Benchmarking Coffee Production and Climate Risk

June 2026

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

act

TechnoServe
Business Solutions to Poverty™

Acknowledgment note

The ACT Programme (Advancing Climate Resilience and Transformation in African Coffee) is a strategic initiative implemented by the United Nations Industrial Development Organization (UNIDO) and funded by the Italian Cooperation within the framework of Italy's Mattei Plan and the EU Global Gateway Strategy.

The programme aims to strengthen climate resilience, promote sustainable industrial development, and enhance local value creation along the coffee value chains in Eastern Africa, while improving socio-economic conditions for coffee-producing communities.

ACT addresses structural vulnerabilities in the sector by combining climate adaptation, regulatory compliance, innovation, inclusion and access to finance within an integrated development approach.

ACT is implemented in collaboration with the **International Coffee Organization**, the **Inter-African Coffee Organisation**, national institutions and international private-sector partners.

The programme is currently active in Ethiopia, Kenya, Tanzania, Uganda and Malawi, with a focus on strengthening institutional capacity, upgrading production and processing systems, and supporting smallholder farmers and local enterprises.

A distinctive feature of the **ACT Programme** is its strong emphasis on public–private partnerships and innovative financial solutions, including risk-management and insurance instruments, to enhance resilience to climate shocks and market volatility.

By fostering dialogue and cooperation among governments, international organizations, financial institutions and the private sector, ACT serves as a platform for sustainable transformation of the coffee sector, aligned with international development priorities and global climate objectives.

Ministero degli Affari Esteri
e della Cooperazione Internazionale

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

act
Advancing Climate-resilience and Transformation of African Coffee

Companies that support the findings of this study

A Climate Risk Lens for Coffee's Regenerative Transition

The challenge and opportunity

- **Coffee is a vital economic sector facing mounting climate pressure.** The millions of livelihoods it sustains are increasingly at risk as climate change and limited farmer capacity for adaptation undermine the sector's long-term viability.
- **Regenerative agriculture offers a path forward–and roadmaps already exist.** TechnoServe's *Regenerative Coffee Investment Case* outlines transition plans for smallholder farmers across priority coffee-producing countries, providing a strong foundation for coordinated action.
- **This study builds on that momentum with a climate risk lens.** The objective is to highlight key differences in coffee production systems and how they are affected by climate change. The report benchmarks ten origins in relation to the following two questions:
    1. How do coffee-producing countries compare across production scale, the socioeconomic importance of coffee, smallholder coffee farm economics, and the GHG footprint of production?
    2. How do they differ in climate risk exposure, sensitivity, and adaptive capacity?

1 Key insights from coffee production and climate risk benchmarking

Climate change will heighten risks across all priority coffee origins. Rising and extreme temperatures and more erratic rainfall will affect crop yields and quality worldwide.

Regional climate vulnerabilities vary. Coffee-producing countries in Latin America and Asia face the greatest threats, while higher-altitude East African systems are relatively less exposed.

Many of the most climate-vulnerable countries show stronger readiness to adapt. Future investments can build on these existing adaptive capabilities to accelerate adaptation.

1.A Strategic priorities for climate resilience and adaptation by climate risk profile

While all coffee-producing origins are impacted by climate change, variations in exposure and sensitivity to thermal and water stress, as well as variations in adaptive capacity, can be used to inform future investments.

- Exposure is measured across thermal and water stress (temperatures and rainfall above or below the suitable biological ranges for coffee production) and the amplification effect (drought).
- Climate sensitivity is shaped by farm management (agronomic practices), natural resource resilience, and elevation, as key drivers of farm susceptibility to climate stress.
- Adaptive capacity captures systemic factors that shape the capacity of farmers, government and private actors to plan for, invest in, and implement adaptation measures.

1 Managing thermal stress

Indonesia, Peru*, Vietnam, and Brazil face the most acute risks from rising temperatures exceeding suitable ranges for coffee cultivation. In these origins, low elevation further amplifies impact from heat stress and temperature variability.

Adaptation priorities: Agroforestry systems, cover crops and soil conservation techniques are critical for reducing soil temperatures and improving moisture retention.

Current adoption: Under-utilized on smallholder farms in these regions.

2 Mitigating the impacts of excessive rainfall

Indonesia, Peru, and Colombia face the highest risk of damage due to excessive rainfall, with Uganda and Kenya closely following. This can lead to erosion, waterlogging, and the spread of pests and diseases.

Adaptation priorities: Agroforestry, mulching, soil conservation and cover cropping, can help prevent soil erosion and increase soil porosity and water infiltration. Integrated disease management (IDM) combined with disease-resistant varieties, can dramatically reduce incidence and spread of diseases. This includes scouting, field hygiene, biological control and, as a last resort, precision application of selective fungicides.

Current adoption: While Colombia appears to be more advanced compared to others, there is opportunity to improve across the board.

3 Enhancing water retention

Brazil faces the greatest risk of thermal-water stress where the combined effect of high temperatures and low rainfall increase drought risk. Specific regions of Kenya and Uganda are expected to experience rainfall deficits.

Adaptation priorities: Rainwater harvesting infrastructure and regenerative practices designed to maximize the water retention in soil.

Current adoption: Under-utilized on smallholder farms in these regions.

While Honduras presents relatively lower risk of thermal and water stress, its lower elevation and low adoption of regenerative practices on some farms means it is still susceptible to any climate-related shock. Improved adoption of practices described here is therefore also highly recommended.

4 Building resource resilience

Beyond changes in climate, the underlying health of natural resources — specifically soil — emerges as a systemic risk across Vietnam, Brazil, Kenya, and Tanzania. National-level data shows moderate risk for water availability and ecosystem condition. To inform context-specific measures, the integrity, health and availability of these critical resources should be further assessed at the sub-national level.

Adaptation priorities: Soil health can be restored through regenerative practices that replenish soil with essential nutrients, enhance nutrient cycling and retention, increase soil biodiversity, strengthen soil carbon stocks and support control of soil erosion and landslides. Specific practices include agroforestry, soil conservation, mulching, integrated nutrient management, organic matter recycling and IPDM.

Current adoption: Varies by practice and region. While Colombia appears to be more advanced compared to others, there is opportunity to improve across the board.

**Except for one producing region in Peru (Junin) which faces risk of temperature going below the suitable threshold.*

1.B Strategic priorities for climate resilience and adaptation by farm economic profile

A producer's ability to adapt is intrinsically linked to the economic performance of their farm. Making coffee production a more prosperous activity is one of the most effective long-term buffers against climate change.

- Key drivers include productivity, farm size, cost of production and share of export price.

1 Securing economic resilience in East Africa and Indonesia:

Despite having the lowest climate vulnerability, East African producers are economically fragile due to small farm sizes (0.2–0.6 hectares) and (like Indonesia) low yields.

Adaptation priorities: Investment here offers a high ROI: low-cost agronomic interventions like rejuvenation, integrated nutrient and soil management (and in cases with high incidence of disease, integrated disease management) can deliver rapid productivity gains, making the business case for adaptation exceptionally strong for the farmer.

Current adoption: Under-utilized on smallholder farms in these regions.

2 Securing economic viability in Latin America

Despite having higher productivity, Latin American producers face the highest cost of production among Arabica origins, putting pressure on margins. Climate-driven yield losses or falling prices can quickly lead to net financial losses, threatening the future of the sector in areas where coffee is the primary income source from the farm.

Adaptation priorities: Investment should focus on efficiency, including targeted nutrition plans based on soil analysis, consistent compost management and IPDM. Meaningful productivity gains can be achieved if combined with renovation, soil conservation and cover cropping, thereby improving profit margins and reducing economic vulnerability.

Current adoption: Under-utilized on smallholder farms in these regions.

3 Improving economic viability in Vietnam

Despite a productivity level that is far above other Robusta origins, Vietnamese farmers have high costs of production per hectare, largely driven by cost of inputs, mechanization, and irrigation.

Adaptation priorities: Investment should focus on optimizing use of inputs including targeted nutrition plans based on soil analysis, consistent compost management, cover cropping and improving efficiency of irrigation systems. Altogether these practices can reduce costs while achieving a modest increase in productivity.

Current adoption: Under-utilized on smallholder farms.

