



Arabica Coffee: Cultivating Connection and Climate Resilience

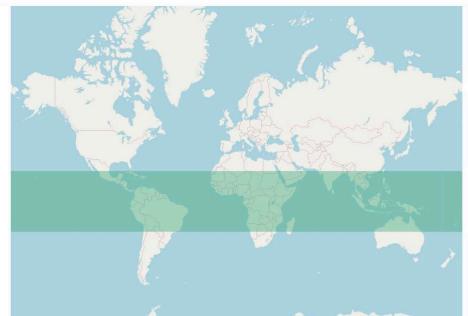
Nina Foster

Coffee is one of the world's most important agricultural commodities, supporting the livelihoods of an estimated 125 million people.¹ With more than 120 species in the genus *Coffea*, one in particular has dominated global production, trade, and consumption, and is prized for its impeccable cup quality: Arabica coffee (*Coffea arabica*). The plant historically accounted for at least two-thirds of the world's coffee production, though the second-most cultivated coffee species, robusta (*Coffea canephora*), is on the rise.²



Plate V
Coffea arabica branch. Hand-color...

Endemic to the highlands of Ethiopia, southeastern Sudan, and northern Kenya, Arabica coffee thrives in humid, montane forests in tropical areas.³ Glossy, evergreen leaves adorn the tree's branches, and clusters of small white flowers give way to oval, fleshy fruits, each containing the two pale seeds we call coffee beans. Through networks of trade and conquest, the plant has traveled across the tropics, where conditions are ideal for coffee cultivation. Today, Brazil, Colombia, and Ethiopia rank among the leading producers of the crop.⁴



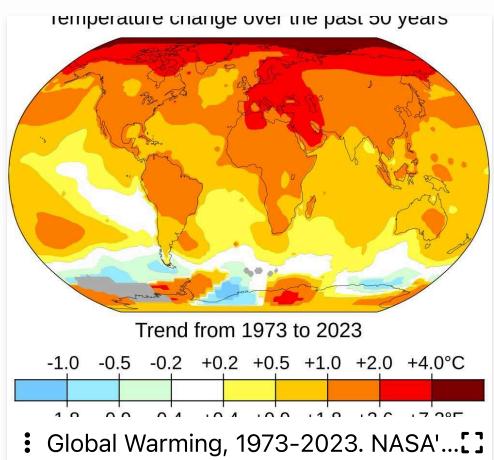
Map of the tropics, where condition...

Arabica became an agent of connection and community building where it was grown and, further down the supply chain, where it was consumed. Coffeehouses have served as centers of intellectual and cultural exchange for centuries. Countless relationships have been sparked by the question, "Do you want to meet for coffee?" Between planting, harvesting, processing, milling, roasting, and every other step of production and distribution, coffee is touched by at least nine sets of hands before it reaches the consumer.⁵



• Coffee Process From Tree to Cup!

Demand for coffee continues to grow, but the future of the industry is uncertain. In addition to concerns over price volatility and labor conditions on coffee farms, Arabica coffee is especially vulnerable to climate change and its associated impacts, such as rising temperatures, altered precipitation, and increased pressure from insect pests and plant pathogens. Researchers have proposed a number of solutions to protect the plant and other coffee species, each with unique benefits and challenges. These suggestions, if implemented thoughtfully and collaboratively by industry stakeholders, can help safeguard coffee production—and with it, the enduring legacy of a rich global history.



• Global Warming, 1973-2023. NASA!

From Ethiopia to the World

The early years of coffee consumption are shrouded in mystery. Most coffee historians have encountered the legend about an Ethiopian goat herder named Kaldi, who noticed his livestock became more energetic after eating the fruits from a coffee plant.⁶ Intrigued, he tried the fruit for himself and felt a thrilling rush of vitality. As the story goes, Kaldi shared his findings with monks at a nearby monastery, initiating coffee's rise to fame.



