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REVIEW

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The long road to a sustainable banana trade

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Societal Impact Statement

Bananas are the world's most popular dessert fruit and a staple starch crop for millions in low- and middle-income countries. The banana export trade that supplies North America, Europe, and other wealthy nations has a history fraught with exploitation and conflict. The price of cheap bananas has been environmental degradation, violence, and poverty. Only recently have efforts to address the power imbalances in this trade been made. Voluntary certification schemes aim to address multiple sustainability issues, while research into biological control, accelerated plant breeding, and efficient irrigation will help prepare the industry for emerging threats from pests, diseases, and climate change.

Summary

Bananas are the world's favorite dessert fruit, a staple starch crop for millions, and an important source of income for producers across the tropics and subtropics. Bananas evolved and diversified as giant perennial herbs of open habitats within the humid forests of Southeast Asia and West Oceania and were domesticated around 7000 years BP through a series of hybridization events. This review considers the journey from rainforest riversides to intensively managed monoculture plantations, focussing on the Cavendish banana that comprises nearly the entire global export trade. Climate change increasingly threatens economic sustainability in several major producer regions, requiring responses such as efficient irrigation systems to maintain productivity and water security. Pests and diseases are spreading globally and have severe direct impacts on production as well as indirect impacts via harm to ecological and human health caused by pesticides. New pest and disease management methods employing biological controls and enhancing soil health and new plant breeding techniques must be developed and implemented. The banana production and trade system has been characterized by power imbalances between international firms that own plantations and supply the market and the local agricultural workers who cultivate and harvest the fruit. Voluntary certification schemes have been developed to address the numerous environmental, social, and economic sustainability issues faced by the industry. There are indications, from research on biological disease control to new deals on wages and benefits for banana workers, that change is slowly coming to the global banana trade.

KEYWORDS
climate change, Fairtrade, organic, rainforest Alliance, regenerative agriculture, soil health, sustainable agriculture, voluntary certification scheme

1 | ORIGIN AND DOMESTICATION

Bananas and plantains are the fruit of species, hybrids, and cultivars in genus *Musa* of the family Musaceae. The Musaceae comprises three genera, *Musa*, *Ensete*, and monospecific *Musella*, of which *Musa* is the most diverse with over 75 described species and subspecies (Häkkinen, 2013; Kallow et al., 2021; Mertens, Swennen, et al., 2021). Banana plants are giant perennial herbs and grow as underground stems, or rhizomes, from which emerge pseudostems composed of tightly packed leaf sheaths ending in large, undivided leaf blades. In the wild, banana plants are found in open areas of Asian humid tropical forests, such as riverbanks (Itino et al., 1991). Bananas are monoecious, with female flowers appearing laterally on the flowering stalk and male flowers at the end. Wild banana species select bird or bat pollinators by flower morphology, color, and timing of access to nectar and pollen (Itino et al., 1991). The fruits are elongate berries with numerous seeds, with the fruit on a single stalk, or peduncle, comprising a bunch. Seeds are dispersed by bats and other mammals (Meng et al., 2012).

Genus *Musa* originated and diversified in northern Indo-Burma during the late Eocene, spreading south east across Southeast Asia and Oceania during the Oligocene and Miocene (Janssens et al., 2016). Species distribution models using biogeographic data on 59 wild species suggest high species richness in the northeast India, northern Indo-Burma, peninsular Malaysia, Sulawesi, lowland Borneo, and northern New Guinea (Mertens, Swennen, et al., 2021). While there are many *Musa* species, only two are important in the story of banana domestication: *M. acuminata* and *M. balbisiana* (Perrier et al., 2011). The haploid genomes of these two species are commonly coded A and B, respectively, and diploid genomes AA and BB. A small number of edible bananas, such as the vitamin A-rich Fe′i banana (*M.* × *troglodytarum* L.) found on South Pacific islands (Englberger et al., 2006), have been domesticated from other progenitors, for example, *Musa maclayi*. Wild *M. acuminata* is diverse, with several subspecies distributed across Southeast Asia, Papua New Guinea, and northeastern Australia (Kennedy, 2008; Mertens, Swennen, et al., 2021; Perrier et al., 2011). *M. balbisiana* is distributed from northern India across Indochina to southern China. Genomic, archeological, and linguistic evidence suggests that domestication began during the Holocene (around 7000 years BP) as human populations moved and interbred *M. acuminata* subspecies to form diploid AA cultivars (Perrier et al., 2011). Hybridization contributed to gametic sterility and parthenocarpy, meaning that the fruits lost their numerous inedible seeds and became highly palatable. Hybridization also resulted in erratic meiosis, sometimes generating diploid gametes that could result in triploid or tetraploid hybrids. The sterile hybrids were propagated vegetatively, leading to further somaclonal diversification.

