularly in states like Karnataka, Kerala, and Tamil Nadu, coffee plantations are often integrated with forested areas, providing a habitat for various bird species [24,25]. The coffee plantations are often interspersed with native forest patches, creating a mosaic of habitats that support a variety of bird species. Research has shown that coffee farms with higher tree diversity attract more bird species. Studies in these regions have shown that birds contribute significantly to pest control. These birds help control pest populations, contributing to the overall health and sustainability of the coffee ecosystem. In the Western Ghats, for example, birds like the white-cheeked barbet and the red-whiskered bulbul are commonly found in coffee plantations and play a role in pest control [26]. Birds have been observed preying on the coffee white stem borer, a major pest in Indian coffee plantations. Birds such as egrets, kingfishers, Indian myna, and drongos are essential components of the ecological services of the avian community by feeding on insects that could otherwise damage the crops [27]. Table 1 highlights the role of various bird species in controlling insect populations within South Indian coffee plantations, contributing to the overall health and sustainability of the coffee ecosystem. This natural pest control mechanism supports the sustainability of coffee farming in India. These natural pest control services enhance agricultural productivity and reduce the need for chemical interventions [28].

Table 1. Common Bird Species in the coffee plantations in the Western Ghats and their Insect prey.

Bird Species	Insect prey in Coffee Plantations	References
Malabar Whistling Thrush	Coffee berry borer, caterpillars, beetles, ants	[29]
Nilgiri Flycatcher	Coffee white stem borer, moths, flies, beetles	[30]
Indian Pitta	Grasshoppers, beetles, ants, caterpillars	[26]
White-cheeked Barbet	Coffee berry borer, beetles, caterpillars, ants	[27]
Red-whiskered Bulbul	Beetles, caterpillars, ants, grasshoppers	[26,27]
Indian Myna	Coffee berry borer, beetles, grasshoppers, caterpillars	[25]
Black Drongo	Moths, beetles, flies, ants	[27]
Greater Racket-tailed Drongo	Moths, beetles, ants, flies	[31]
Jungle Babbler	Beetles, ants, caterpillars, grasshoppers	[26]
Oriental Magpie-Robin	Beetles, ants, grasshoppers, caterpillars	[26]
Common Tailorbird	Caterpillars, beetles, ants	[27]
Asian Koel	Beetles, caterpillars, grasshoppers	[25]
Spotted Dove	Beetles, caterpillars, ants	[26]
White-throated Kingfisher	Beetles, grasshoppers, caterpillars	[25]
Indian Paradise Flycatcher	Flies, beetles, ants, caterpillars	[30]

In Indian coffee plantations, pest control is a critical concern. Traditional methods often involve the use of chemical pesticides, which can have detrimental effects on the environment and human health. However, integrating bird-friendly practices in coffee farming can provide a sustainable solution [29]. By maintaining forested areas and planting native trees, coffee farmers can attract birds that prey on coffee pests. This approach not only protects the coffee crop but also promotes biodiversity and environmental health.

The integration of coffee cultivation with agroforestry practices offers significant potential for sustainability [32]. By maintaining a diverse canopy of trees, coffee farmers can create a habitat for birds and other wildlife, enhancing biodiversity. Agroforestry practices also improve soil health, water retention, and carbon sequestration. This holistic approach promotes ecological balance and supports the long-term viability of coffee farming.

In South India, there is a growing recognition of the benefits of sustainable coffee agroforestry [33]. Initiatives aimed at promoting shade-grown coffee and conserving forested areas are gaining momentum. These efforts not only support biodiversity but also provide economic benefits to farmers through premium prices for sustainably grown coffee [13]. By fostering a harmonious relationship between coffee cultivation and forest conservation, South India can serve as a model for sustainable coffee agroforestry.

The economic significance of coffee and pepper farming extends beyond domestic markets, with both crops being exported to international destinations [18]. Sustainable farming practices, supported by certifications and market access initiatives, enable farmers to fetch premium prices for their produce. This economic sustainability is crucial for the livelihoods of farming communities in Tamil Nadu's hilly terrains, where agriculture remains a cornerstone of rural economies.

Coffee and pepper farming in Tamil Nadu exemplifies the synergy between traditional agricultural practices and modern sustainability principles [17]. By embracing agroforestry and

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sustainable farming techniques, farmers in the Western Ghats region ensure the long-term viability of their crops while preserving the region's rich biodiversity and natural resources [20].