• The Kaldi Story

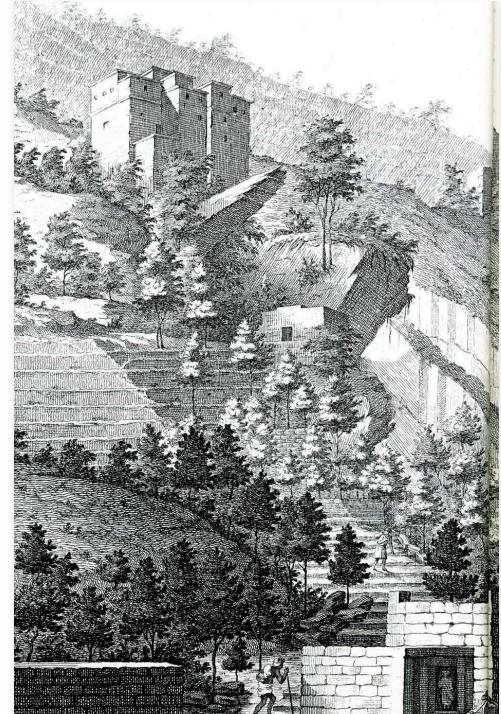
It is believed that Kaldi's alleged discovery of coffee dates to the ninth century, but the earliest written record with any resemblance to the myth appears much later. Mehrej Ibn Nimirūm, a Maronite scholar and priest also known as Antonio Faustus Naironi or Banesius, was the first to reference the legend in his 1671 treatise on coffee's history and virtues.⁷ Instead of Ethiopia, the story is set in Yemen, where Arabica arrived as early as the sixth century.⁸ Nimirūm describes a man who complained to monastics that his livestock—camels in some variations, goats in others—were "frisking and dancing" instead of sleeping.⁹ The head of the monastery purportedly visited the pasture and, after locating the fruits upon which the livestock fed, "resolved to try the virtues of these berries himself; thereupon, boiling them in water, and drinking thereof, he found by experience, it kept him awake in the night."¹⁰ He then told his fellow monks about the beverage, offering revitalization in their pursuit of the divine.

44G @ 418
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them Hurf, they chose rather to quench
their Thirst with Water. It happened,
as they were going away, they met
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the Wine, believing it better for him
to die than live in such Misery. But
as soon as he had drank of the Wine,
he recovered in a wonderful Man
ner. From hence came the Use of f
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This, as Galenicks was Experience
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the Drinking the Liquor call'd Ghee
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A discourse on Coffee: its descrip-

The history of coffee solidifies around 1450, when Sufi practitioners in Yemen reported using the beverage to aid their concentration in prayer.¹¹ In the sixteenth century, the Ottoman state harnessed coffee cultivation to fill the gap created by the economic downfall of the Red Sea spice trade.¹² A matrix of coffee trading posts developed in Yemen, including inland sites of cultivation, a wholesale market in the lowland city of Bayt al-Faqih, and the ports of Mocha, al-Hudaydah, and al-Luhayyah. Merchants carried coffee beans across terrestrial routes and the Red Sea to the Hejaz, Cairo, the Levant, and Istanbul.



⋮ A coffee plantation in Yemen, 1762.... []

The Dutch East India Company introduced coffee cultivation to the Dutch colony of Java in the late seventeenth century. Using fresh coffee seeds obtained in the Yemeni port of Mocha, the Dutch raised a number of seedlings that would eventually populate the island's coffee plantations.¹³ One tree was gifted to the Amsterdam Botanical Garden in 1706, and in 1718, the Dutch transported coffee plants from Amsterdam to Suriname, then known as Dutch Guiana.¹⁴ From there, coffee traveled to French Guiana and Brazil.