A comprehensive approach to investment

To address these findings, capital must be deployed across three distinct but interconnected categories:

1. Farmer training and technical assistance

Knowledge is a critical prerequisite for adaptation, encompassing awareness, understanding of the business case, and technical skills. Investments should fund the delivery of technical support to implement regenerative practices, addressing the specific thermal and water risks of the local landscape. For example, practical training delivered via on-farm demonstration plots, covering topics such as grafting techniques to introduce improved, climate-resilient varieties.

2. Farmer capital and financial products

Farmers need access to affordable capital to fund the transition. Depending on the context, adopting regenerative practices can involve upfront investments, increased operating costs, or the need to bridge the income gap during the early years of farm renovation. To be effective, capital should be deployed through mechanisms that reach farmers cost-efficiently, and financial products should be designed based on context-specific farm cash flow and risk profile.

3. Addressing systemic and infrastructure gaps

Investment must also target the enabling environment including:

- **Disaster preparedness:** Enhancing government-led disaster response and early warning systems.
- **R&D and innovation:** Accelerating the development of climate-resilient varieties and nature-based technical solutions.
- **Market systems:** Ensuring inclusive access to regenerative inputs, finance, and premium markets for both men and women farmers, and increasing the share of export price earned by farmers in some countries.
- **Enabling reforms:** Policy-level interventions to address the inherent tensions between short-term economic pressures and long-term environmental sustainability.

A combination of capital is required to unlock this transition:

- **Commercial capital:** Best suited for scaling proven regenerative models where the business case for productivity and quality is already established.
- **Concessional capital:** Necessary for on-farm investments that have a longer term return horizon and for temporary income support during renovation cycles.
- **De-risking capital:** Instruments such as first-loss guarantees or climate insurance, essential for making smallholder lending attractive for commercial banks and private investors.
- **Non-returnable capital:** Necessary for farmer education and incentives to overcome barriers and drive behavior change.

TRANSLATING RISK INTO ACTION

Addressing these vulnerabilities requires moving beyond high-level country benchmarking toward the development of granular, sub-national coffee adaptation roadmaps. Investment plans and deployment mechanisms must be specifically tailored to local risks while aligning with the coffee market systems and socioeconomic realities of each context. Crucially, these investments must also future-proof the sector by ensuring deforestation-free, legally compliant production while ensuring coffee companies continue to be incentivized to make sustainability investments.

For a detailed cost-benefit analysis of the regenerative practices identified here, including the specific returns for farmers, national economies, and the global industry, refer to TechnoServe's *Regenerative Coffee Investment Case*. This report provides foundational data for these strategic interventions.

2 Benchmarking Coffee Production Systems

This analysis establishes a benchmark for comparison.

It benchmarks priority coffee-producing countries across production volume, socioeconomic importance, farm-level economics, and the GHG footprint of production.

Coffee is produced in diverse contexts around the world.

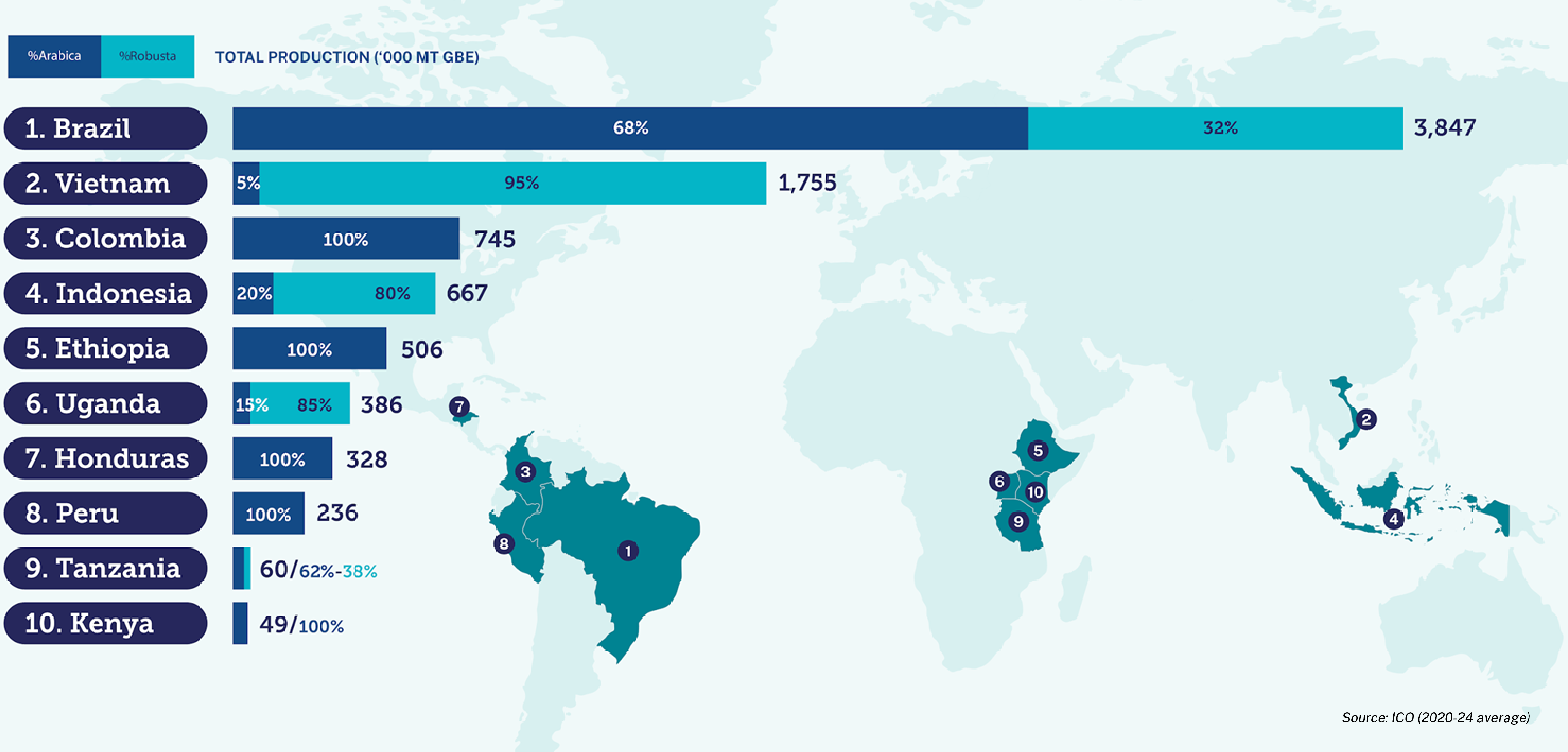
Each origin is shaped by a different mix of Arabica and Robusta production, varied economic role of coffee, and distinct farm profiles.

Benchmarks show a high variability of productivity, profitability, and GHG footprint.

While higher yield, conventional systems traditionally involve high emissions, there is evidence that regenerative systems can achieve sustainable economic performance and low emissions.

Coffee production by species

Global coffee production is highly concentrated, with Brazil and Vietnam accounting for nearly two-thirds of output across the ten priority countries.



Source: ICO (2020-24 average)

Socioeconomic importance of coffee

Coffee production plays a central role in sustaining livelihoods and economies, fueling exports and supporting millions of smallholder farmers across all origins.

	Brazil	Vietnam	Colombia	Indonesia	Ethiopia	Uganda	Honduras	Peru	Tanzania	Kenya
COFFEE'S SHARE OF MERCHANDISE EXPORTS (%)[1]	2%	1%	6%	0.4%	43%	15%	21%	1%	3%	4%
TOTAL COFFEE FARMS ('000S)[2]	290	600	600	1,345	2,200	1,818	120	220	337	454
SMALLHOLDERS' SHARE OF COFFEE FARMS (%)[2]	80%	99%	92%	99%	99%	99%	80%	59%	99%	99%
COFFEE'S SHARE OF SMALLHOLDER FARM INCOME (%)[3]	60%	70%	70%	30%	50%	30%	90%	95%	80%	12%

Legend: 100,000 Smallholder farms

Subsequent analysis focuses on the smallholder farm segment and the dominant coffee species (Arabica or Robusta) in each country

1. Source: UN Comtrade (2023) *2. Source: Enveritas (2018)* *3. Source: Solidaridad (2024) for Brazil; IDH (2019) for Colombia; Fairtrade (2017) for Tanzania; TechnoServe field data for Kenya, Ethiopia, Uganda; Expert interviews for all others*

Smallholder farm size thresholds vary by country: <2 ha in Ethiopia, Uganda, Tanzania, Indonesia, Kenya, and Vietnam; <3 ha in Honduras; <5 ha in Colombia and Peru; and <10 ha in Brazil.