Genomic analyses indicate that *M. acuminata* subsp. *banksii*, from New Guinea, is among the most important contributor to banana cultivar diversity, including the AAA East African Highland Banana and the AAA Cavendish, the raw material of the international banana trade. Gros Michel, the variety previously used in the international trade, is closely related to Cavendish (Hippolyte et al., 2012). *M. balbisiana* contributed to important cultivars like plantain (AAB) with very high diversity and importance as a staple food in Central and West Africa, Bluggoe (ABB) used primarily in cooking, and Pome bananas (AAB) grown as dessert fruit. Intraspecific and interspecific crosses gave rise to a diverse range of genetic compositions, including Lady Finger (AA), Nei Poovan (AB), Golden Beauty (AAAA), and Goldfinger (AAAB). Recent genomic analyses have shown that the story of banana domestication is more complex than simple combinations of A and B gametes. For example, the Cavendish genome is composed of contributions from four ancestral groups, with individual chromosomes composed of mosaics of sequences of diverse origin (Martin et al., 2020). Hence, the origin of cultivated bananas likely involved multiple hybridization and backcrossing events resulting in mosaic genomes with recombinant chromosomes (De Langhe et al., 2010; Martin et al., 2020). Banana phytoliths at archeological sites in Cameroon demonstrate that bananas had reached Africa by 2700 to 2100 bp (Perrier et al., 2011). Less is known about the arrival of bananas in Latin America, though Alexander von Humboldt believed that this had occurred long before the Spanish conquest (Browne, 1944).

2 | THE INTERNATIONAL BANANA TRADE

Today, bananas (including plantains and other cooking varieties) are grown across the tropics and subtropics, with around 150 million tonnes produced per annum (FAOSTAT data, 2011–2020 mean, "banana" and "plantain and other" categories). In context of other fruit, this puts global banana production between apples (83 million tonnes per year) and tomatoes (174 million tonnes per year). Bananas are therefore arguably the world's most important "fruit" in the sense of a sweet dessert crop, with the caveat that in many countries bananas are cooked and eaten as a starchy staple, for example, the East African Highland Banana in Uganda. By far the most important producer is India (29 million tonnes per year) followed by China (11 million tonnes per year). The only banana cultivar exported in any quantity is Cavendish, of which around 50 million tonnes are produced each year, and over 20 million tonnes are exported (Voora et al., 2020). The most important exporters are Ecuador, the Philippines, Guatemala, Costa Rica, and Colombia, while the EU and the United States are the most important importers. The trade is worth around US$11 billion, greater than any other exported fruit (Voora et al., 2020).

The global banana trade has a fraught history. Economic exploitation of Latin American nations by corporations like the United Fruit Company in the early 20th century created "Banana Republics", run by corrupt governments and controlled by foreign economic interests (Moberg, 1996). In December 1928, banana workers of the United Fruit Company in Ciénaga, Colombia, went on strike for better pay and conditions in line with Colombian labor laws (Elias Caro & Vidal Ortega, 2012). The Colombian army, sent to disperse the strike, opened fire on unarmed protesters killing hundreds. The influence of corporations has continued. In 2007, Chiquita Brands International (formerly United Fruit) was fined by the US Department of Justice for illegal payments made to Colombian paramilitary groups (Department of Justice, 2007), while the Colombian government continues to investigate involvement of transnational banana companies in similar activities. Wageworkers in banana plantations remain poorly paid and at risk of violence, even where certification schemes aim to improve conditions (Brown, 2013).