Map of the port of Mocha used by... []

The French colonial empire facilitated the passage of Arabica to the Caribbean. In 1720, French naval officer Gabriel de Clieu journeyed to the colony of Martinique with two coffee plants from Amsterdam, only one of which survived. In the decades that followed, coffee spread throughout the Caribbean islands. Several coffee plantations in European colonies relied on enslaved labor. In eighteenth-century Grenada, for example, enslaved people tended more than 12,000 acres of coffee properties.¹⁵



CULTIVATION AND COLONIZATION: COFFEE'S GLOBAL SPREAD

1450-1720



Coffeehouse Culture

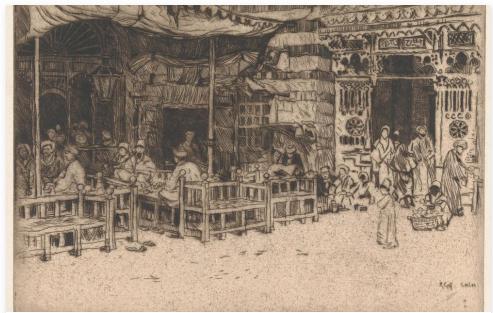
As coffee dispersed via merchants and colonial powers, so did the establishment of coffeehouses. According to James Douglas, an eighteenth-century anatomist, botanist, and bibliophile, the first coffeehouse was founded in Mecca near the end of the fifteenth century.¹⁶ "Thither crowds of people resorted at all hours of the day, to enjoy the pleasure of conversation, play at chess and other games, dance, sing, and divert themselves all manner of ways, under the pretense of drinking coffee," he writes.¹⁷ These meeting places appeared wherever coffee was consumed, hosting lively exchanges of news, ideas, and political debates. Travelers who visited coffeehouses often left inspired and brought the custom back to their home countries.

The screenshot shows a mobile or tablet interface with a white header bar featuring three horizontal lines, a red heart icon, a magnifying glass icon, and a person icon. Below the header is a search bar with a magnifying glass icon and a three-dot menu icon. The main content area contains a historical text in black font. At the top right of the text is a small bracketed label '(H)'. The text discusses the introduction of coffee to Aden and its spread to Mecca, mentioning the social activities that occurred there. Below the text are three action buttons: a book icon labeled 'Favorite', a share icon labeled 'Share', and a flag icon labeled 'Flag'.

A supplement to the description of the

In some cities, the initial establishment of coffeehouses did not receive unanimous support. Authorities questioned the merits of these gathering spaces, condemning their associations with merry-making and disorder. In sixteenth-century Cairo, for instance, an imam employed his rhetoric against coffee and called its consumption unlawful. Douglas recounts, "His discourse had so great an effect on the mob who heard it, that, as soon as service was over, they went and pulled down all the coffeehouses that fell in their way, broke the pots and dishes, and maltreated the company they found in them."¹⁸ Coffee ultimately triumphed in court after a judge consulted an assembly of doctors, all of whom decided in favor of the beverage. The drink was redeemed by its delectable flavor and presumed medicinal benefits, said to "keep the body in good health," "quicken the spirits," and "make the heart lightsome."¹⁹

In seventeenth-century Europe, coffeehouses served as forums for the dissemination of Enlightenment culture. German social theorist Jürgen Habermas points to the English coffeehouse as "a public sphere that functioned in the political realm."²⁰ Heads of state, such as England's King Charles II, tried and failed to suppress the vibrant exchange of political news among coffeehouse clientele.²¹ Patrons continued to criticize their governments, authors gathered to discuss literature, and merchants and stockbrokers turned their tables into unofficial offices.



⋮ Coffee House and Mosque Entranc... [•]



⋮ Interior of a London coffeehouse,... [•]

Historian Brian Cowan summarizes the Habermasian view of the coffeehouse as "a novel unique and social space in which distinctions of rank were temporarily ignored and uninhibited debate on matters of political and philosophical interest flourished."²² But not all social distinctions were cast aside. Scholars have criticized the locales for only serving "prosperous middle-class Londoners" and excluding women from the debate and business transactions commonly associated with coffeehouse society.²³ To compensate for this dismissal in the public domain, affluent women took to the private sphere to mirror such socializing and discourse. They gathered close acquaintances for daily or weekly coffee parties, which historian Wolfgang Schivelbusch deemed "a surrogate for the original coffeehouse created for male society."²⁴



⋮ Le Dejeuner (Morning Coffee) by... [x]

With the rise of industrialization in the eighteenth century, coffee became entangled with labor. As a stimulant, it was a "first-rate efficiency factor" that "promised nothing less than to lengthen and intensify the *time* available for work."²⁵ Coffee enabled the working class to fend off drowsiness in favor of endurance and productivity.