Smallholder productivity

Smallholder farms-the largest coffee farm segment in each country-show wide yield variation, with smaller farms generally less productive.

1. *Planting density reflects # of coffee trees per hectare and might be influenced by prevalence of agroforestry system or intercropping in some origins*

Source: TechnoServe, Regenerative Coffee Investment Case (2025)

Smallholder production economics and GHG footprint

While higher yield, conventional systems traditionally involve high emissions, there is evidence that regenerative systems can achieve sustainable economic performance and low emissions.

GHG footprint measures the total greenhouse gas emissions (CO_2e) from coffee production, including inputs, energy use, and on-farm practices (incl. processing where applicable), expressed as metric tons of CO_2-equivalent per metric ton of green coffee

Source: TechnoServe, Regenerative Coffee Investment Case (2025)

3 Benchmarking Climate Risk in Coffee Production

Climate change is reshaping where and how coffee can thrive.
Understanding which countries face the greatest risks–and which are best positioned to adapt–provides a baseline perspective on climate resilience.

This analysis evaluates climate risk holistically across three dimensions: Exposure, Sensitivity, and Adaptive Capacity, whereby the combination of exposure and sensitivity defines the overall vulnerability of countries' coffee production systems.

Vulnerability: Overall degree to which coffee production is susceptible to relevant climate risks

Exposure:

Extent to which coffee production is exposed to relevant climate risks over the short and long term

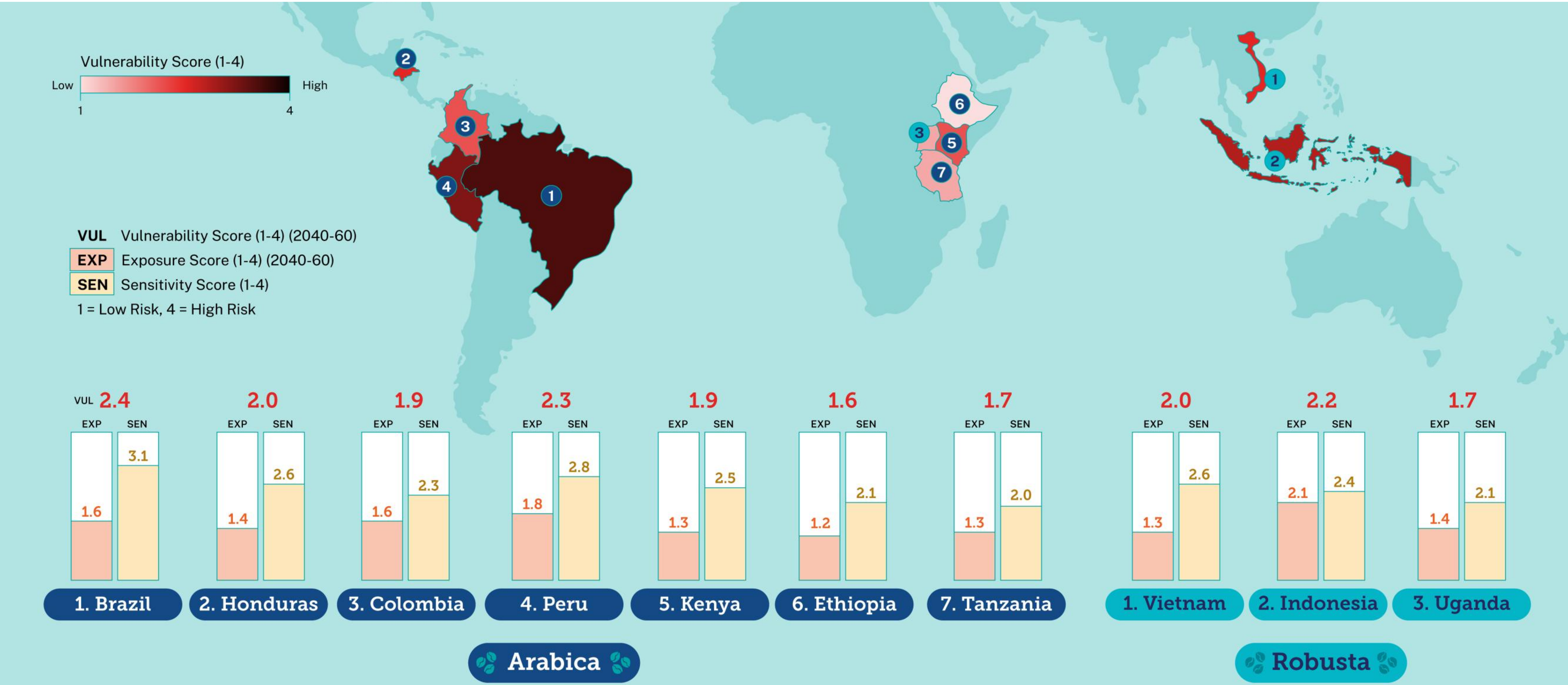
Sensitivity:

Extent to which coffee production is likely to be affected by those climate risks, reflecting the production environment's current ability to absorb and respond to stressors

Adaptive Capacity: Readiness and ability of farmers, governments, and private actors to plan for, invest in, and implement adaptation measures

Climate risk vulnerability

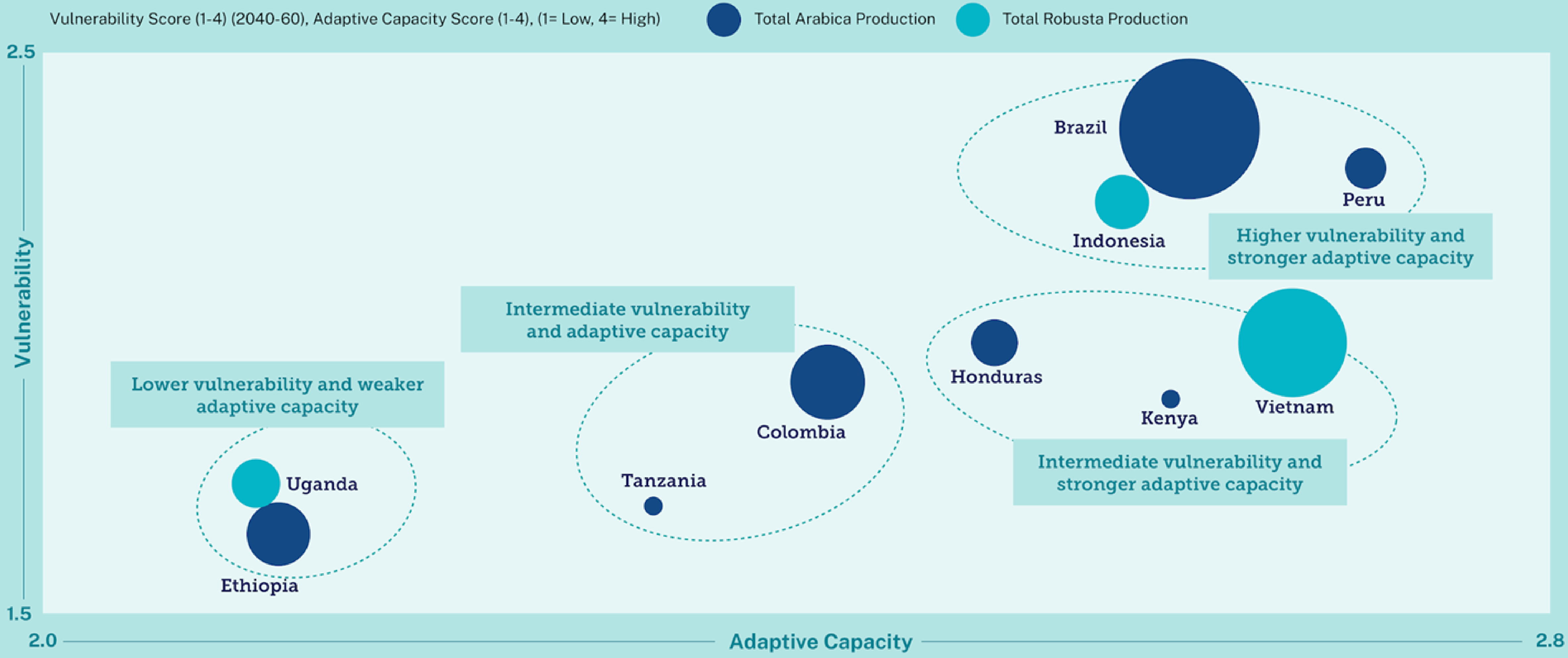
Latin American coffee-producing countries and Indonesia are the most vulnerable to climate risks, driven by greater water and temperature stress in low-altitude regions.