Somewhat surprisingly, bananas were the cause of one of the longest multilateral disputes in international trading history (WTO, 2012). Before 1992, European nations individually set their own banana import regimes, which varied from a completely free market in Germany to significant tariffs and quotas imposed on Latin American producers by the UK and others (Patterson, 2001). The purpose of these tariffs, formalized via the Lomé Convention, was to help protect small-scale producers in former European colonies like the Windward Isles from competition of cheaper imports from the large, industrial plantations of Latin America (Raboy et al., 1995). In 1993, a complex EU-wide regime that imposed heavy duties on non-ACP (African, Caribbean and Pacific) nations was implemented, starting a trade dispute between the EU on one side and the United States and major Latin American producers on the other. Following major donations by Chiquita Brands International, the Clinton Administration in the United States, along with several Latin American countries, initiated legal proceedings via the US Trade Representative and the World Trade Organization (WTO) (Patterson, 2001). Though the EU amended its regime, the United States eventually instigated 100% tariffs on a range of EU export goods, from French cheese to Scottish cashmere, amounting to $520 million per year—the estimated losses to US-based companies resulting from failure of the EU to comply with WTO rulings. The dispute was finally resolved in November 2012, when the EU agreed to gradually reduce tariffs on Latin American bananas to US$75 per tonne in 2020 (WTO, 2012).

With thousands of edible cultivars and somaclonal varieties of banana available, it is perhaps surprising that the international trade relies on only one at a time. Partly, this is due to economies of scale. Monocultures are easier to manage, and identical plants and fruits are easier to plant, grow, harvest, process, and transport (Figure 1). Low retail price in comparison with domestically produced fruit has always been the attraction of imported bananas for consumers. The other reason is that very few banana varieties can be shipped long distances without perishing. Cavendish is relatively robust to postharvest mechanical and biological damage, with well-defined ripening properties (BMT, 2022). Though attempts have been made to develop

FIGURE 1 A Cavendish banana plantation in Latin America. Note the blue plastic bags covering the bunches. Credit: D. P. Bebber

systems for the international trade of other varieties (e.g., Ketsa & Wongs-aree, 1998), Cavendish remains the industry choice. Bananas have been transported in refrigerated ships ("reefers") since 1889, famously in United Fruit's Great White Fleet painted white to minimize solar gain. Since the 1970s, bananas have been shipped in refrigerated containers with integrated cooling units. Cavendish bananas are harvested green and must be maintained at between 13.2°C and 14°C to prevent transition to the climacteric stage during which the fruit emits ethene and ripens but not below 13°C which induces chilling injury (BMT, 2022). Transatlantic shipping from Colombia to Europe takes 10 to 14 days. Ripening is induced artificially in ripening rooms using ethene until they begin to yellow, at which point they are distributed for wholesale and retail. Bananas are usually treated with fungicides to reduce postharvest losses and wrapped in polyethene bags to reduce oxygen and elevate humidity and carbon dioxide, extending the green life stage. Plastic wrapping is also used to protect developing bunches on the farm (Hernandez & Witter, 1996). Reliance on plastic bags presents a significant sustainability challenge which is starting to be addressed by the industry through recycling (Fresh Plaza, 2020) and compostable plastics (Compagnie Fruitière, 2018). The carbon footprint of export bananas is very low in comparison with other foods and comparable with other fresh fruit (Poore & Nemecek, 2018). This is because shipping is far more efficient than road haulage and international transport adds little to total emissions (Li et al., 2022). Ensuring that container ships are full on return journeys and switching from ammonium nitrate to urea fertilizer have been proposed as means to reduce the carbon footprint of banana production still further (Iriarte et al., 2014).

3 | THREATS FROM CLIMATE CHANGE

Cavendish bananas are able to grow in mild subtropical climates (e.g., the Canary Islands) and at very high temperatures given sufficient water (Carr, 2009). Optimal mean annual growing temperatures are estimated at between 20°C and 30°C, with a global optimum of around 27°C (Varma & Bebber, 2019). Bananas are grown successfully in regions with seasonal temperatures exceeding 45°C, such as Sindh, Pakistan (Dahri et al., 2020), but have a lower thermal limit of around 10°C (Turner & Lahav, 1983; Varma & Bebber, 2019). Annual water requirements vary between around 1000 and 2000 mm depending on climate (temperature and humidity) and other factors (Carr, 2009; Varma & Bebber, 2019). Changes in annual temperature and rainfall since the 1960s have had varying effects on banana yields around the world. African production appears to have benefited as have many countries in Latin America, but Brazil and Southeast Asian yields have been negatively impacted (Varma & Bebber, 2019). Climate projections suggest that African production will continue to benefit in coming decades, while important producers like India, Costa Rica, and Colombia will be increasingly negatively affected as temperatures begin to exceed optima for banana production. Extreme climate events like hurricanes can also disrupt banana production for many months (Huigen & Jens, 2006; Varma et al., 2020), and the intensity of such events may be increasing (Knutson et al., 2021).

