RESEARCH ARTICLE

The Tea Supply Chain: A Comparative Analysis of Environmental Sustainability Challenges in Divergent Economies

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Abstract

Tea production is one of the most important agri-food chains in the world and plays a crucial role in global agriculture and trade. As the tea industry continues to expand, it faces increasing pressure to address the challenges of environmental sustainability within its complex supply chains, which is of particular importance for two of the major producing countries: China, the world's largest tea producer, and Kenya, a major exporter of black tea. Although both countries differ in their environmental, socioeconomic, and cultural contexts, they face growing challenges in transitioning to a more sustainable model. The comparison between China and Kenya highlights different strategies for environmental sustainability in the tea supply chain. China relies on technological innovation and strict policies to reduce pesticide use and improve efficiency. Kenya relies on international cooperation and local solutions to address food insecurity and climate change. In both countries, environmental sustainability often takes a backseat to the socioeconomic interests and food production that are crucial to their development. This delicate balance requires more attention to combine effective environmental policies with economic development, ensuring a sustainable tea supply chain in the long term. The challenge is to reconcile environmental concerns with economic growth and food security in these diverse tea-growing countries.

Keywords: Tea supply chain, Environmental sustainability challenges, Divergent economies.

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Introduction

The tea supply chain is a complex and multifaceted system that spans across the globe, with various countries playing crucial roles in its production, processing, and consumption. As the world's most widely consumed beverage after water, tea has significant economic, social, and environmental implications. For these reasons, tea is not only a cultural staple but also a key economic commodity that is an integral part of the daily routine for almost half of the global population and provides a livelihood for millions of people in various economies.[1] As a global commodity, tea plays a significant role in local economies, in international trade, and in the cultural practices of many countries. The tea industry involves a complex supply chain from cultivation to processing, distribution and consumption, involving millions of stakeholders worldwide and influenced by a variety of factors, including price, income levels and demographic characteristics such as age, education, and cultural background.[2] According to recent estimates, tea production will reach around 6.7 million tons in 2022 and exports exceed 1.8 million tons per year, with forecasts suggesting further growth in the coming years.[3] This expansion, while economically beneficial, raises important questions about environmental sustainability and social responsibility within the tea sector. The cultivation of tea, primarily concentrated in tropical and subtropical regions, has substantial environmental implications, including impacts on land use, water resources, biodiversity, and climate change.[4] Tea production is particularly vulnerable to climate variability and changes, with recent studies highlighting the potential threats to yield, quality, and the livelihoods of smallholder farmers who form the backbone of the industry in many countries.[5,4] Moreover, the intensification of tea cultivation to meet growing global demand has led to increased use of agrochemicals, raising concerns about soil degradation, water pollution, and the long-term sustainability of tea ecosystems.[6] In response to these challenges, there has been a growing emphasis on sustainable practices within the tea industry. This includes the adoption of organic farming methods, the implementation of water-efficient irrigation systems, and the development of climate-resilient tea cultivars.[7] Additionally, various certification schemes and sustainability initiatives have emerged, aiming to promote environmentally friendly practices and improve social conditions for tea workers.[8]

The global tea industry is valued at over $50 billion, with an estimated two billion cups of tea consumed daily.[9] However, the economic value of tea extends beyond its direct production and trade, playing a crucial role in the economies of many countries, particularly in Asia and Africa.[10] Two nations that stand out in this sector are China and Kenya, representing opposite ends of the economic spectrum yet both significant players in the tea market. China, the world's largest tea producer and exporter, boasts of a rich cultural heritage associated with tea production dating back thousands of years. In contrast, Kenya, a relative newcomer to the global tea market, has rapidly risen to become one of the world's leading tea exporters, particularly of black tea. While China's tea industry is characterized by a large scale and diverse product range, Kenya's tea sector is more export-oriented and has been increasingly influenced by market-driven sustainability initiatives. Despite their differences in history, scale, and economic development, both countries face pressing environmental challenges in their tea industries. These challenges range from water

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management issues to the impacts of climate change and the use of agrochemicals to soil degradation.[11] The comparison between these two economies is particularly relevant as it provides insights into how different socioeconomic contexts, market structures, and environmental policies shape the sustainability practices within the tea supply chain.

