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Coffee's innovation crisis

Determining the size of the agricultural R&D investment gap for coffee amid growing consumer demand and the climate crisis

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Key takeaways

- Coffee faces an innovation crisis. Climate change is reducing coffee origin diversity and endangering smallholder production, while demand continues to grow around the world. By mobilizing greater investment in coffee agriculture R&D, we can ensure a sustainable future for coffee.

- Despite its global economic importance, the world is shockingly underinvested in coffee agricultural research and development (R&D). The current global investment is estimated to be $115m/year, with 90% of this investment coming from the public sector and 10% from the private sector. This equates to $0.0048 (half a cent) for every dollar of green coffee produced globally.

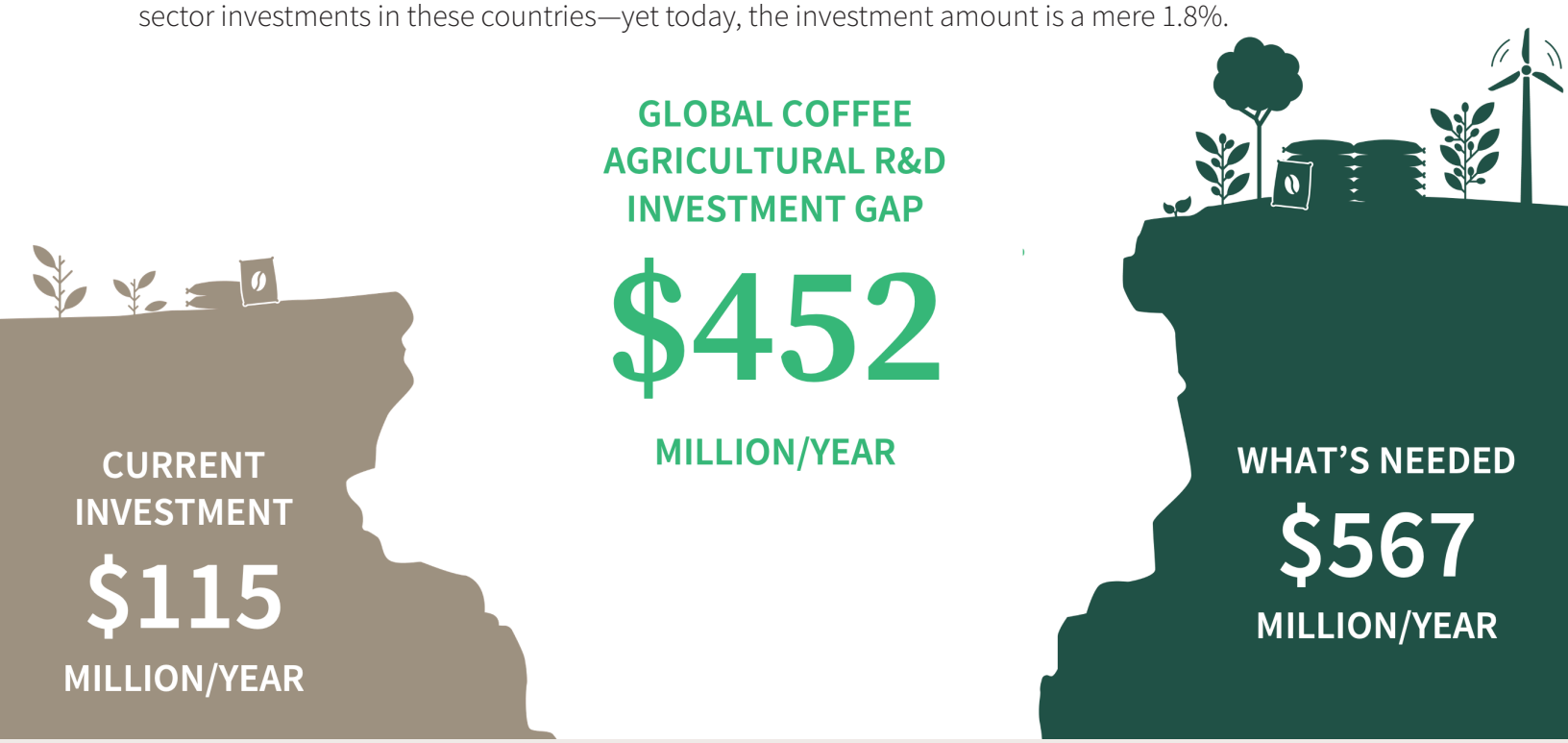
- This scale of underinvestment cannot continue if the world wants to continue drinking its favorite beverage. Furthermore, coffee will be unable to contribute to achievement of the Sustainable Development Goals, avoid deforestation, mitigate climate emissions from agriculture, and provide livelihood improvements to farmers without a significant increased investment in coffee agricultural R&D. Innovation-driven productivity gains are needed to ensure the long-term viability of coffee producers and the industry as a whole.