While climate-driven trends in yields are apparent, statistical models suggest that other, presumably anthropogenic, factors have had much greater influence (Varma & Bebber, 2019). For example, Indonesian yields increased dramatically between 1980 and 2000 in the absence of significant climate change benefits, while Colombian yields declined. Technologies and management methods such as intensive monoculture, fertilization, use of more productive varieties, tissue culture to ensure clean planting material (Kabunga et al., 2012), pest and disease control, optimization of planting density, and irrigation likely explain these nonclimate yield trends. Banana growth and yield are highly sensitive to soil water deficit; hence, irrigation is common in dry or seasonally dry regions. However, the benefits of different irrigation methods and regimes remain poorly understood, with earlier studies often providing unclear results (reviewed in Carr, 2009). More recent research has shown that technologies such as sensor-based automated drip irrigation can reduce water use while increasing yields, compared with manual or timed irrigation (Panigrahi et al., 2019). Low cost sensor-based systems, suitable for low- and middle-income countries, are being developed (Nallani & Hency, 2015).

4 | THREATS FROM PESTS AND DISEASES

Nonclimatic yield trends are also likely to have been driven by investment in disease control and management. Banana production is beset by numerous pests and pathogens. Black sigatoka, or black leaf streak disease, caused by the fungus *Pseudocercospora fijiensis*, is the most important foliar disease of banana (Marín et al., 2003; Ploetz, 2001). The disease was first reported from Fiji and has since spread across the tropics, perhaps encouraged by climate change (Bebber, 2019). The Latin American invasion began in Honduras in 1972, likely on infected plants from Asia imported for a banana breeding program (Robert et al., 2015). Control of the disease is via frequent fungicide or mineral oil spray applications, though fungicide resistance appears frequently (Marín et al., 2003). Black sigatoka limits the implementation of organic production without foliar fungicides, to drier climates like those found in La Guajira, Colombia, and the Dominican Republic, the latter producing more than half of the world's organic bananas. Other major pests and diseases of banana include banana weevil, xanthomonas wilt, burrowing nematode, moko, and bunchy top virus (Ploetz et al., 2015). Banana diseases appear to be spreading internationally more rapidly than those of other crops (Bebber, 2015). Post-harvest losses to anthracnose and crown rot (caused by the fungus *Colletotrichum musae* and others) can be significant, particularly as fruit for export must be entirely free of blemishes (Alvindia & Natsuaki, 2008).

Perhaps the most well-known disease is Fusarium Wilt, or Panama Disease, caused by the soilborne fungus *Fusarium oxysporum* f.sp. *cubense* (Foc). Foc infects banana plants via the roots, blocking the xylem vessels and killing the plant, which releases further fungal inoculum into the soil (Dita et al., 2018; Pegg et al., 2019). The fungus originated in South East Asia and comprises a range of genetic races, which are virulent against different banana cultivars (Mostert et al., 2017; Ploetz, 2021; Ploetz & Churchill, 2011). Before the 1960s, the AAA Gros Michel cultivar made up most of the international trade, but Foc Race 1 made commercial production of this variety untenable. Fortunately, the resistant Cavendish variety was available to take Gros Michel's place, until the rise of Tropical Race 4 in the 1970s and its subsequent spread across Southeast Asia, South Asia, the Middle East, East Africa, and, most recently, Colombia and Peru (Ploetz, 2021). Being soilborne, Foc is hard to eradicate, and there are no alternative tradeable banana varieties which can replace Cavendish. Efforts are underway to develop nonchemical controls for TR4. In China, farmers have noticed that underplanting bananas with a species of leek, *Allium tuberosum*, appears to prevent infection by Foc (Huang et al., 2012). Root exudates of this plant contain a number of constituents, particularly dimethyl trisulfide, that dramatically reduces Foc spore viability and fungal growth (Zuo et al., 2015). Large numbers of potential microbial biocontrols for TR4, both endophytic and soilborne, have been identified from laboratory and field trials (Bubici et al., 2019). For example, combining a *Bacillus amyloliquefaciens* isolate from a Foc-suppressive soil with a bioorganic fertilizer decreased disease incidence by more than half and doubled yield (Xue et al., 2015). Microbial biocontrols also offer a promising alternative to chemical fungicides for other banana diseases, including postharvest losses to fungal rots (Alvindia & Natsuaki, 2008). Though TR4 is feared as an existential threat to commercial banana production, much remains to be learned about the potential impact of this disease. For example, the Philippines has maintained relatively stable yields over recent years, despite the presence of TR4 across a large fraction of the production area (Montiflor et al., 2019).