See Appendix for methodological details and data sources. Scores reflect values from the top coffee-producing countries in each country, using suitability thresholds specific to Arabica and Robusta. Vulnerability and exposure scores included here reflect long-term (2040-2060) values.

Climate risk vulnerability and adaptive capacity

Levels of climate vulnerability and readiness to adapt vary across origins. Future investments can build on these existing adaptive capabilities to accelerate adaptation.



See subsequent slides for adaptive capacity scores per country. See Appendix for methodological details and data sources. Vulnerability scores reflect long-term (2040-2060) exposure values.

Short-term climate risk exposure

Climate risk exposure — measured across thermal, water, and combined stress — is highest for Peru and Indonesia, where 2020-2040 conditions are projected to fall increasingly outside of coffee-suitable ranges.

Short-term Exposure Score (2020-2040) (1-4)

Low 1 — High 4

Group	Country	Short-term total exposure score (Extent to which coffee production is exposed to relevant climate risks over the short-term)	Short-term thermal stress score (Variation in annual and cold-season temperatures affecting coffee suitability over the short-term)	Short-term water stress score (Variation in annual rainfall, dry-season length, and humidity influencing moisture availability over the short-term)	Short-term thermal-water stress amplification score (Combined temperature and precipitation extremes increasing drought risk over the short-term)
Higher vulnerability and stronger adaptive capacity	Brazil	1.54	1.52	1.36	1.73
	Peru	1.65	1.90	2.04	1.00
	Indonesia	2.03	2.00	3.09	1.00
Intermediate vulnerability and stronger adaptive capacity	Vietnam	1.25	1.69	1.04	1.00
	Kenya	1.25	1.10	1.64	1.00
	Honduras	1.31	1.44	1.49	1.00
Intermediate vulnerability and adaptive capacity	Colombia	1.56	1.44	2.24	1.00
	Tanzania	1.25	1.50	1.24	1.00
Lower vulnerability and weaker adaptive capacity	Uganda	1.30	1.07	1.85	1.00
	Ethiopia	1.15	1.28	1.15	1.00

See Appendix for methodological details and data sources. Scores reflect values from the top coffee-producing counties in each country, using suitability thresholds specific to Arabica and Robusta.

Long-term climate risk exposure

While most countries show minimal change in exposure from the short-to long-term, Peru, Vietnam, and Tanzania face the largest increases, as growing thermal and water stress are projected to interact and intensify overall risk exposure from 2040-2060.

Long-term Exposure Score (2040-2060) (1-4)

Low 1 — 4 High

% — % Change from the short-to long-term exposure score

Long-term total exposure score: Extent to which coffee production is exposed to relevant climate risks over the long-term

Long-term thermal stress score: Variation in annual and cold-season temperatures affecting coffee suitability over the long-term

Long-term water stress score: Variation in annual rainfall, dry-season length, and humidity influencing moisture availability over the long-term

Long-term thermal-water stress amplification score: Combined temperature and precipitation extremes increasing drought risk over the long-term

Group	Country	Long-term total exposure score	%	Long-term thermal stress score	%	Long-term water stress score	%	Long-term thermal-water stress amplification score	%
Higher vulnerability and stronger adaptive capacity	Brazil	1.59	4%	1.52	0%	1.36	0%	1.90	10%
	Peru	1.77	7%	1.97	4%	2.14	5%	1.20	20%
	Indonesia	2.08	2%	2.04	2%	3.19	3%	1.00	0%
Intermediate vulnerability and stronger adaptive capacity	Vietnam	1.33	7%	1.69	0%	1.31	25%	1.00	0%
	Kenya	1.27	2%	1.13	3%	1.69	3%	1.00	0%
	Honduras	1.37	4%	1.53	6%	1.49	0%	1.08	8%
Intermediate vulnerability and adaptive capacity	Colombia	1.56	0%	1.44	0%	2.24	0%	1.00	0%
	Tanzania	1.33	7%	1.50	0%	1.24	0%	1.26	26%
Lower vulnerability and weaker adaptive capacity	Uganda	1.38	5%	1.20	12%	1.93	5%	1.00	0%
	Ethiopia	1.15	0%	1.28	0%	1.15	0%	1.00	0%

See Appendix for methodological details and data sources. Scores reflect values from the top coffee-producing counties in each country, using suitability thresholds specific to Arabica and Robusta.

Climate risk sensitivity

Climate sensitivity — shaped by farm management, resource resilience, and elevation — is highest for Brazil and Peru, where lower altitudes and lower baseline adoption of regenerative practices heighten susceptibility to climate stress.

Sensitivity Score (1-4)[1]

Low 1 – 4 High

Group	Country	Total sensitivity score Extent to which coffee production is likely to be affected by climate risks	Farm management score Degree of regenerative practice adoption; lower adoption increases farm sensitivity to climate risks	Resource resilience score Strength of ecosystem, soil, and water conditions supporting production; weaker conditions increase sensitivity	Elevation score Average altitude of coffee areas; lower elevations heighten sensitivity
Higher vulnerability and stronger adaptive capacity	Brazil	3.1	2.6	2.7	4.0
	Peru	2.8	3.0	2.4	3.0
	Indonesia	2.4	2.9	2.3	2.0
Intermediate vulnerability and stronger adaptive capacity	Vietnam	2.6	2.6	2.2	3.0
	Kenya	2.5	2.7	2.8	2.0
	Honduras	2.6	2.6	2.1	3.0
Intermediate vulnerability and adaptive capacity	Colombia	2.3	2.2	2.6	2.0
	Tanzania	2.0	2.5	2.6	1.0
Lower vulnerability and weaker adaptive capacity	Uganda	2.1	2.7	2.5	1.0
	Ethiopia	2.1	2.7	2.7	1.0

1. A higher score indicates higher sensitivity to climate risks. A higher score therefore indicates a lower degree of regenerative practice adoption under farm management, a lower level of resource resilience and lower elevation of coffee growing regions.

See Appendix for methodological details and data sources.

Climate risk adaptive capacity

Adaptive capacity-reflecting farmer readiness and broader systemic factors-is highest in Vietnam, Peru and Brazil, where stronger support systems and institutional stability enable adaptation.