As the tea industry continues to evolve in the face of environmental, economic, and social pressures, there is an urgent need for comprehensive research that explores the challenges and opportunities of sustainability in different production contexts.[10] This comparative study aims to examine the current practices, policies, and initiatives in China and Kenya's tea sectors, focusing on their efforts towards environmental sustainability. By juxtaposing these two contrasting cases, we aim to contribute to a broader understanding of sustainable supply chain management in the global tea industry and identify potential ways to improve environmental performance in different economic contexts.

China

China is the world's largest tea producer, accounting for over 50% of global tea production. The top tea-producing provinces in China are Fujian, Yunnan, Sichuan, and Guizhou, which account for half of China's tea production. The expansion of Chinese tea production has been particularly pronounced, where output has soared from 1.92 million tons in 2013 to 3.34 million tons in 2022 and the Chinese tea market is expected to grow at a compound annual growth rate of 5.7% to 2027.[12] In addition, the tea trade has become a significant source of export earnings for China, with the global tea trade valued at $9.5 billion [12]. This remarkable growth is fueled by rising domestic demand, increased awareness of the health benefits associated with tea consumption, and government initiatives promoting tea cultivation as part of rural development programs.[13] In recent years, there has been a noticeable shift in consumer preferences toward healthier and more natural beverages, driving a surge in demand for specialty and high-quality teas.[14] This trend is further bolstered by the growing popularity of organic and sustainably sourced products as consumers become increasingly conscious of environmental and ethical considerations. These evolving preferences present new growth opportunities within the global tea market, encouraging innovation in product development and marketing strategies to cater to diverse consumer tastes and expectations. On this drive, The Chinese government has promoted organic tea production. In 2019, the area under organic tea cultivation in China reached 60,000 ha, accounting for about 1.5% of the total area under tea cultivation. As the tea industry continues to expand, it will come under increasing pressure to address the challenges of environmental sustainability within its supply chain. Moreover, the country has seen remarkable advances in technology and e-commerce, which have transformed traditional methods of marketing and distributing tea.[15]

Despite its global prominence, the Chinese tea industry faces several challenges, including rising production costs, fluctuating tea prices, and increasing competition from other tea-producing countries. Additionally, the industry has struggled with issues related to sustainability, such as labor exploitation, food safety concerns, and environmental degradation.[16] The intensive use of chemical fertilizers and pesticides aimed at enhancing productivity has led to widespread soil and water pollution. This pollution poses severe risks not only to the immediate environment but also impacts the broader ecological health of the regions. Moreover, the expansion of tea plantations often involves deforestation, which exacerbates biodiversity loss and contributes to a cycle of environmental degradation.[16] This rapid modernization raises concerns about environmental sustainability, particularly in rural areas where ecological degradation is becoming increasingly evident due to intensive agricultural practices.[17] To address these challenges, the Chinese government has implemented various initiatives aimed at promoting sustainable tea production and trade practices. These measures include stringent regulations on pesticide and fertilizer use, the promotion of organic farming, and financial incentives for farmers who adopt environmentally friendly practices. In 2021, the Ministry of Agriculture and Rural Affairs (MARA) set a target to reduce chemical pesticide use in tea production by 10% by 2025, compared to 2020 levels. Moreover, China updated its national food safety standard for maximum residue limits (MRLs) of pesticides in food:[18] this standard, GB 2763-2021, includes specific MRLs for acetamiprid and imidacloprid in tea and banned several highly toxic pesticides that were previously used in tea production. Besides, the adoption of advanced agricultural technologies, such as drip irrigation and integrated pest management, with natural predators like *Trichogramma* wasps, is encouraged to enhance sustainability.[19] These technologies help reduce the environmental footprint of tea cultivation by optimizing resource use and minimizing chemical inputs.