⋮ How Caffeine Addiction Changed... [x]

Today, coffee continues to power labor forces in diverse workplaces, from offices to farms and factories. Contemporary coffeehouses have come a long way from their earliest ancestors, with modern brewing equipment and fewer social limitations, but they embody many of the same virtues. John Frederick Frank's 1947 poem "Coffee Hour" paints the coffeehouse as a community hub. It begins, "Society solidified: three old ladies / Sipping primly, facing friends."²⁶ Centuries after Yemen's initial cultivation of Arabica, the plant continues to connect us.



⋮ A modern-day coffeehouse in... [x]

An Industry under Threat

Whether hot or iced, sweetened or plain, instant or the outcome of a patient brew, coffee is one of the most consumed beverages in the world. Approximately 2.3 billion cups of coffee are consumed daily, and global consumption is on the rise.²⁷ But climate change is threatening the long-term security and stability of the industry.



⋮ Brewing coffee using the pour-over... [x]

Genetic diversity is key to climate resilience. Species with a diverse gene pool are more likely to possess traits that are well suited for survival and reproduction in an altered environment.²⁸ Although Arabica coffee has an extensive range, its genetic diversity is severely limited. All of today's cultivars are the descendants of two Arabica varieties that underwent successive reductions in genetic diversity as they radiated from Yemen.²⁹ This homogeneity is exacerbated by the fact that Arabica tends to reproduce through self-fertilization, meaning it uses its own pollen instead of relying on other plants. Under a changing climate, cultivated coffee will struggle to adapt.



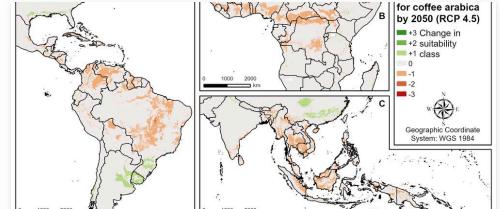
⋮ Coffee farms in San Marcos, Costa... []

The optimal growing conditions for Arabica coffee include temperatures between 57 and 79 degrees Fahrenheit, moderate rainfall, and an annual dry period of one to three months.³⁰ These conditions will become harder to achieve in current coffee-growing regions as fossil fuel combustion and deforestation—including the clearing of forests for coffee farms—alter worldwide temperatures and weather patterns. Global warming and changes in precipitation will interfere with coffee plant growth, flowering, and fruiting, resulting in poor yields and lower-quality beans.³¹



⋮ Is climate change impacting coffee... []

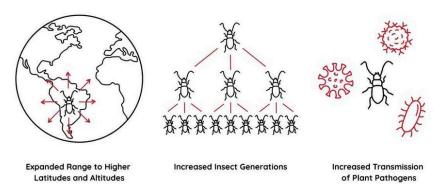
Researchers predict that climate change will drastically reduce coffee-suitable lands in the coming decades. One study projects that by 2050, the world's most suitable areas for growing Arabica coffee could shrink by 54 to 60 percent.³² Another study estimates that Latin America could lose as much as 88 percent of its coffee-growing land by the same year.³³



⋮ Change in climate-suitable lands b... []

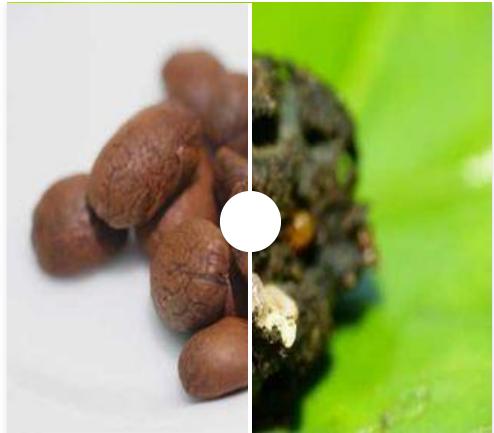
Arabica is further threatened by another climate-related shift: more frequent and severe outbreaks of insect pests and plant diseases. The effects of climate change on insect pests are not uniform, but in general, rising temperatures are advantageous for insects.³⁴ With global warming, these pests can proliferate at higher latitudes and elevations that were once too cold for survival.