Adaptive Capacity Score (1-4): Low 1 – High 4

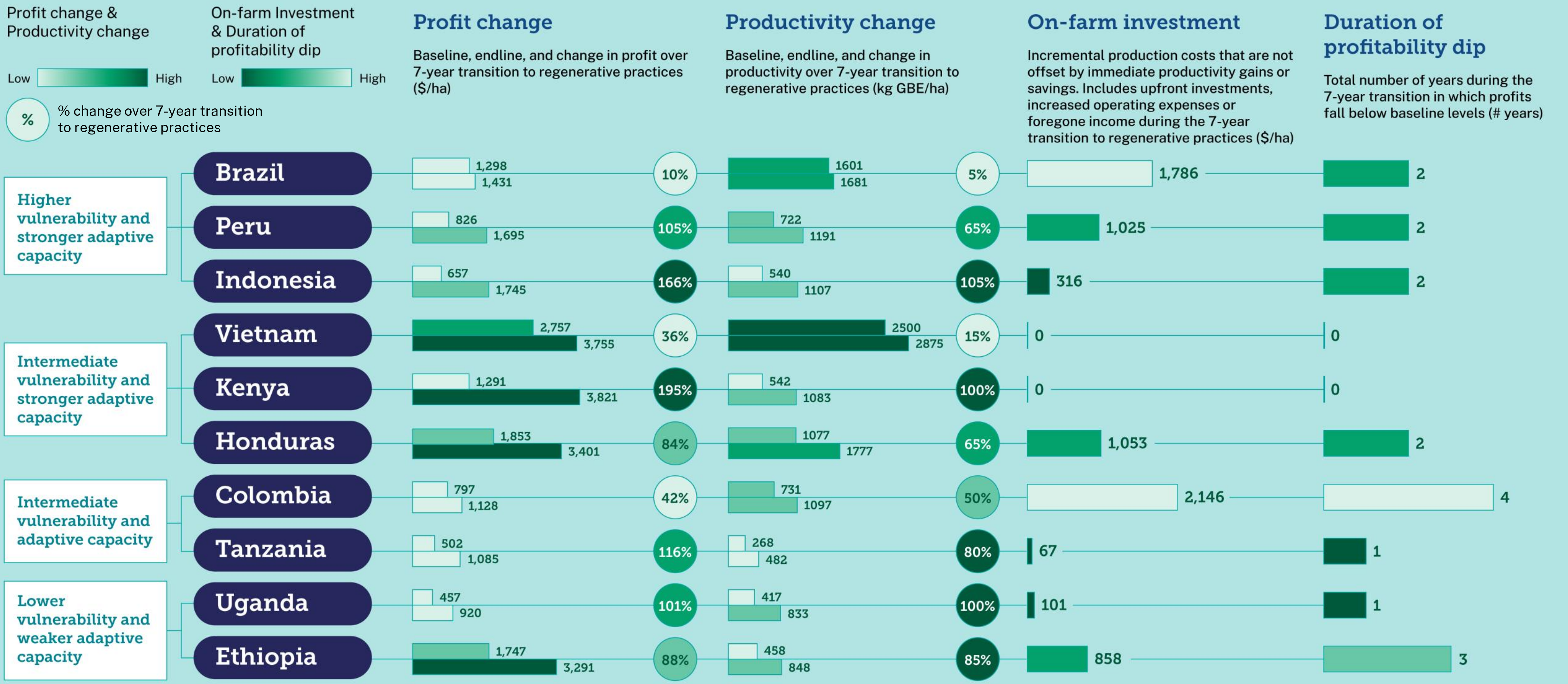
Group	Country	Total adaptive capacity score (Readiness and ability of farmers, governments, and private actors to adapt)	Farmer readiness (Farmer access to key resources and demographic factors influencing the ability to adapt (e.g., education level and age))	Government stability score (Institutional strength and political stability supporting sustained climate action)	Government readiness score (Government commitment and responsiveness to environmental goals and adaptation)	Economic readiness score (Strength of the investment climate enabling adaptation and private-sector participation)	Social readiness score (Inclusiveness and security of social systems, including labor rights and gender equality)
Higher vulnerability and stronger adaptive capacity	Brazil	2.6	2.7	2.8	3.0	1.9	2.6
	Peru	2.7	2.6	2.7	2.6	2.3	3.3
	Indonesia	2.6	2.8	2.6	2.8	2.2	2.6
Intermediate vulnerability and stronger adaptive capacity	Vietnam	2.7	2.9	2.9	2.6	2.5	2.5
	Kenya	2.6	3.0	2.8	2.5	2.0	2.8
	Honduras	2.5	2.5	2.7	2.7	1.8	2.9
Intermediate vulnerability and adaptive capacity	Colombia	2.4	2.5	1.7	2.8	2.2	2.9
	Tanzania	2.3	2.3	2.8	2.2	1.8	2.5
Lower vulnerability and weaker adaptive capacity	Uganda	2.1	2.5	1.4	2.2	1.9	2.5
	Ethiopia	2.1	2.5	1.5	2.3	2.0	2.4

Due to limited globally consistent datasets across priority countries, only the farmer readiness indicators for farmer age and farmer business case for adaptation are coffee-sector specific. All other indicators draw on broader agricultural data, which may result in some deviations from expected patterns.

See Appendix for methodological details and data sources.

Farmer business case for adaptation

Complementing adaptive capacity, the farmer business case for adaptation-measured by returns, investment costs, and transition profitability-highlights where adaptation is most attractive to farmers. Notably, East African coffee-producing countries stand out due to their comparatively high productivity gains and low investment costs.



All values are derived from 7-year country-specific adaptation roadmaps that identify proven regenerative practices most relevant to local contexts and beneficial to both farmer incomes and nature.

Source: TechnoServe, Regenerative Coffee Investment Case (2025)

Appendix

Additional detail on methodology

Climate Risk Exposure

Indicators were selected given their critical impact on potential coffee yields

- **Level of Analysis:** Indicators were compiled at the county administrative level, focusing on the principal coffee-producing counties within each country
- **Analytical Approach:** Each indicator was scored from 1 to 4 based on coffee-specific climatic risk thresholds, as defined in the subsequent slide
- **Data Source:** All climate indicators were obtained from the World Bank Climate Change Knowledge Portal, derived from the CMIP5 ensemble of global circulation models at a 0.25° spatial resolution. The analysis utilized the SSP2–4.5 scenario, representing an intermediate "middle-of-the-road" socioeconomic pathway characterized by a continuation of historical development trends throughout the 21st century

Indicators included:

Pillar	Indicator	Rationale
Thermal stress	Mean annual temperature	Deviations harm cherry maturation, accelerating ripening or stunting plant growth
	Mean minimum temperature of coldest month	Extremes risk frost or insufficient chilling, disrupting flowering and ripening
Water stress	Mean annual precipitation	Deviations induce drought stress or water logging, increasing disease risk
	Length of dry season	Extended or shortened dry periods prevent proper flowering
	Mean relative humidity of driest month	Extremes trigger increased evapotranspiration and water stress or promote disease
Thermal-water stress amplification	Drought risk (SPEI index)	Elevated drought risk leads to water deficits that stunt plant growth and cherry development

Climate Risk Exposure

Selected indicators were scored against Arabica-or Robusta-specific climate risk thresholds, reflecting the tipping points at which conditions become less suitable for coffee production

Climate risk thresholds:

Score		1: Highly suitable		2: Moderately suitable		3: Marginally suitable		4: Unsuitable	
Species		Arabica	Robusta	Arabica	Robusta	Arabica	Robusta	Arabica	Robusta
Thermal stress	Mean annual temperature (C)	17-22	22-25	22-25 15-17	25-28	25-28 12-15	28-32 19-22	>28 <12	>32 <19
	Mean minimum temperature of coldest month (C)	10-19	-	19-21 7-10	-	21-23 4-7	-	>23 <4	
Water stress	Mean annual precipitation (mm)	1,400-1,800	1,500-2,000	1,800-2,300 1,000-1,400	2,000-2,500	2,300-4,200 750-1000	2,500-3,000 1,000-1,500	>4200 <750	>3,000 <1,000
	Length of dry season (months)	1-4	-	4-5 0-1	-	5-6	-	>6 <1	-
	Mean relative humidity of driest month (%)	40-70	-	70-80 30-40	-	80-90 20-30	-	>90 <20	-
Thermal-water stress amplication	Drought risk (SPEI index)	> (-0.5)		(-0.8) - (-0.5)		(-1.3) – (-0.8)		<(-1.3)	

Robusta thresholds are not included for mean minimum temperature of coldest month, length of dry season, and mean relative humidity of coldest month due to a lack of robust estimates in the reviewed literature.

Sources: Arabica: Grüter, R., Trachsel, T., Laube, P., & Jaisli, I. (2022). Expected global suitability of coffee, cashew and avocado due to climate change. PLOS ONE, 17(2).
Robusta: Sarvina, Y. et al. (2023). Projection of Robusta coffee's climate suitability for sustainable Indonesian coffee production. International Journal of Sustainable Development and Planning, 18(4), 1069-1078.