Among the different policies, the Chinese government introduced voluntary sustainability standards (VSSs), which are designed to improve the social, environmental, and economic performance of tea farms and processing facilities.[20] This standard provides a framework for tea farms and processing facilities to implement sustainable practices, such as reducing chemical use, conserving water, and promoting fair labor practices. These standards focus on building climate resilience and improving the prices and incomes of smallholder farmers, and VSS-compliant tea now represents at least a quarter of total global production.[12] In 2019 was launched the China Tea Sustainability Standard (CTSS), a VSS developed by the China Tea Marketing Association in collaboration with the International Trade Centre, designed to be applicable to all types of tea producers in China, from small-scale farmers to large plantations. CTSS is part of broader sustainability initiatives in China's tea industry like the One Country One Priority Product (OCOP) China Tea Programme launched in 2024.[21] The CTSS aims to improve the sustainability of tea production in China by addressing environmental, social, and economic aspects of tea farming and processing. The CTSS focuses on reducing carbon emissions, promoting eco-friendly practices, minimizing the environmental impacts of tea production, ensuring fair labor practices, and improving conditions for tea workers and improving profitability and market access for tea producers.[13] The implementation of CTSS involves the following steps: self-assessment by tea producers, training and capacity building, third-party auditing and certification and, finally, continuous improvement. However, the implementation of the CTSS faces some challenges, such as: the diverse nature of tea production in China - ranging from small-scale farmers to large plantations -, the need for extensive training and capacity building (especially for smaller producers), as well as the cost of implementation and certification, which can be a barrier for some producers.

Despite these advancements, challenges persist, primarily due to the scale of the industry and the diverse practices among smallholders who may not have adequate resources or knowledge to implement sustainable methods effectively. Sustainable agricultural technologies in tea production in China aim to enhance productivity while minimizing environmental impact, but the adoption of

these technologies has been slow among farmers, primarily due to various socio-demographic, technological, and institutional factors that influence their decision-making processes.[22] Despite the potential benefits of new technologies, farmers often face challenges related to economic gains, environmental concerns, and the complexity of integrating new practices into existing systems. Ensuring compliance and extending modern practices to remote tea farming areas remains a significant hurdle.

Kenya

The Kenyan tea industry is a crucial component of the country's economy, representing one of its primary export commodities and a significant source of foreign exchange. Kenya is renowned for its black tea and is consistently ranked among the world's top tea exporters, competing with countries like China, India, and Sri Lanka. Tea production in Kenya is primarily concentrated in both parts of the Kenyan Highlands (East and West of the Rift Valley), where the climate and soil conditions are ideal for tea cultivation.[23] The industry involves both large-scale plantations and smallholder farmers, with the latter accounting for a significant portion of the country's tea production. It is estimated that more than 650,000 people live in tea-growing regions in Kenya. These farmers are crucial to the industry, yet they face numerous challenges that threaten their livelihoods and the sustainability of the tea sector. The Kenyan government, recognizing the importance of the tea sector, has implemented various initiatives to support and regulate the industry. In 2020, the Tea Act[24] introduced significant reforms aimed at improving the efficiency of the tea value chain and increasing returns for farmers. This act established the Tea Board of Kenya (TBK), which is responsible for regulating, developing, and promoting the tea industry.

Kenya's tea sector generates about 26% of the total export earnings and about 4% of gross domestic product (GDP).[25] Moreover, Kenya's tea production has shown remarkable growth in recent years: in February 2024, tea production reached 55.44 million kgs, a significant increase of 22.71 million kgs compared to the same period in 2023, according to the TBK.[26] According to the TBK,[27] tea exports generated approximately 120 billion Kenyan shillings (about $1.1 billion) in 2022, highlighting its importance to the national economy. This growth in production has been attributed to favorable rainfall patterns, highlighting the industry's dependence on climatic conditions. The Kenyan tea industry is particularly susceptible to the impacts of climate change, which manifests as unpredictable weather patterns and more frequent drought conditions, adversely affecting tea production. Soil degradation and the improper use of fertilizers further contribute to the declining quality and quantity of tea production. Additionally, the need for expansion of tea cultivation areas often leads to deforestation, which poses a direct threat to the local biodiversity and the ecological balance.[28] The tea industry in Kenya, therefore faces several sustainability challenges, including the impact of climate change on tea growing areas and the need for more environmentally friendly practices.