- **$452m per year is the additional investment needed over the next decade** to meet rising demand (2.5%/year) in the face of yield losses (0.25%/year) and land area losses (0.46%/year) expected due to climate change if buyers wish to secure supplies of coffee from diverse origins.

- This is a relatively small amount to set aside – it amounts to an additional 2 pennies per pound of green coffee produced globally (based on a farm-gate value of $23.6 billion), or less than half a cent for every $1 of coffee sold to consumers (based on $200 billion retail value).

- More than 80% of this additional investment should benefit Latin America and Africa, the two historically underinvested regions of the coffee producing world.

- The total value of green coffee makes up about 4.8% of the total value of agricultural output in the 45 countries included in this analysis. Coffee should therefore make up a similar percentage of agriculture sector investments in these countries—yet today, the investment amount is a mere 1.8%.



Introduction

Coffee is the world's most popular beverage and consumption is expanding in both importing and exporting countries (Kileen and Harper 2016; Torga and Spers, 2020; Bunn et al. 2012), but the looming climate change crisis poses an existential threat to coffee producers. At the same time, coffee has seen persistently stagnant or declining productivity trends in most producing countries outside the three biggest producers—Brazil, Vietnam, and Colombia—despite prior calls to action and collective efforts to address this challenge.

This combination of factors should be a cause of urgent concern for the whole industry. If current trends continue, we will be unable to meet the world's growing demand for coffee, let alone to ensure that coffee production is economically and environmentally sustainable. Increasing global investments in coffee R&D to accelerate innovations across multiple countries can help reverse this trend and support the coffee sector to keep up with growing consumer demand and respond to the challenges of climate change and poverty, while avoiding further consolidation of production.

Yet coffee's current level of investment in agricultural R&D is shockingly low. We estimate that current total agricultural R&D investments[1] in coffee for the global south total is about US $115 million (in constant 2020 US dollars). In our estimates, 90% of these investments are made by the public sector and 10% are made by the private sector. As a general rule, R&D investments to different commodities should be allocated proportionally to their market value (Fuglie, 2022). The total value of green coffee makes up about 4.8% the of total value of agricultural output in the 45 countries included in this analysis. Coffee should therefore make up a similar percentage of agriculture sector investments in these countries—yet today, the investment amount is a mere 1.8%.

It is clear that more investment is needed. This paper develops an economic model in order to provide a rational basis for understanding the true size of coffee's agricultural R&D gap in the face of rising demand and climate change.