Sustainable Coffee and Bird Conservation in South India

Strategies for sustainability

Sustainable practices in coffee plantations involve a multifaceted approach. One key strategy is growing organic coffee sans fertilizers and pesticides while promoting bird conservation.

Shade-grown coffee is cultivated under a canopy of diverse tree species, mimicking a natural forest environment. This method benefits biodiversity, including avian species, by providing habitat and food resources. Promoting shade-grown practices involves educating farmers on the ecological and economic benefits [2,3]. Financial incentives, such as subsidies or premium prices for shade-grown coffee, can encourage farmers to transition from sun-grown to shade-grown methods [34]. Extension services and workshops can disseminate knowledge on managing shade trees and integrating coffee plants, ensuring farmers are equipped to adopt and sustain these practices [35].

The practice of agroforestry involves the integration of trees and shrubs into agricultural systems which is here, growing coffee plants alongside a variety of trees, enhancing biodiversity, soil health, and resilience against climate change [12]. Diverse tree species can provide shade, improve soil fertility through nitrogen fixation, and create habitats for birds and other wildlife [10,11,33]. Implementing agroforestry practices while collaborating with agricultural experts to select appropriate tree species and developing management plans that balance coffee production and ecosystem health is a beneficial strategy toward this goal [36].

Currently, various initiatives and certification programs certify high-quality, sustainable agricultural practices. Certification programs such as Fair Trade, Rainforest Alliance, and Bird Friendly provide frameworks for sustainable coffee production [37-41]. These programs set standards for environmental and social practices, rewarding compliant farmers with premium prices and market access. Certification involves regular audits to ensure adherence to criteria, such as maintaining tree cover, reducing chemical use, and conserving wildlife habitats [39]. Encouraging farmers to participate in these programs can elevate sustainability standards across the coffee sector. Additionally, certified coffee often appeals to environmentally conscious consumers, creating market demand that supports sustainable practices [39].

Community engagement

Local community engagement is vital for the long-term success of sustainable coffee and bird conservation efforts [42]. Involving communities fosters a sense of ownership and stewardship over natural resources. Educating farmers about the ecological benefits of shade-grown coffee can enhance their understanding and appreciation of biodiversity. Training programs can highlight the role of birds in pest control, pollination, and maintaining ecological balance. Involving farmers in bird monitoring programs allows them to observe firsthand the positive impacts of sustainable practices, fostering a deeper connection to conservation efforts. Collaborations with universities and conservation organizations can provide technical support and resources for effective monitoring.

Promoting eco-tourism in coffee-growing regions can provide alternative income sources for local communities, reducing their dependence on coffee alone [43]. Eco-tourism initiatives can include bird-watching tours, farm stays, and educational workshops on sustainable agriculture and biodiversity. Developing eco-tourism requires investment in infrastructure, such as trails, guides, and visitor facilities, as well as marketing efforts to attract tourists. Successful eco-tourism not only generates revenue but also raises awareness about the importance of conserving biodiversity in coffee landscapes [44-47].

Sustainable coffee cultivation in South India, particularly in Tamil Nadu, can significantly contribute to bird conservation and overall biodiversity [24]. By promoting shade-grown practices, implementing agroforestry, participating in certification programs, and engaging local communities, the region can create a resilient and ecologically sound coffee industry [41]. These strategies not only benefit the environment but also enhance the livelihoods of coffee farmers, ensuring a sustainable future for both people and wildlife.

Limitations of Shade-Grown Coffee Production

Agroforestry systems, including shade-grown coffee, offer multiple ecological and economic benefits. Shade-grown coffee production, while beneficial for biodiversity and environmental sustainability, has several limitations. One significant drawback is the lower yield compared to sun-grown coffee. The shaded environment slows down the coffee plant's growth and reduces the quantity of beans produced, impacting the overall profitability for farmers [1-3].

Additionally, shade-grown coffee often requires more labor-intensive practices, such as manual weeding and pest control, increasing production costs [37]. Farmers may also face challenges in securing premium prices despite the higher ecological value of shade-grown coffee, as market access and consumer awareness can be limited. Furthermore, the transition from conventional to shade-grown methods can be costly and time-consuming for farmers, who may lack the necessary resources and technical knowledge. Lastly, the scale of production is often smaller, limiting the ability to meet high demand and compete with larger, sun-grown coffee operations [13]. These challenges highlight the need for supportive policies and market incentives to sustain and expand shade-grown coffee practices.