Sustainability has become a growing concern in the Kenyan tea industry as environmental issues such as deforestation, soil degradation, and water scarcity pose significant challenges. Additionally, social issues like fair labor practices and gender equality in the tea sector have gained attention in recent years.[25] To address these sustainability concerns, various initiatives have been implemented. The Kenya Tea Development Agency (KTDA), which represents smallholder farmers, has been working on implementing sustainable agricultural practices.[29] For instance, they have introduced a program to plant trees in tea-growing areas to combat deforestation and provide alternative fuel sources for tea factories. Planting of the trees is meant to provide a sustainable and inexpensive source of wood fuel as well as manage climate change by ensuring constant regeneration of cleared areas. The KTDA also sponsors the Farmer Field School (FFS), a series of annual classes covering best agricultural practices (soil preparation, planting, tea harvesting, pest control, fertilizer, etc.) and economic diversification (dairy and cattle farming, beekeeping, fruit farming, vegetable gardens) to train farmers. The courses are an important effort to empower farmers with the information they need to greatly improve their livelihoods, protect and nurture the environment, and create a sustainable tea value chain. More than 400 courses are currently underway in the 69 factories managed by KTDA. Besides, the KTDA and the factories it operates are constantly engaged in upgrades to maximize energy efficiency, which results in reduced energy costs and more money for growers. The factories have taken several initiatives, including regular energy examinations and replacing standard machine parts (such as wilting fans and motors) with high-efficiency ones, to reduce energy consumption. Factories are also insulating their steam systems to prevent heat loss and save on the amount of wood fuel used. Other initiatives include installing LED lights that consume less, training production staff on energy efficiency, and installing air preheaters in boilers, which help reduce wood fuel consumption by about five percent. The results have been good: the energy used to produce one Kg of tea, for example, decreased by 15% between 2013 and 2017.[30] Kenya's long-term development plan, *Vision 2030*, aims to transform Kenya into a newly industrialized, middle-income country. The agricultural sector is a key component of this vision: concerning tea. The project aims to increase the value of tea exports and promote Kenyan tea as a premium brand globally.

Furthermore, international cooperation and certification schemes, such as Rainforest Alliance and Fairtrade, have gained traction in the Kenyan tea industry. International cooperation includes the promotion of climate-smart agricultural practices, supported by international figures, which help improve resilience to climate change.[8] These certifications aim to promote sustainable and ethical practices in tea production and trade. However, challenges remain in fully implementing sustainable practices across the entire tea supply chain. Problems such as the high cost of certification for small farmers and the need for more robust monitoring of all farms and evaluation systems remain.

The ongoing efforts in Kenya aim to balance productivity with sustainability. However, similar to China, challenges such as the adoption of sustainable practices across all farmer segments, particularly smallholders who lack resources, remain prevalent.

Comparative Analysis

While both China and Kenya are pivotal in the global tea market, their approaches to sustainability and environmental management differ significantly, reflecting their unique socioeconomic and geographical settings. China produces a wide variety of teas, including green, black, oolong, white, and pu-erh teas. In contrast, Kenya, despite being a younger player in the global tea market, has established itself as the world's largest exporter of black tea, specializing primarily in black tea. While China leads in production, Kenya outperforms in terms of export volume for black tea. Kenya exports about 95% of its tea production, making it more export-oriented than China, which has a large domestic market. A mix