Impacts of Rising Temperatures on Insect Pests



⋮ Climate change generally benefits... []

Such is the case for the coffee berry borer (*Hypothenemus hampei*), the world's most notorious coffee insect pest.³⁵ At less than two millimeters long, the female beetles bore into coffee fruits and feed on the developing seeds, creating galleries in which they can lay as many as 100 eggs. The larvae feast on the seed in which they hatch, further reducing its size and quality. The beetle has spread from West Africa to almost all coffee-producing regions, resulting in yearly losses that easily surpass 500 million dollars.³⁶



⋮ Swipe across the images to see the... []

Farmers typically treat these infestations by spraying chemical insecticides, releasing biological control agents, or removing and destroying infested coffee berries. However, the adoption and effectiveness of these practices vary based on cost, labor availability, and producer knowledge. With climate change, the problem will only get worse. The beetle is expected to plague previously unaffected regions, and its developmental time has been shown to decrease with warmer temperatures, meaning more insect generations and more damage.³⁷



⋮ A coffee producer in Nicaragua... []

Climate change could also intensify outbreaks of coffee leaf rust (*Hemileia vastatrix*). This fungal pathogen has caused extensive damage since it was first identified in the nineteenth century.³⁸ The ailment blemishes coffee leaves with yellow and brown spots, coating their undersides with orange fungal spores. Infected trees lose their rusted leaves, produce lower yields, and usually die within a few years. In 2011, an epidemic that began in Central America damaged crops on roughly 70 percent of Latin American coffee farms, causing more than three billion dollars in damages by 2021. Now, higher temperatures and extreme weather events like flooding may create environments that are more conducive to the growth of the pathogen.³⁹



⋮ Swipe across the images to compare... []

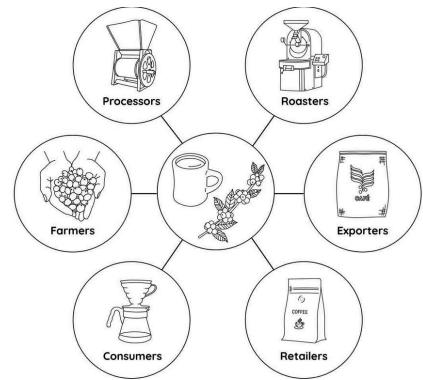
These challenges send ripples throughout the supply chain. In January 2025, coffee prices soared as a result of poor growing seasons due to drought, frost, and floods in Brazil and Vietnam.⁴⁰ Low yields, coupled with rising demand, drove the retail price of ground coffee to an all-time high of seven dollars per pound, up from four dollars in January 2020. In theory, higher prices should yield higher profits for coffee growers—but it's not that simple. The costs of labor, fertilizers, and other inputs are rising alongside coffee prices.⁴¹ Some coffee growers are concerned that coffee drinkers may limit their consumption in response to high prices, opting for cheaper sodas or energy drinks to satisfy their caffeine cravings.⁴²



BRAZIL: DROUGHT HITS WORLD'S LARGEST COFFEE PRODUCER

⋮ Global coffee prices rise as drought h... []

Climate change impacts both the coffee plant and the billions of people with a relationship to the crop, exacerbating the challenges that industry stakeholders already face. Extreme weather events, inflation, interest rates, unstable energy prices, and global conflicts drive market volatility.⁴³ Some farmers toil under intense heat for eight to ten hours a day for very low wages.⁴⁴ Smallholder farmers, who are responsible for at least 60 percent of the global coffee production, often have little negotiating power in coffee supply chains and are forced to get by on meager payments for their crops.⁴⁵ In an ethnographic study of the Vietnamese coffee industry, Sarah G. Grant describes "a complicated web of risks and uncertainty" in which the decisions of state and global actors often fail to meet the needs of farmers.⁴⁶



⋮ Some of the stakeholders in the...