Climate Risk Exposure

Country-level total scores were derived as the average across the three pillars: thermal stress, water stress, and thermal–water stress amplification. Scores were calculated for two time horizons — near-term (2020–2040) and long-term (2040–2060) — to capture projected climate stress dynamics over time

Scores range from 1–4 (1 = Low, 4 = High)

Short-term (2020-2040) score / Long-term (2040-2060) score

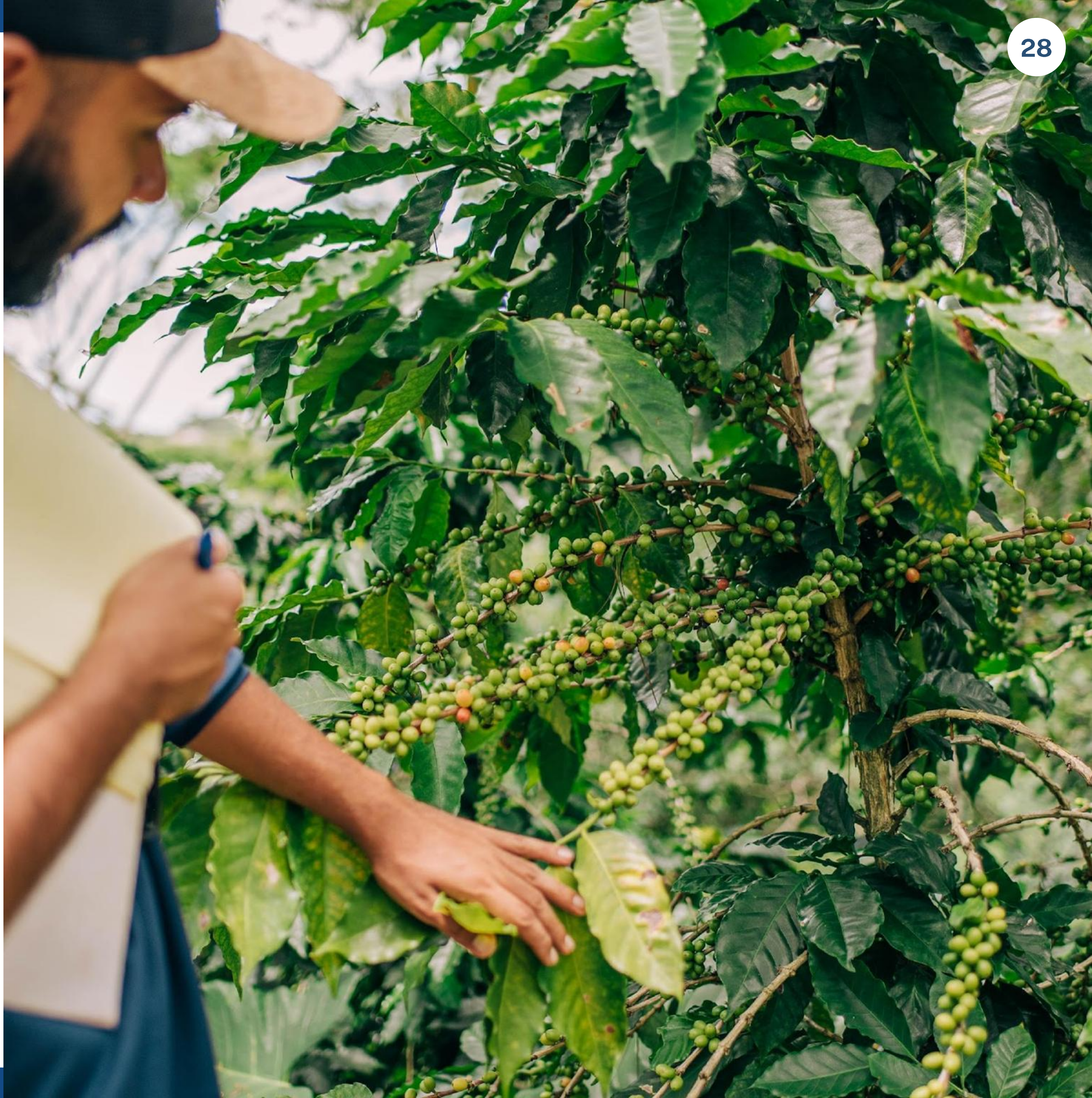
	Higher vulnerability and stronger adaptive capacity			Intermediate vulnerability and stronger adaptive capacity			Intermediate vulnerability and adaptive capacity		Lower vulnerability and weaker adaptive capacity	
	Brazil	Indonesia	Peru	Vietnam	Kenya	Honduras	Colombia	Tanzania	Ethiopia	Uganda
	Arabica	Robusta	Arabica	Robusta	Arabica	Arabica	Arabica	Arabica	Arabica	Robusta
TOTAL EXPOSURE	**1.54 / 1.59**	**2.03 / 2.08**	**1.65 / 1.77**	**1.25 / 1.33**	**1.25 / 1.27**	**1.31 / 1.37**	**1.56 / 1.56**	**1.25 / 1.33**	**1.15 / 1.15**	**1.30 / 1.38**
Thermal stress	**1.52 / 1.52**	**2.00 / 2.04**	**1.90 / 1.97**	**1.69 / 1.69**	**1.10 / 1.13**	**1.44 / 1.53**	**1.44 / 1.44**	**1.50 / 1.50**	**1.28 / 1.28**	**1.07 / 1.20**
Mean annual temperature	2.03 / 2.03	2.00 / 2.04	2.16 / 2.11	1.69 / 1.69	1.20 / 1.26	1.81 / 2.06	1.48 / 1.48	2.00 / 2.00	1.40 / 1.40	1.07 / 1.20
Mean minimum temperature of coldest month	1.00 / 1.00	-	1.64 / 1.84	-	1.00 / 1.00	1.08 / 1.00	1.40 / 1.40	1.00 / 1.00	1.17 / 1.17	-
Water stress	**1.36 / 1.36**	**3.09 / 3.19**	**2.04 / 2.14**	**1.04 / 1.31**	**1.64 / 1.69**	**1.49 / 1.49**	**2.24 / 2.24**	**1.24 / 1.24**	**1.15 / 1.15**	**1.85 / 1.93**
Mean annual precipitation	1.89 / 1.89	3.09 / 3.19	2.42 / 2.71	1.04 / 1.31	2.02 / 2.18	1.59 / 1.59	3.14 / 3.14	1.52 / 1.52	1.09 / 1.09	1.85 / 1.93
Length of dry season	1.10 / 1.10	-	2.00 / 2.00	-	1.89 / 1.89	1.63 / 1.63	1.92 / 1.92	1.21 / 1.21	1.28 / 1.28	-
Mean relative humidity of driest month	1.10 / 1.10	-	1.71 / 1.71	-	1.00 / 1.00	1.26 / 1.26	1.66 / 1.66	1.00 / 1.00	1.09 / 1.09	-
Thermal-water stress amplification	**1.73 / 1.90**	**1.00 / 1.00**	**1.00 / 1.20**	**1.00 / 1.00**	**1.00 / 1.00**	**1.00 / 1.08**	**1.00 / 1.00**	**1.00 / 1.26**	**1.00 / 1.00**	**1.00 / 1.00**
Drought risk (SPEI Index)	1.73 / 1.90	1.00 / 1.00	1.00 / 1.20	1.00 / 1.00	1.00 / 1.00	1.00 / 1.08	1.00 / 1.00	1.00 / 1.26	1.00 / 1.00	1.00 / 1.00

Robusta scores are not included for mean minimum temperature of coldest month, length of dry season, and mean relative humidity of coldest month due to the lack of robust suitability thresholds in the reviewed literature.

Climate Risk Sensitivity

Indicators were chosen for their influence on farms' susceptibility to climate stresses, determining their capacity to maintain productivity and resilience under the quantified climate risk exposure

- **Level of Analysis**: Indicators were compiled at the country level
- **Analytical Approach**: Indicators drawn from existing global indexes (e.g., WWF Risk Filter) were scored using their original methodologies and rescaled to a 1–4 range. All other indicators were evaluated using tailored thresholds aligned to the same 1–4 scale
- **Data Sources**: Indicators were sourced from established global studies and indexes to ensure cross-country comparability



Climate Risk Sensitivity

Indicators included:

Pillar	Indicator	Rationale	Source
Farm management	Rehabilitation and renovation adoption	Rejuvenation of aging, diseased or poorly managed trees with improved, genetically resilient varieties reduces susceptibility to yield loss from new pests, diseases, and heat stress	*TechnoServe Regenerative Coffee Investment Case*
	Agroforestry adoption	Growing shade trees reduces crop exposure to extreme heat, thereby mitigating risk of damage and reduced quality	*TechnoServe Regenerative Coffee Investment Case*
	Integrated nutrient and soil management adoption	Balanced fertilization and soil conservation improves soil fertility and water retention, strengthening resilience to drought and erosion	*TechnoServe Regenerative Coffee Investment Case*
	Integrated pest, disease and weed management adoption	Monitoring protocols, mulching, and nature-based preventative controls reduce use of chemical controls to promote healthy soil and functional biodiversity, reducing vulnerability to pest and disease outbreaks	*TechnoServe Regenerative Coffee Investment Case*
	Integrated water management adoption	Efficient water use and riparian buffer zones protect water availability and quality, supporting consistent production under variable rainfall	*TechnoServe Regenerative Coffee Investment Case*
Resource resilience	Ecosystem condition	Measures the integrity of surrounding ecosystems that sustain key services such as pollination, pest control, fertile soil and clean water. Based on the Biodiversity Intactness Index, Functional Connectivity of Protected Areas, and Ocean Health Index	*WWF Biodiversity Risk Filter*
	Soil condition	Assesses the health of soil through soil organic carbon content, a key determinant of fertility, structural stability, and water-holding capacity. Derived from the Global Soil Partnership SOC map	*WWF Biodiversity Risk Filter*
	Water availability	Measures the availability of freshwater from surface and groundwater sources, as insufficiencies increase evapotranspiration stress and reduce soil moisture. Integrates data from global hydrological models to provide a comprehensive view of risk	*WWF Biodiversity Risk Filter*
	Irrigation status	Indicates the prevalence of irrigation systems supporting consistent yields during dry periods	*TechnoServe Regenerative Coffee Investment Case*
Elevation	Coffee-growing elevation	Captures the average altitude of coffee production areas, as higher elevations mitigate exposure to heat stress and temperature variability	*Country-specific literature review*

Climate Risk Sensitivity

Country-level total scores were derived as the average across the three pillars: farm management, resource resilience, and elevation

Scores range from 1–4 (1 = Low, 4 = High)[1]	Higher vulnerability and stronger adaptive capacity			Intermediate vulnerability and stronger adaptive capacity			Intermediate vulnerability and adaptive capacity		Lower vulnerability and weaker adaptive capacity	
	Brazil	Indonesia	Peru	Vietnam	Kenya	Honduras	Colombia	Tanzania	Ethiopia	Uganda
	Arabica	Robusta	Arabica	Robusta	Arabica	Arabica	Arabica	Arabica	Arabica	Robusta
TOTAL SENSITIVITY	**3.1**	**2.4**	**2.8**	**2.6**	**2.5**	**2.6**	**2.3**	**2.0**	**2.1**	**2.1**
Farm management	**2.6**	**2.9**	**3**	**2.6**	**2.7**	**2.6**	**2.2**	**2.5**	**2.7**	**2.7**
Rehabilitation and renovation adoption	1.8	2.7	3.2	1.8	2.5	2.5	2.2	2.3	3.0	2.3
Agroforestry adoption	4.0	2.0	3.0	2.0	2.0	2.0	1.5	2.0	1.5	2.0
Integrated nutrient and soil management adoption	2.6	3.2	3.0	2.9	3.3	2.8	2.5	3.5	3.5	3.0
Integrated pest, disease, and weed management adoption	2.3	3.1	2.7	2.7	3.2	2.7	2.3	2.9	2.9	3.4
Integrated water management adoption	2.5	3.5	3.3	3.8	2.5	3.2	2.7	2.0	2.5	3.0
Resource resilience	**2.7**	**2.3**	**2.4**	**2.2**	**2.8**	**2.1**	**2.6**	**2.6**	**2.7**	**2.5**
Ecosystem condition	2.1	1.9	1.6	2.6	2.0	2	2.0	1.8	2.1	2.0
Soil condition	3.2	1.6	2.0	3.4	3.2	1.3	2.7	3.1	3.0	2.8
Water availability	1.7	1.5	1.9	1.9	1.8	1.3	1.6	1.4	1.7	1.3
Irrigation status	4.0	4.0	4.0	1.0	4.0	4.0	4.0	4.0	4.0	4.0
Elevation	**4.0**	**2.0**	**3.0**	**3.0**	**2.0**	**3.0**	**2.0**	**1.0**	**1.0**	**1.0**

1. A higher score indicates higher sensitivity to climate risks. A higher score therefore indicates a lower degree of regenerative practice adoption under farm management, a lower level of resource resilience and lower elevation of coffee growing regions.

Climate Risk Adaptive Capacity

Indicators were chosen to capture systemic factors that shape the capacity of farmers, government and private actors to plan for, invest in, and implement adaptation measures

- **Level of Analysis**: Indicators were compiled at the country level
- **Analytical Approach**: Indicators drawn from existing global indexes (e.g., World Bank EBA, ND-GAIN Index, INFORM Climate Risk Index, WWF Risk Filter, OECD SIGI) were scored using their original methodologies and rescaled to a 1–4 range. All other indicators were evaluated using tailored thresholds aligned to the same 1–4 scale
- **Data Sources**: Indicators were sourced from established global studies and indexes to ensure cross-country comparability

Indicators included:

Pillar	Indicator	Rationale	Source
Farmer readiness	Farmer access to inputs, finance, and markets[1]	Measures the robustness of support systems that enable farmer access to key inputs (seeds, fertilizer, water), finance, and markets (not specific to coffee farmers)	*World Bank Enabling Business of Agriculture Index*
	Rural education level	Reflects the general level of formal education among farmers, influencing their ability to adopt new practices effectively (not specific to coffee farmers)	*TechnoServe coffee programs, Country-specific literature review*
	Farmer age	Indicates the mean age of coffee farmers, which is a key determinant of farm longevity and the propensity to invest in measures promoting future resilience	*Global Data Lab*
Government stability	Rule-based governance	Evaluates the foundational ability of state institutions to coordinate, enforce, and maintain climate-related policies. Considers government control of corruption, regulatory quality, and rule of law from World Governance Indicators	*ND-Gain Index*
	Conflict intensity	Measures political instability that may interrupt execution and continuity of climate adaptation projects through diversion of resources and access. Incorporates measures from the Heidelberg Institute for International Conflict Research conflict barometer and Global Conflict Risk Index	*INFORM Climate Risk Index*
Government readiness	Disaster preparedness	Measures government responsiveness to climate hazards. Based on monitoring from the Hyogo Framework Action Plan	*ND-Gain Index*
	Reputational factors	Reflects public scrutiny and incentive for government action. Includes measures of media scrutiny around environmental issues, humanitarian crises risk preparation, and existence of world heritage sites for preservation from RepRisk and RAMSAR databases	*WWF Biodiversity Risk Filter*
	Country biome protection	Measures government commitment to maintaining natural ecosystems essential for underlying coffee resilience. Based on Yale Environmental Performance Index	*ND-Gain Index*
	Engagement in international environment conventions	Measures government capacity to engage in multilateral negotiations needed to facilitate climate finance and adaptation measures. Based on levels of country participation in international forums from Environmental Treaties and Resource Indicators	*ND-Gain Index*
Economic readiness	Ease of doing business	Evaluates capacity to attract private adaption investments. Considers ten core areas from World Bank Doing Business Indicators (including investor protections, contract enforcements, credit access, etc.)	*ND-Gain Index*
Social readiness	Labor and human rights	Assesses workforce security and capacity for long-term adaptation investments. Derived from the V-Dem civil liberties index	*WWF Water Risk Filter*
	Social institutions and gender inequality	Captures barriers to female empowerment affecting access to resources and decision-making. Considers physical integrity, access to productive and financial resources, and civil liberties	*OECD*

1. The World Bank Enabling the Business of Agriculture Index does not include Indonesia. For Indonesia, the "Farmer access to inputs, finance, and markets" indicator was derived from the average of the World Bank Global Findex (% of rural adults with bank accounts) and the ND-GAIN agricultural capacity score

Climate Risk Adaptive Capacity

Country-level total scores were derived as the average across the five pillars: farmer readiness, government stability, government readiness, economic readiness, and social readiness