COFFEE FACTS[2]

- **12.5 million** smallholder farms operate on 10.6 million hectares worldwide
- Farm-gate value is **$23.5 billion**
- Retail value is **$200 billion**

[1]We define agricultural R&D investments to encompass public (primarily the national agricultural research systems in coffee-producing countries) and private (primarily World Coffee Research and one private company) investments in coffee agricultural research for coffee producing countries in the global south, which includes south and southeast Asia (including Pacific islands), sub-Saharan Africa, and Latin America and the Caribbean. The scope of coffee research investments considered in this analysis support innovations in coffee production through improvements in varieties (tree stock), cultural/management practices (agronomy, land and water resources, irrigation, soil fertility, pest control), farm operations (planting, weeding, harvesting, on-farm or near-farm cherry processing), and marketing (related to policies and systems that connect coffee producers to markets).

[2]Browning, 2018; Estimated calculation based on FAOSTAT coffee area/production data and ICO composite producer pricing; Panhuysen and Pierrot, 2018.

Why innovation matters

There is a strong case to increase investments in agricultural R&D to address coffee's fundamental challenges. Although investments in other thematic areas to support the sustainability of the coffee sector are important (such as renovation and rehabilitation, social protection, financial technologies, etc.), investment in agricultural R&D is critical for three reasons:

1. First is the importance of innovation and technical change in driving total factor productivity (TFP)[3], which is an essential contributor to growth in agricultural production (Fuglie, 2018; Evenson and Fuglie, 2010; Rada and Valdes, 2012; Fan 1991). The long-term success of the industry requires innovations that respond to consumer priorities (i.e., reductions in GHG emissions, reductions in use of chemical crop protectants) and preferences (i.e., high quality, unique flavors, diverse taste) and are also aligned with farmer priorities in producing countries (i.e., new technologies to respond to very rapidly changing production environments due to climate change).

2. Second, in many developing countries in Africa and Latin America, coffee is mostly produced by smallholder farmers. Technology-induced productivity gains play an important role in increasing incomes for smallholder farmers and contribute to the goal of poverty reduction (Evenson and Gollin, 2003).

3. A third reason for our focus on coffee R&D is to correct the global under-investment compared to other agricultural commodities.

[3]Total factor productivity (TFP) is a measure of the effectiveness with which inputs (like land, labor, and capital) are transformed into outputs, representing the portion of the output that is not explained by the inputs used; it captures the impact of innovation and overall technological progress on production.

The existential threat of underinvestment

The trend of underinvestment, if continued, will lead to the disappearance of many countries from the current list of coffee exporting countries. This prognosis is worrisome for three reasons:

1. First, it consolidates the benefits of agricultural productivity and profitability gains in the hands of fewer farmers and fewer countries.

2. Second, it makes it harder to find the unique flavors that consumers increasingly want, and coffee businesses rely on.

3. Third, greater concentration of coffee production in fewer countries leads to the loss of coffee diversity and increases the risk of climate-induced instability in coffee supplies and prices (World Coffee Research, 2020).

Constructing an economic model to estimate coffee's R&D gap

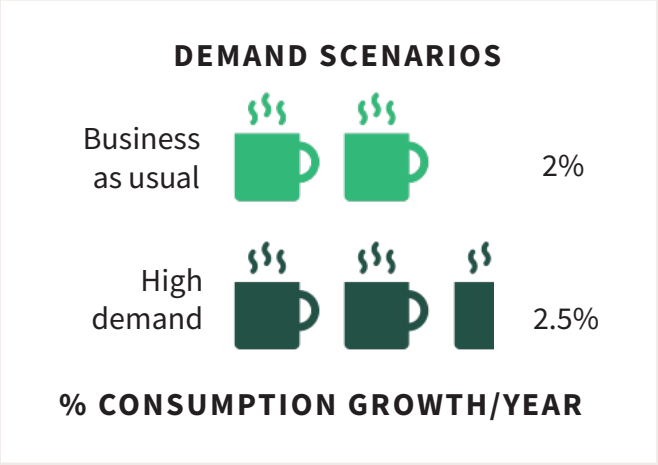
This research uses multiple sources of data to estimate the global coffee area, production, yield, and consumption growth, total factor productivity growth (TFP), growth rate in coffee R&D, and responsiveness of TFP growth to coffee R&D investments, and builds an economic model to estimate the size of research investment needed for different scenarios of demand growth and the impact of climate change. We then constructed six scenarios which represent a combination of plausible ranges of future trends in coffee consumption and production based on extensive review of literature and our analysis of documented trends in coffee area, production, and yield.