Climate change poses an additional threat, as shifting weather patterns can affect the delicate balance required for optimal shade-grown coffee production [48]. Further, climate conditions can affect both bird populations and pest dynamics, complicating pest control strategies.

Another limitation is the potential for increased disease and pest pressure due to the moist, shaded conditions, necessitating more vigilant management practices [28]. Establishing and maintaining bird-friendly habitats, such as diverse canopy structures and native plant species, can be costly for farmers. There can be a perceived or actual trade-off between maximizing coffee yield and maintaining biodiversity-friendly practices [31].

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There is limited specific research on the interactions between birds and coffee pests, especially in diverse geographic regions like South India [25-31]. Traditional knowledge about bird species and pest control might be undervalued or underutilized in scientific approaches. Not all bird species consume the same pests [49]. Some might target only certain types of insects, leaving others unchecked. This can result in uneven pest control. The use of pesticides for pest control can harm beneficial bird species, reducing their effectiveness in natural pest control. Birds that are effective in pest control may prefer specific types of habitats that might not be present in all shade-grown coffee systems. Promoting bird conservation may inadvertently favor certain bird species over others, potentially disrupting the local ecological balance. Introducing or attracting non-native bird species can sometimes lead to the displacement of native birds and other wildlife [50]. Inconsistent or improper shade management can reduce the habitat quality for birds, affecting their populations and pest control abilities. Monoculture systems, even with shade, may not support a bird population as diversely as polyculture systems, reducing the effectiveness of birds in pest control.

Despite the limitations there is scope for ecofriendly coffee production in the future, supported by efforts both from government and private stakeholders.

Prospects for Eco-Friendly Coffee Cultivation and Preservation Of Avian Biodiversity

The future of sustainable coffee and bird conservation in South India, particularly in Tamil Nadu, is promising. By implementing comprehensive strategies that include policy support, branding and certification, research and development, technology adoption, and improved market access, the region can create a resilient and profitable coffee industry

Incentives and policy support

Governments and NGOs can play a crucial role in fostering the adoption of shade-grown coffee through a range of incentives and supportive policies. Financial incentives, such as subsidies for planting shade trees and grants for sustainable farming practices, can significantly reduce the initial costs for farmers transitioning to eco-friendly methods [51]. For example, in Tamil Nadu, policies aimed at protecting the Western Ghats can be designed to support agroforestry practices that benefit both coffee production and biodiversity [52].

Additionally, technical support is essential for the successful implementation of sustainable practices. Governments and NGOs can provide training programs and extension services to educate farmers on the benefits and methods of shade-grown coffee. Access to credit is another critical factor; providing low-interest loans or microfinance options can enable farmers to invest in sustainable practices without financial strain [42]. For instance, the establishment of community banks or cooperatives that offer favorable loan terms for sustainable agriculture projects could be highly effective.

Branding

Creating a strong brand identity for shade-grown coffee as a premium, sustainable product can attract environmentally conscious consumers and fetch higher prices. Certifications such as Organic, Fair Trade, and Bird Friendly play a pivotal role in enhancing the marketability of shade-grown coffee [52]. These certifications assure consumers that the coffee is produced in an environmentally and socially responsible manner, which can justify a higher price point.

Marketing campaigns that highlight the ecological benefits of shade-grown coffee, such as its role in conserving bird habitats and promoting biodiversity, can create a niche market [38,52,53]. For instance, Tamil Nadu could leverage its rich biodiversity and scenic coffee landscapes in promotional materials to appeal to eco-tourists and specialty coffee buyers. Collaborations with influencers, participation in international coffee fairs, and online marketing strategies can also help in creating a robust brand image.

Research and development

Continued research is critical for advancing the understanding and implementation of shade-grown coffee practices, particularly in the Western Ghats and Tamil Nadu [54]. Institutions such as the Coffee Board, the National Conservation Foundation (NCF) in Bangalore, the National Centre for Biological Sciences (NCBS), and the Salim Ali Centre for Ornithology and Natural History (SACON) play pivotal roles in this effort.