Pests and diseases present an important sustainability risk to banana production, through direct impacts of agrochemicals on the environment, yield losses that increase area required for production, and health risks to banana workers. In the 1950s, accumulation of copper in soils treated with Bordeaux mixture rendered the entire Pacific coast production area of Costa Rica toxic to banana cultivation (Thrupp, 1991). United Fruit abandoned the area, and today bananas are only grown on Costa Rica's Caribbean coast. The manganese-based fungicide Mancozeb has been key to Black Sigatoka control across Latin America and the Caribbean, where its breakdown products manganese and Imidazolidine-2-thione (ethylene thiourea, a teratogen and probable human carcinogen) have contaminated soils and surface water (Geissen et al., 2010; van Wendel de Joode et al., 2016). The majority of contact dermatitis cases in Panamanian banana plantation workers examined in the late 1980s and early 1990s were caused by various fungicides (Penagos, 2002). Agrochemical use by indigenous producers in Costa Rica tends to be greater in export banana production than in plantain production for local markets (Polidoro et al., 2008). In the French West Indies, populations were still contaminated with the toxic organochlorine pesticide chlordecone many years after its use in banana plantations ceased (Multigner et al., 2016).

5 | ROUTES TO SUSTAINABILITY

Given the inherent vulnerability of monocultures to the combined threats of climate change, pests, and diseases, diversification of planting stock should be a priority. Numerous Cavendish somaclones are grown for international export, including Grande Naine, Williams, and Valéry, which differ in plant height, fruit shape, yield, and physiology (Robinson et al., 1993). For example, Grande Naine is reported to be less vulnerable to windthrow than Valéry, with a more upright canopy allowing denser planting (Stover, 1988). Though some tissue culture variants have been promoted as tolerant to Foc TR4, this has not been supported in independent trials (Dale et al., 2017). Breeding of new banana varieties is time-consuming and labor intensive, largely because of hybrid sterility issues. For example, an improved hybrid of the East African Highland Banana took more than two decades to develop, test, and release to farmers (Batte et al., 2019). New plant breeding techniques involving genetic modification offer the opportunity to accelerate this process (Zorrilla-Fontanesi et al., 2020). An important consideration is the reluctance in many markets to accept transgenic produce, that is, plants containing genes of other organisms. One way to avoid this is to employ direct gene editing using CRISPR-Cas that could knock out disease susceptibility genes, or perhaps even 'knock-in' disease resistance genes through modification of paralogs. Breeding or genome editing for complex traits such as drought resistance is likely to be more difficult than disease resistance (A. Brown et al., 2020). Phenotypic targets for breeding might include leaf size and epicuticular wax composition, stomatal density and behavior, and the root system architecture. Though the "B" genome has been implicated in drought tolerance, other factors such as the presence of endogenous viral sequences limit its utility in breeding. Certain genetic transformations have resulted in enhanced drought tolerance, though these remain untested in the field (A. Brown et al., 2020). Given the lack of genetic variation within domesticated bananas (Dempewolf et al., 2017), wild banana species could harbor beneficial traits for generating new disease- and climate-resilient varieties (Mertens, Bawin, et al., 2021). For example, recent collections of *M. acuminata* ssp. *banksii* from Papua New Guinea showed significant variation in traits related to drought avoidance (Eyland et al., 2021). However, natural forests across Southeast Asia have faced rapid rates of deforestation which must be halted to preserve remaining biological and genetic diversity (Estoque et al., 2019). Another potential risk to breeding new bananas is declining expertise in banana biology and breeding (Dempewolf et al., 2017).