Assumptions

Origins. We focus our analysis on 45 major coffee producing countries in the world, all from the global south. We divide the coffee producing world into four groups—1) The "Big Three"—Brazil, Vietnam and Colombia; 2) Asia (other than Vietnam, including pacific islands); 3) Africa; and 4) Latin America and the Caribbean (Latin America, excluding Brazil and Colombia).

Arabica and Robusta. There are two main types of coffee produced in the world—Arabica (~60% share) and Robusta (~40% share), with different suitability to agroclimatic conditions, yield potential, susceptibility to diseases, and quality of beans. The projections of demand and climate change impacts are expected to vary by coffee type (Sachs et al. 2019; Adams et al. 2021). However, due to lack of high-resolution data at country level, the investment gap analysis does not distinguish between the two coffee types. Below is an explanation of the assumptions and scenarios underlying this analysis; the full economic model used to estimate coffee's R&D investment gap will be published in a forthcoming academic paper.

Demand. We considered two demand scenarios—business as usual (2%/year consumption growth) and high demand (2.5%/year). According to many experts, the demand for coffee is expected to grow considerably in the remainder of the 21st century (Torga and Spers, 2020) due to demographic trends (i.e., growing population and more younger people in some parts of the world), income growth, cultural shift in tea-consuming countries, growth of e-commerce,

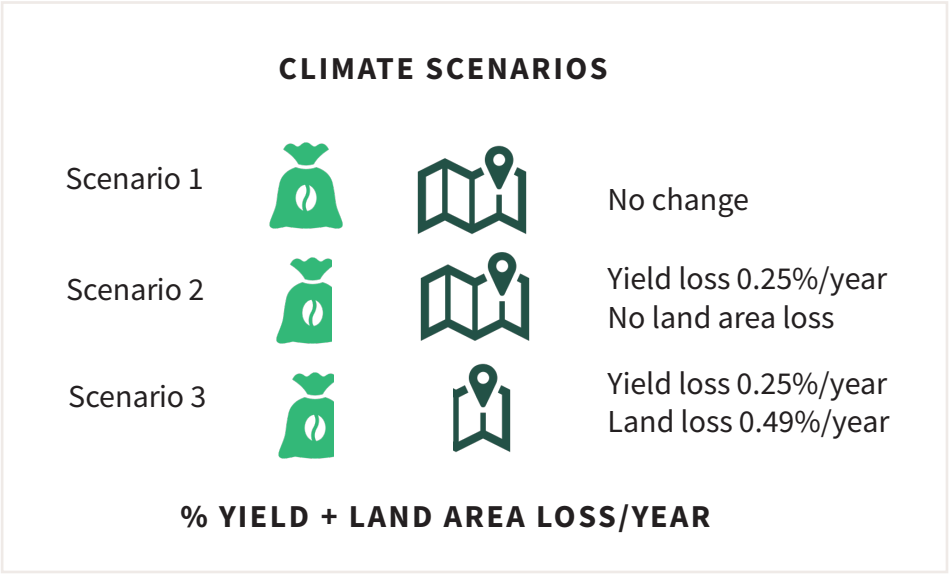


and product innovations (World Coffee Research, 2017; Kileen and Harper, 2016). Historically, coffee production has kept pace with rising demand. In the last 30 years (1990-2020), production has increased on average by 2%/year. However, the documented growth rate in production in the last 10 years has been 2.5%/year and in the last 5 years, it has been 3.4%/year. We consider a growth rate assumption of 2.5%/year to be more realistic and even on the conservative side of projected demand increases found in the literature.