Research focusing on optimal tree species for providing shade, improving soil health, and enhancing pest control dynamics is essential [4,15]. For instance, the Coffee Board of Tamil Nadu contributes by investigating the most suitable shade trees that support both coffee production and biodiversity. The SACON is associated with conducting studies on how different shade trees influence bird populations, thereby informing better agroforestry practices that promote avian conservation [54].

Collaborative research involving universities, research institutions, and farmers is vital for driving innovation. Partnerships with institutions like Tamil Nadu Agricultural University can facilitate field trials and the development of best practices tailored to local conditions. These collaborations can also involve the NCBS, which can contribute to understanding the ecological impacts of shade-grown coffee systems.

Research on climate resilience, particularly in the context of changing weather patterns and their impact on coffee production, is crucial. Understanding how shade-grown coffee systems can buffer against climate extremes can help in developing more resilient agricultural practices [26,32,43]. The NCF, with its expertise in biodiversity conservation, can study how these systems support broader ecosystem stability and resilience. Economic research, including studies by the Coffee Board and other economic research institutes, is necessary to illustrate the long-term financial benefits of shade-grown coffee compared to conventional methods. These insights can help convince more farmers to adopt sustainable practices.

The expertise and resources of these institutions could prove pivotal in advancing sustainable coffee cultivation and bird conservation in Tamil Nadu, creating a more sustainable and resilient agricultural landscape.

Technology and innovation

The adoption of technology and innovation in shade-grown coffee farming can significantly enhance productivity and sustainability. Precision agriculture tools, such as soil sensors and drones, can help optimize resource use by providing

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detailed data on soil health, water needs, and pest presence. Mobile applications that offer real-time information on pest management, weather patterns, and market prices can empower farmers with the knowledge needed to make informed decisions.

In Tamil Nadu, leveraging technology to connect farmers with markets can be particularly beneficial [54]. For instance, e-commerce platforms that facilitate direct sales to consumers can help farmers get better prices for their produce [34]. Additionally, online training modules and virtual workshops can provide ongoing education and support to farmers, ensuring they stay updated on the latest sustainable practices.
The Coffee Board of India also plays a crucial role in supporting local farmers [55,56]. With its model plantations, it provides hands-on training and demonstrates best practices in coffee cultivation. Local farmers are trained in innovative farming techniques, including using shade trees, soil health management, and pest control, all aimed at improving productivity and sustainability. The Coffee Board's efforts help farmers adopt more efficient and environmentally friendly practices, which can lead to higher yields and better-quality coffee.

Private players have been significant in supporting small farmers through technology and innovation [57,58]. They have introduced the use of advanced coffee dryers that help small farmers efficiently process their coffee cherries, reducing post-harvest losses and ensuring better-quality beans. By partnering with small farmers, these companies not only ensure a steady supply of high-quality coffee for its products but also help these farmers increase their income through improved processing techniques.

Market access and export opportunities

Improving market access for shade-grown coffee is essential for enhancing profitability [34]. Establishing cooperatives and farmer groups can strengthen the bargaining power of individual farmers, allowing them to negotiate better prices and terms. These cooperatives can also facilitate direct sales to specialty coffee markets, where consumers are willing to pay a premium for sustainably produced coffee [53].

Exploring export opportunities can open new revenue streams for farmers in Tamil Nadu. Regions with high demand for sustainable and organic products, such as Europe and North America, represent significant markets for shade-grown coffee [41]. Establishing partnerships with international distributors and participating in global trade fairs can help in tapping into these markets. Additionally, developing a strong online presence and utilizing digital marketing strategies can help in reaching a broader audience [38].

Conclusions

The future of sustainable coffee cultivation and bird conservation in South India, particularly Tamil Nadu, is promising. Key strategies like promoting shade-grown coffee, certification programs, and technological innovation enhance biodiversity, soil health, and farmer livelihoods. Certification programs such as Fair Trade and Bird Friendly elevate sustainability standards and offer better market access. Community engagement and eco-tourism initiatives further support conservation efforts. Despite challenges like lower yields, the ecological and economic benefits make shade-grown coffee viable. These efforts not only benefit the environment by conserving biodiversity and bird habitats but also enhance the livelihoods of coffee farmers, ensuring a sustainable future for all stakeholders involved. Collaborative efforts can position Tamil Nadu as a model for sustainable coffee cultivation and bird conservation, ensuring a resilient future for both people and wildlife.

Disclosure statement

No potential conflict of interest was reported by the authors.

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