Growing concern social and environmental awareness among consumers, and aversion to reputational risks among retailers, has resulted in the establishment of several voluntary certification schemes for agricultural products. The schemes establish a range of criteria around social, economic, and environmental sustainability against which producers are then graded by registered certification agencies (DeFries et al., 2017). Producers pay a fee for the certification process and receive price premiums and potentially market access in reward for meeting sustainability standards. The first certification standard was Organic, established in 1972 by the International Foundation for Organic Agriculture (IFOAM). Organic certification focusses on replacement of agrochemical fertilizers and pesticides with organic fertilizers (e.g., manures and composts), biological disease control, crop rotation, and other methods that maintain soil health and ecosystem services (Reganold & Wachter, 2016). Rainforest Alliance certification was established in 1987 and includes a broader range of criteria including ecosystem and wildlife protection, water conservation, good working conditions, occupational health and safety, and community relations. Fairtrade International, established 1997, focusses on ensuring that producers receive prices that cover the costs of sustainable production via a Fairtrade Premium. This premium amounts to US$55 per tonne and is designed for business and community investment. Fairtrade standards cover social, economic, and environmental development and vary depending on the industry sector and crop considered. Fairtrade covers a slightly smaller fraction of banana production than Organic. By far the largest certification system in terms of area is GLOBALG.A.P. (established 1997), a business-to-business system designed to provide retailers with assurance on issues of food safety, environment, occupational health and safety, and quality management. GLOBALG.A.P. has become virtually mandatory for producers to enter certain markets, especially the EU (Fiankor et al., 2020). In 2018, 5.2% of the total global harvested banana area was certified by GLOBALG.A.P., 2.9% by Rainforest Alliance, 1.3% by Organic, and 0.7% by Fairtrade, amounting to a total of 6%–10% of global production area depending on the amount of multiple certification occurring (Meier et al., 2020). Demand for certified bananas is growing, but the certified production area lags some way behind crops like cocoa (27%–44%) and coffee (21%–40%).

Voluntary sustainability standards are detailed and exhaustive, placing a significant administrative burden on producers, as well as the financial cost of auditing and certification itself. For example, the Rainforest Alliance Sustainable Agriculture Standard farm requirements alone run to over 80 pages. Given these costs, the realization of financial and other benefits is an important consideration. Whether certification results in improved market access and sustainability outcomes remains an open question, which can be difficult to answer due to the difficulties in disentangling the direct impacts of certification standards from potential confounding effects of nonrandom entry into certification schemes by producers, that is, producers with preexisting high standards may be more likely to become certified (van Rijn et al., 2020). A systematic review of the evidence that voluntary certification achieves sustainability goals for small-scale producers found only two studies (both on Fairtrade) of banana production that were sufficiently unbiased for consideration (DeFries et al., 2017). There is little published evidence for the effectiveness of Rainforest Alliance certification, though one relatively small study found no benefits of certification for biodiversity metrics (Bellamy et al., 2016).

To overcome selection bias and confounding variables in their analysis of Fairtrade certification, van Rijn et al. (2020) included nearby paired noncertified farms and a number of statistical techniques to control for biases in variables such as worker age, migrant status, and education level. The majority of banana plantation workers in the Dominican Republic are undocumented migrants from Haiti, limiting their access to social security. In addition, wages for banana workers, though above the minimum wage, are insufficient according to the living wage definition. Hence, Fairtrade certification could play an important role in improving worker conditions. However, the analysis revealed a mixed picture regarding economic and social effects of certification. While wages and perceptions of job security did not differ between Fairtrade and uncertified farms, in-kind benefits such as education, transport, and healthcare were clearly linked to Fairtrade certification (van Rijn et al., 2020). Variation in social benefits such as sense of ownership, job satisfaction, and in-house training could be attributed to certification, while differences in paid leave, awareness of policies regarding workers rights, and dialog with co-workers and managers could not. The efficacy of Fairtrade certification is likely to vary depending on the local social and political context. In Colombia, for example, Fairtrade may have been ineffective against a sometimes violent anti-union environment (S. Brown, 2013). However, it is worth noting that SINTRAINAGRO, Colombia's agricultural union and the largest labor union in Latin America, recently negotiated pay increases and other benefits for banana workers.