of large-scale state-owned plantations, private enterprises, and smallholder farmers characterizes the Chinese tea industry. In Kenya, the industry is dominated by smallholder farmers, who account for about 70% of the country's tea production, with the rest coming from large estates. Both countries have recognized the importance of sustainability in their tea sectors. China has implemented the China Tea Sustainability Standard, focusing on environmental protection and social responsibility. China is using technological innovations, including advanced agricultural techniques and mechanization, integrated into the tea production process to increase efficiency and reduce environmental impact. The use of precision agriculture, such as satellite imaging and drone technology, helps in monitoring crop health and optimizing resource use. Kenya, on the other hand, through organizations like the KTDA emphasizes community engagement and international cooperation. Initiatives often involve grassroots movements and partnerships with global organizations to implement sustainable practices tailored to smallholder farmers' needs, such as agroforestry and organic farming.

The *Belt and Road Initiative* (BRI), launched by China in 2013, aims to enhance regional connectivity and economic cooperation.[31] While not specifically focused on tea, this initiative has implications for the global tea industry as the BRI has led to increased investment in infrastructure in partner countries, which could benefit the tea trade.[32] In particular, as part of the BRI, China has invested in infrastructure projects in Kenya, such as the Standard Gauge Railway; while not directly related to tea, improved transportation infrastructure could benefit tea logistics and exports. Similarly, the *Maritime Silk Road Initiative* has increased the flow of goods from East Africa, including tea from Kenya to other BRI countries.

Conclusion

The tea supply chains of China and Kenya, while presenting significant differences in scale, variety, and market orientation, both play a crucial role in their respective national economies and the global tea market. This comparative analysis has revealed several key aspects of the challenges and opportunities facing these two tea powers. China has implemented initiatives to address environmental and social issues in its tea sector, bringing improvements within the agricultural sector. Kenya has focused on improving the livelihoods and production of its smallholder farmers while pursuing sustainability certifications to meet international market demands. Both countries have recognized the importance of sustainability in their tea sector, as evidenced by China's CTSS-OCOP and Kenya's adoption of several actions moved by the KTDA. However, it is critical to recognize that the implementation of environmental sustainability measures is often subordinate to socioeconomic interests and food production, which are vital to the development of both countries.

In China, the rapid economic growth and the need to maintain its position as the world's largest tea producer have sometimes overshadowed environmental concerns. The country's vast tea-producing regions face challenges such as soil degradation, water scarcity, and the overuse of agrochemicals. While the CTSS aims to address these issues, its implementation across the diverse and expansive Chinese tea industry remains a significant challenge. Similarly, in Kenya, where tea is a major foreign exchange earner and a source of livelihood for millions of smallholder farmers, economic considerations often take precedence over environmental sustainability. The pressure to increase yields and maintain competitiveness in the global market can lead to practices that may not be environmentally optimal, such as the expansion of tea cultivation into ecologically sensitive areas. The tension between environmental sustainability and socioeconomic development is further exemplified in both countries' national development strategies. China's Belt and Road Initiative, while not specifically focused on tea, prioritizes economic cooperation and infrastructure development, which may indirectly impact environmental considerations. Kenya's Vision 2030, while acknowledging the importance of sustainable development, places a strong emphasis on economic growth and industrialization, potentially creating conflicts with environmental conservation efforts. However, it is important to note that both countries are increasingly recognizing that long-term economic sustainability is intrinsically linked to environmental sustainability. Climate change, for instance, poses a significant threat to tea production in both China and Kenya, potentially affecting yields, quality, and the livelihoods of millions of farmers. This realization is gradually leading to more integrated approaches that attempt to balance economic growth with environmental protection.

In summary, while China and Kenya have made progress in implementing sustainability measures in their tea industries, the path to truly sustainable tea production remains challenging. While prioritizing socioeconomic interests and food production is crucial for development, it often comes at the expense of environmental concerns. In the future, it will be essential for both countries to find innovative ways to reconcile economic growth and environmental sustainability in their tea sectors.

Ethical Review

This article does not contain any studies with human participants or animals performed by any of the authors.

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