Climate change. Both Arabica and Robusta are expected to be impacted by climate change, both in terms of rising temperatures and erratic rainfall. We draw our estimates of area and yield declines from the extensive model-based estimates derived by Sachs et al. (2019). These estimates represent a combined net effect of some countries expanding production and some contracting due to climate change. The net effect is predicted to be a 13% decrease in planted area globally and a 7% decline in yield by 2050. In annual percentage growth rate terms, this implies area will be decreasing on an average rate of 0.46% and yield at 0.25% over the next 3 decades.

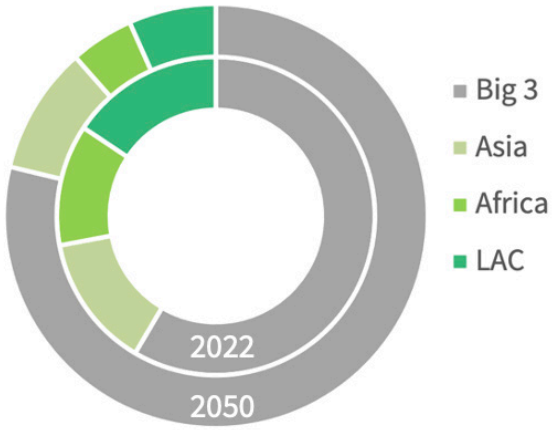
We construct three scenarios of climate change effects based on these expected trends—the first assumes area and yield will follow historic trends without any additional detrimental effects of climate change (i.e., the business-as-usual scenario). The second assumes yield will decrease 0.25% per year and planted area will continue to follow historical trends (scenarios 2 and 5). The third assumes yield will decrease 0.25% per year and planted area will decrease by 0.46%/year due to effects of climate change (scenarios 3 and 6). These estimates of area and yield changes assume constant prices for coffee; we assume that any slight increase in price that may come from a reduction in production (from declining area and yield) will not significantly affect consumer demand, which has been shown to be highly inelastic (Sachs et al, 2019).[4] While it is very difficult to predict with accuracy the long-term effects of climate change on coffee productivity and land area, recent research from Kath et al. (2020) suggests that coffee productivity may suffer more than previously thought due to heat increases. This, combined with the robustness of the Sachs et al. modelling, leads us to the conclusion that the high-impact scenario (decrease of land area of 0.46%/year and yield at 0.25%/year over the next three decades) is the most likely to occur.

Consolidation of coffee origins. In addition to demand and climate change projections, we estimate the R&D investment needed to fill the supply gap under two supply scenarios. The first assumes an increasing share of coffee supplies will come from producing countries with higher productivity (especially Brazil, Vietnam, and Colombia), with the implication that there will be less diversity in types and flavors of coffee to meet consumer demand (see outer ring of figure 1). The second scenario assumes the geographic diversity of coffee supplies would be maintained at 2020 levels (58% of production coming from Brazil, Vietnam, and Colombia; 14% from Asia; 12% from Africa; and 16% from Latin America; see inner ring of figure 1).



[4]The authors found that a 10% increase in price led to a very small decrease in demand of <1% for Arabica and 1.5% for Robusta on average, although price sensitivity was higher or lower in specific countries. production.

Figure 1. Origin consolidation scenarios.