Climate change will make coffee prices more unpredictable, labor conditions more hazardous under extreme heat, and economic losses more devastating. "For us, producing coffee is our life," said Honduran producer Moises Herrera in an interview with journalist Peter S. Goodman. "A lot of producers are starting to lose hope."⁴⁷



⋮ A farmer in Colombia harvests ripe...

Climate-proofing Coffee

In an ideal world, we would address the root cause of climate change by minimizing greenhouse gas emissions and protecting carbon sinks, such as oceans and forests. Unfortunately, our current climate mitigation policies are proving insufficient.⁴⁸ The coffee industry must adapt accordingly.



⋮ Adaptation and Mitigation | Climate...

Researchers have identified three main pathways to climate resilience in coffee production.⁴⁹ The first involves relocating coffee farming to areas with suitable climates, including higher elevations. Although relocation would alleviate thermal stresses on coffee plants, the transition could result in the loss of livelihoods for farming communities at lower elevations as well as deforestation in favor of agricultural expansion.⁵⁰



⋮ A coffee tree in bloom at high...

The second pathway is to increase the adoption of sustainable farming practices like agroforestry, which integrates coffee plants with shade trees. In Central and South America, coffee was predominantly grown in agroforestry systems until the advent of the Green Revolution in the mid-twentieth century, which transformed agricultural operations in favor of higher yields and disease resistance.⁵¹ Many coffee farmers, most notably in Costa Rica and Colombia, shifted to unshaded, intensive farms with dwarf coffee varieties that required substantial fertilizer and pesticide applications.⁵² Today, those growing Arabica in full sun recognize that agroforestry would boost their plantation's climate resilience, provide habitat for migratory birds and other wildlife, and reduce soil erosion. But the transition could also mean a drop in productivity and an increased risk of coffee leaf rust.⁵³



⋮ Coffee growing in an agroforestry... [2]

The third pathway—which is considered “the least disruptive, the most cost-effective, and probably the most successful”—is using the principles of genetics to develop climate-resilient coffee cultivars.⁵⁴ Breeders played a key role in the Green Revolution by creating the dwarf Arabica plants that could grow more densely in monoculture than traditional varieties. Toward the end of the twentieth century, however, coffee breeding pivoted from an emphasis on productivity to address the growing concerns of climate change, pests and diseases, and cup quality.⁵⁵



⋮ Researchers extracting bacterial... [2]

Using traditional plant breeding methods, scientists can develop hybrid coffee plants with desirable traits like disease resistance and drought tolerance. Current breeding efforts focus primarily on first-generation (F1) hybrid varieties, which are created by transferring pollen from the flower of one genetically distinct parent to another using a paintbrush, then planting the resulting seeds. Breeders typically cross wild Arabica varieties from Sudan or Ethiopia with common American cultivars. According to World Coffee Research, “One of the key distinguishing features of F1 hybrids is their ‘hybrid vigor,’ which can translate into everything from higher yields, to wider climate adaptability, to resilience in the face of stresses like disease (e.g., coffee rust), frost, or drought.”⁵⁶



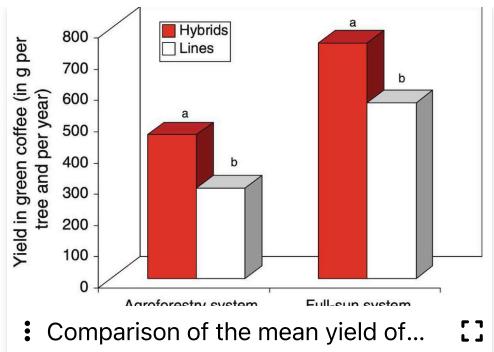
⋮ Breeding: How It Works [2]

Early breeding efforts have prioritized Arabica and robusta, the species and flavor profiles that consumers know and love. But researchers are turning to other coffee species in search of climate-resilient traits. *Coffea stenophylla*, for instance, is a narrow-leaved species once farmed in Sierra Leone with a much higher temperature tolerance than Arabica.⁵⁷ The plant’s beans have been described as “superior to those of all other species.”⁵⁸ Their flavor resembles a premium Arabica, with undertones of peach, jasmine, chocolate, and elderflower syrup. *Coffea stenophylla* produces comparatively low yields, but the plant’s heat tolerance, coupled with the impeccable cup quality, makes it a promising contender for coffee breeding.