Bonisoli et al. (2019) applied the FAO Sustainability Assessment of Food and Agriculture (SAFA) methodology to compare Organic-certified with conventional banana production in Ecuador. The analysis suggested that Organic farms had better scores in certain aspects of governance, environmental, and economic sustainability but poorer outcomes in social dimensions such as fair trading, labor rights, and equity. Biodiversity scores were poor for both farm types, due to the intensive, monoculture production system. However, the Organic farms were small (mean area 6.6 ha) and sold to the Western European market, whereas the conventional farms were large (mean area 43 ha) and sold to the Eastern European market. These biases preclude confident conclusions on the role of certification in determining sustainability outcomes. The role of voluntary certification in improving access to markets was investigated using gravity models, which are econometric models estimating trade flows from economic sizes of, and distances between, trading partners (Fiankor et al., 2020). The models revealed positive and significant increases in apple and grape exports with increasing GLOBALG.A.P. certification but very little effect for bananas. Fiankor et al. (2020) suggest that this lack of observed response may be due to low producer capacity to respond to demand, supply chain issues like shipping delays, competition from the other certification schemes, and the influence of the large, vertically integrated banana firms (Chiquita, Dole, Fyffes, Del Monte etc.) that may have their own standards.

6 | A SUSTAINABLE FUTURE?

Bananas evolved to exploit sunny spaces in the humid forests of Southeast Asia and have been part of the human diet for thousands of years. Bananas are now one of the most important traded commodities and staple foods. The export trade was designed to supply bananas to consumers in Europe and North America as cheaply as possible, whatever the cost to the countries and people producing them. These costs are still borne today, with agricultural workers often earning below the living wage and experiencing poor working conditions in some regions, while soils and waterways are degraded by agrochemicals. These externalized costs must be internalized and passed on to consumers, if these sustainability issues are to be

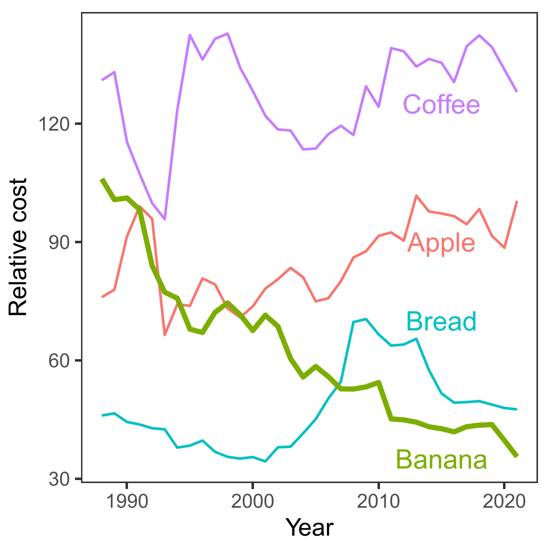

FIGURE 2 Relative retail cost of bananas (green) compared with coffee (purple), apples (red), and bread (blue) in the UK. Prices are scaled to the Consumer Price Index (CPI), where CPI in 1988 is scaled to 1. Data are from the UK Government Office of National Statistics. Prices are pence per kg for bananas and apples, per 100 g for instant coffee, and per 800 g sliced white loaf. Banana retail price has declined to around one third of 1988 level in real terms, while costs of other items have increased slightly.

addressed. However, export bananas are becoming ever cheaper while the cost of other foods and imported commodities has increased (Figure 2). Voluntary certification schemes like Fairtrade may be one way to achieve this, but evidence for their efficacy remains sparse and equivocal in the academic literature. Given the financial and administrative expense of certification, better evidence on what works and what could be improved is urgently required, not least to improve consumer confidence in the labels they are choosing. The principals of regenerative agriculture, which emphasizes improvement in soil health and ecosystem services through methods such as reuse of organic wastes in production (Fiallos-Cárdenas et al., 2022), should be implemented. Lessons could also be learned from biodiverse agroforestry systems that grow bananas for local consumption (Zorrilla-Fontanesi et al., 2020). Such systems employ cover crops that can suppress weeds, pests, and diseases and also spread financial risk and reward among many food crops. Though reducing photosynthetic rates and thus yield through shading, other benefits like reduced impact of Black Sigatoka toxins might be gained (Busogoro et al., 2004). Finally, the power dynamics of the industry must be rebalanced to give workers a stronger voice. Recent developments in Colombia offer hope in this direction. Banana consumption in Europe and North America is not growing, and it is unlikely that consumers will want to eat more bananas. However, given recent growth in sales of certified bananas, they may wish to eat better ones.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHOR CONTRIBUTIONS

D.B. conceived and wrote the manuscript.

DATA AVAILABILITY STATEMENT

The UK Government consumer price inflation (CPI) time series data (dataset ID MM23) are available online (https://www.ons.gov.uk/economy/inflationandpriceindices/datasets/consumerpriceindices).

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