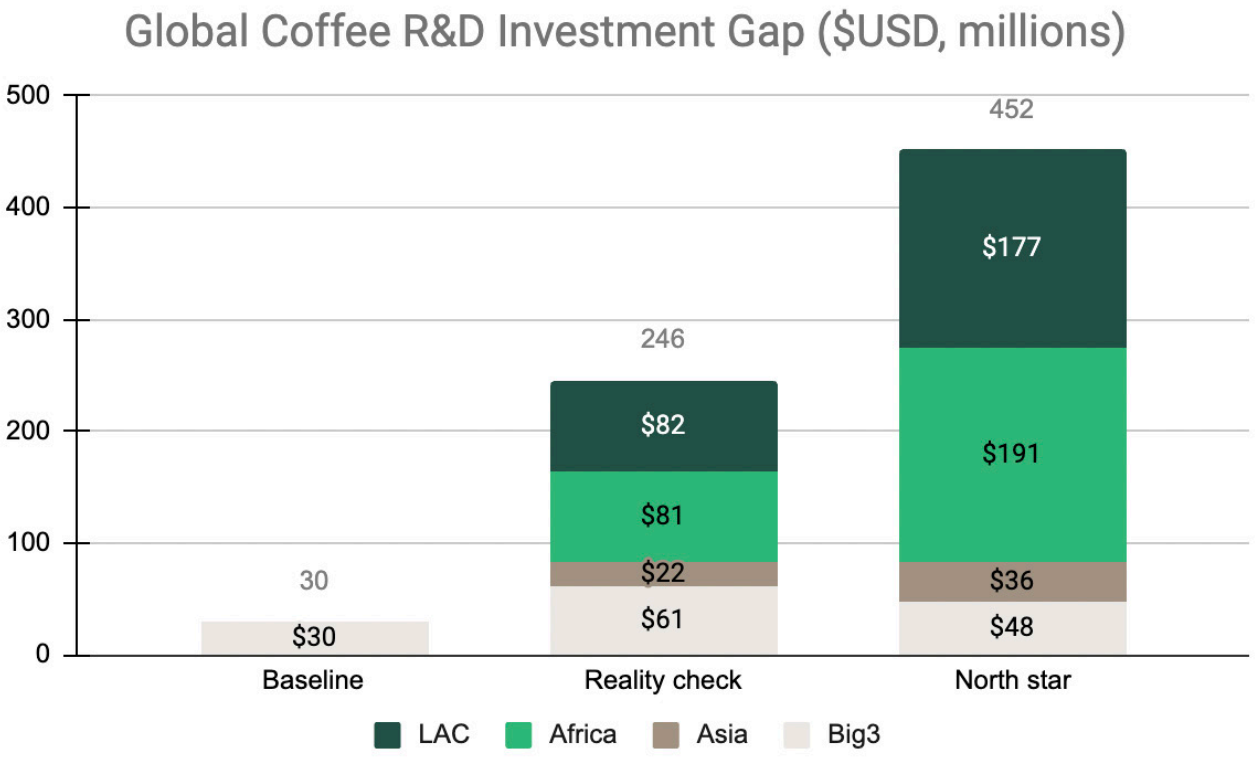
Calculating coffee's investment gap. Under each scenario and market share assumption, we assume supply (i.e., production) will match demand at a relatively stable price. This allows us to estimate additional yield needed to bring the global market to a state of equilibrium. The estimate of additional yield is relative to the business-as-usual scenario (2% consumption growth and no losses of yield or planted area due to climate change). The estimated total yield under each is converted into percentage annual growth rate from 2021-2030. This projected yield growth rate parameter is then used as an exogenous shock in an economic model to assess the gap in agricultural R&D investment over the next 10 years. It is defined as the additional annual investments (ΔR) above the 2019-2020 level—the reference period in our analysis.

Results

How much should the world invest in agricultural R&D for coffee amid growing consumer demand and the climate crisis? To meet increasing demand growth in the face of expected reduction to both yields and land area available for coffee, the world needs to invest millions of additional dollars per year in coffee agricultural R&D. In Figure 2, we present two simplified scenarios (see Appendix 1 for more detailed scenario results).