⋮ *Coffea stenophylla* in the Berlin... [2]

An additional benefit of F1 hybrids is their capacity to complement sustainable farming practices. A 2011 analysis of F1 hybrids in Central America found that the plants not only produced earlier and higher yields than traditional American cultivars; they also performed better in agroforestry systems than in full sun.⁵⁹



F1 hybrids are a promising climate solution, and a handful of cultivars are now commercially available to farmers. However, costs and logistical challenges pose a barrier to widespread implementation. "It is neither simple nor cheap to introduce a new cultivar, which takes at least 12 to 16 years from generation to approval for commercial use," explain researchers in Brazil.⁶⁰ The price of a hybrid coffee seedling is 40 to 160 percent higher than a seedling of a traditional variety, and caring for F1 hybrids requires additional labor, fertilizer applications, and management know-how.⁶¹ Still, the benefits of higher outputs and fewer losses may outweigh the extra costs, especially for large-scale farms.



Coffee breeding will rely on an abundance of genetic resources from which to select useful traits. Wild coffee species are an invaluable tool, offering the genetic variability that Arabica cultivars in the Americas lack. But many of these wild plants, like cultivated Arabica, are losing suitable habitat to climate change and human activity. At least 60 percent of the world's wild coffee species are threatened with extinction.⁶²



Preserving the genetic diversity of wild coffee species will require a combination of *in situ* conservation, which protects existing plants in their natural habitats, and *ex situ* conservation, which relocates plants to controlled environments.⁶³ At present, *ex situ* collections are the primary method of conserving coffee genetic resources. Coffee is not a suitable candidate for long-term seed banking, because its seeds are sensitive to drying and freezing and cannot survive storage beyond two or three years.⁶⁴ Instead, collections must care for live coffee plants.



Just over half of all coffee species are preserved in germplasm collections. But researchers argue that the current system is "not sustainable, secure, cost effective, or rational."⁶⁵ Most genetic resources are contained in nationally focused collections that are isolated from each other and from external users. Disagreements arise over ownership of genetic material. Furthermore, the collections often struggle with funding, outdated facilities, and staffing shortages. Many are located in ecological conditions that are ill-suited for plant performance or survival, leading to inappropriate cultivation methods and the loss of coffee trees.⁶⁶ To more effectively conserve coffee genetic resources, stakeholders will have to expand protected areas and address the challenges that *ex situ* collections currently face.



⋮ A researcher at the International... ☰

Brewing Partnerships

A central theme emerges in publications on coffee, climate change, and the preservation of genetic resources. Several authors emphasize the need for improved collaboration and communication among industry stakeholders. For example, the Innova Global Arabica Breeding Network—a global breeding effort led by World Coffee Research—argues that "individual national research programs face significant limitations working alone."⁶⁷ Similarly, the authors of the 2017 *Global Conservation Strategy for Coffee Genetic Resources* write, "The global community will need to operate together as a platform for collaboration on conservation, breeding, research, and enhanced use."⁶⁸



⋮ Coffee is an agent of connection.... ☰

Failing to adapt coffee to climate change would be catastrophic for the millions who depend on the crop for their livelihoods, especially the farmers who are already struggling to make ends meet. It won't be easy, but for these climate solutions to be sustainable, researchers and policymakers must embrace cross-cultural dialogue and decide on a path forward that all stakeholders can agree to.



⋮ Coffee farmers in Sao Paulo, Brazil,... ☰

We cannot abandon the plant that has shaped societies in its travels from the forests of Ethiopia to the rest of the world. Safeguarding the future of this crop necessitates the very thing that coffee does best: cultivating connections, not just among consumers, but among everyone with ties to the production and deep-rooted history of this beloved seed.



⋮ A handful of coffee's cherished frui... ☰

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