North star—a diverse, resilient global supply that sustains millions of smallholder farmers. If consumers, industry, and coffee producing countries want to sustain anything like the current levels of diversity in coffee production (58% of global production supplied by the Big Three, 14% Asia, 12% Africa, and 16% Latin America), coffee agricultural R&D investments are needed at a larger scale. Sustaining

Figure 2. Global coffee R&D investment gap scenarios, simplified.



current levels of diversity in the face of rising demand and negative climate impacts will cost an additional $452m/year. To achieve this goal of diversity in supply, increasingly more research resources will need to be devoted to Latin America and Africa regions for the reasons explained above. Of these additional investments, more than 80% should be directed to Latin America and Africa, the two historically underinvested regions of the coffee producing world (42% Africa, 39% to Latin America, 8% to Asia, and 11% the Big Three).[5]

Reality check—the bare-minimum investment to sustain global supply, with major consolidation. If significant consolidation of coffee supplies is not a concern, additional investment of $246 million is needed—a 215% increase over current levels. Assuming continued high demand growth and negative impacts of climate change on yield and land area, even today's highly productive regions will not be able to meet 100% of global demand growth in 10 years. About 20% of global coffee production will still need to occur in Africa and Latin America to meet demand, and R&D investments will need to be made to ensure these two regions are able to supply 20% of the world's coffee. In the absence of these additional investments in R&D in Africa and Latin America, yields will continue to decline in these two regions, and projected expansion in area will not be enough to fill the projected production gap.

Baseline—the Big Three supply the world. If consumption increases more slowly (2% per year), and climate change has no impact on land area or yields, the world's current most efficient producers could likely absorb most demand growth, but this would lead to severe consolidation of supplies. To meet global demand, a minimum of an additional $30 million per year—a 21% increase over current global investment levels—would be needed to support the world's current most efficient producers to continue improving their productivity to meet new demand.

[5]A significant portion of the costs is due to the fact that it is more expensive to increase yields in Africa and Latin America than in the Big Three. According to our model estimates, to increase the yield growth rate by 1%, it costs about $54 million in Africa and $43 million in Latin America, which is two times more than what it costs in the Big Three ($20 million).

Conclusion

The current scale of underinvestment cannot continue if the world wants to source its favorite beverage from diverse regions of the world, while sustaining millions of livelihoods and healthy ecosystems and contributing to the economic prosperity of coffee producing countries and the global coffee trade.

According to this analysis, current investment levels are nowhere close to enough to sustain a diverse supply of coffee in the face of climate change and rising demand over the next 10 years.

An almost four-fold increase in current R&D investment suggested by our analysis implies a total investment (i.e., current + additional) of $567 million per year over the next decade, which is a little over 2% of the annual value of green coffee exports. For an industry with a retail value of more than US$200 billion, this would mean setting aside less than 0.3 cents for every $1 of coffee retailed to consumers.

Appendix

Price tag for additional R&D investment under different demand, climate change, and market share scenarios

$30m	• Demand rises 2%/year • No climate change impact • Severe consolidation	**$184m**	• Demand rises 2%/year • No climate change impact • Diverse origins maintained
$44m	• Demand rises 2.5%/year • No climate change impact • Severe consolidation	**$239m**	• Demand rises 2.5%/year • No climate change impact • Diverse origins maintained
$160m	• Demand rises 2%/year • Yield declines by 0.25%/year • Severe consolidation	**$364m**	• Demand rises 2%/year • Yield declines by 0.25%/year • Diverse origins maintained
$206m	• Demand rises 2.5%/year • Yield declines by 0.25%/year • Severe consolidation	**$411m**	• Demand rises 2.5%/year • Yield declines by 0.25%/year • Diverse origins maintained
$203m	• Demand rises 2%/year • Yield declines by 0.25%/year • Area declines by 0.46%/year • Severe consolidation	**$407m**	• Demand rises 2%/year • Yield declines by 0.25%/year • Area declines by 0.46%/year • Diverse origins maintained
$246m	• Demand rises 2.5%/year • Yield declines by 0.25%/year • Area declines by 0.46%/year • Severe consolidation	**$452m**	• Demand rises 2.5%/year • Yield declines by 0.25%/year • Area declines by 0.46%/year • Diverse origins maintained

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