Scores range from 1–4 (1 = Low, 4 = High)	Higher vulnerability and stronger adaptive capacity			Intermediate vulnerability and stronger adaptive capacity			Intermediate vulnerability and adaptive capacity		Lower vulnerability and weaker adaptive capacity	
	Brazil	Indonesia	Peru	Vietnam	Kenya	Honduras	Colombia	Tanzania	Ethiopia	Uganda
	Arabica	Robusta	Arabica	Robusta	Arabica	Arabica	Arabica	Arabica	Arabica	Robusta
TOTAL ADAPTIVE CAPACITY	**2.6**	**2.6**	**2.7**	**2.7**	**2.6**	**2.5**	**2.4**	**2.3**	**2.1**	**2.1**
Farmer readiness	**2.7**	**2.8**	**2.6**	**2.9**	**3.0**	**2.5**	**2.5**	**2.3**	**2.5**	**2.5**
Farmer access to inputs, finance, and markets	3.2	2.8	2.3	2.8	2.9	2.4	3.5	2.8	2.4	2.6
Rural education level	2.0	2.0	3.0	3.0	3.0	2.0	2.0	2.0	1.0	2.0
Avg. age of farmers	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	4.0	3.0
Government stability	**2.8**	**2.7**	**2.6**	**2.9**	**2.8**	**2.7**	**1.7**	**2.8**	**1.5**	**1.4**
Rule-based governance	1.9	1.8	1.9	2.0	1.7	1.5	2.1	2.1	2.0	1.6
Conflict intensity	3.8	3.6	3.2	3.8	3.9	3.9	1.3	3.6	1.0	1.3
Government readiness	**3.0**	**2.6**	**2.8**	**2.6**	**2.5**	**2.7**	**2.8**	**2.2**	**2.3**	**2.2**
Disaster preparedness	4.0	4.0	3.9	4.0	3.7	4.0	4.0	3.0	4.0	2.3
Reputational factors	2.5	2.6	2.5	2.2	2.0	2.5	2.3	2.6	1.7	2.6
Country biome protection	3.1	2.9	2.6	2.3	2.5	2.8	3.0	2.3	1.8	2.3
Engagement in international environmental conventions	2.6	1.0	2.0	1.6	1.8	1.7	2.1	1.0	1.6	1.8
Economic readiness	**1.9**	**2.3**	**2.2**	**2.5**	**2.0**	**1.8**	**2.2**	**1.8**	**2.0**	**1.9**
Ease of doing business	1.9	2.3	2.2	2.5	2.0	1.8	2.2	1.8	2.0	1.9
Social readiness	**2.6**	**3.3**	**2.6**	**2.5**	**2.8**	**2.9**	**2.9**	**2.5**	**2.4**	**2.5**
Labor and human rights	1.8	3.3	2.5	1.8	2.5	2.5	2.5	2.5	1.8	1.8
Social institutions and gender inequality	3.4	3.4	2.7	3.3	3.0	3.2	3.3	2.5	3.1	3.2

Additional considerations and opportunities for refinement

Scoring methodology: The analysis emphasizes climate variables and thresholds most relevant to coffee systems. However, the current reliance on linear thresholds to define suitability does not fully capture multivariate interactions among climatic variables or the seasonal dynamics that influence coffee growth, flowering, and fruit development. In addition, thresholds for Robusta are relatively limited due to the lack of consistent, robust parameters in the reviewed literature.

Future refinements could incorporate multilinear thresholds, a broader range of seasonal climate variables, and improved Robusta-specific parameters as new data become available.

Spatial scale of analysis: Climate indicators were analyzed at the county level for climate risk exposure, representing the highest globally consistent administrative scale available. This approach may obscure localized differences among distinct coffee-growing zones within counties.

Future analyses could benefit from integrating finer-scale spatial data as it becomes more consistently available across countries.

Adaptive capacity indicator selection: Indicators related to farmer access to knowledge and resources were included but were not specific to the coffee sector due to the lack of globally consistent data.

Metrics such as women's joint or sole management of coffee farms and farmer access to coffee-specific support programs should be incorporated in future analyses once such data are systematically available.

Sources and references

To develop this report, TechnoServe drew on the extensive experience of internal experts and the rich data accumulated through years of implementing coffee programs. In addition, the analysis incorporated insights from existing literature and global climate risk indexes. The following sources and references are presented in alphabetical order.

- Baca, M., Läderach, P., Haggar, J., Schroth, G., & Ovalle, O. (2014). An Integrated Framework for Assessing Vulnerability to Climate Change and Developing Adaptation Strategies for Coffee Growing Families in Mesoamerica. *PLOS ONE*, 9(2): e0088463.
- Bunn, C., Läderach, P., Ovalle Rivera, O., & Kirschke, D. (2015). A bitter cup: climate change profile of global production of Arabica and Robusta coffee. *Climatic Change*, 129(1): 89-101.
- Bunn, C., Läderach, P., Pérez Jimenez, J. G., Montagnon, C., & Schilling, T. (2015). Multiclass Classification of Agro-Ecological Zones for Arabica Coffee: An Improved Understanding of the Impacts of Climate Change. *PLOS ONE*, 10(10): e0140490.
- Chen, C., Noble, I., Hellmann, J., Coffee, J., Murillo, M., & Chawla, N. (2024). University of Notre Dame Global Adaptation Initiative: Country Index Technical Report.
- Davis, A. P., Gole, T. W., Baena, S., & Moat, J. (2012). The Impact of Climate Change on Indigenous Arabica Coffee (Coffea arabica): Predicting Future Trends and Identifying Priorities. *PLOS ONE*, 7(11): e0047981.
- Global Data Lab. (2025). Education and Work indicators: Levels 1 & 2. Global Data Lab.
- Grüter, R., Trachsel, T., Laube, P., & Jaisli, I. (2022). Expected global suitability of coffee, cashew and avocado due to climate change. *PLOS ONE*, 17(1), e0261976.
- Intergovernmental Panel on Climate Change. (2001). Climate change 2001: Impacts, adaptation, and vulnerability. Working Group II, Third Assessment Report. Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. Summary for policymakers. Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC.
- Läderach, P., Ramirez-Villegas, J., Navarro-Racines, C., Zelaya, C., Martinez-Valle, A., & Jarvis, A. (2017). Climate change adaptation of coffee production in space and time. *Climatic Change*, 141(1): 47-62.
- Magrach, A., & Ghazoul, J. (2015). Climate and Pest-Driven Geographic Shifts in Global Coffee Production: Implications for Forest Cover, Biodiversity and Carbon Storage. *PLOS ONE*, 10(7): e0133071.
- OECD. (2023). SIGI 2023 Global Report: Gender Equality in Times of Crisis, Social Institutions and Gender Index. OECD Publishing, Paris.
- Ovalle-Rivera, O., Läderach, P., Bunn, C., Obersteiner, M., & Schroth, G. (2015). Projected Shifts in *Coffea arabica* Suitability among Major Global Producing Regions Due to Climate Change. *PLOS ONE*, 10(4): e0124155.
- Poljansek, K., Marzi, S., Galimberti, L., Dalla Valle, D., Pal, J., Essenfelder, A. H., Mysiak, J., & Corbane, C. (2022). INFORM Climate Change Risk Index, EUR 31138 EN. Publications Office of the European Union, Luxembourg.
- Sarvina, Y., June, T., Sutjahjo, S. H., Nurmalina, R., & Surmaini, E. (2023). Projection of Robusta coffee's climate suitability for sustainable Indonesian coffee production. International Journal of Sustainable Development and Planning, 18(4), 1069-1078.
- TechnoServe. (2024). The Investment Case for Regenerative Coffee Production. TechnoServe.
- World Bank. (2025). Global Findex Database: Connectivity and financial inclusion in the digital economy. World Bank.
- World Bank. (2019). Enabling the Business of Agriculture (EBA): Methodology. World Bank.
- WWF. (2024). WWF Biodiversity Risk Filter Indicator Documentation version 2.0.
- WWF. (2024). WWF Water Risk Filter Indicator and Scenarios Documentation Version 2.0.

Disclaimer

Acknowledgements

This report was prepared by TechnoServe with funding from the United Nations Industrial Development Organization (UNIDO) under the Advancing Climate-resilience and Transformation in African Coffee Programme (ACT Coffee Programme), supported by the Italian Cooperation. The content, analysis, and recommendations presented herein are those of TechnoServe and do not necessarily represent the official position of UNIDO, its Member States, or the Government of Italy.

The authors thank Andrea De Marco (ACT Programme Manager and Partnership Advisor, UNIDO) for his partnership and guidance throughout. The work also reflects contributions from Stefan Cognigni, Giulia Vaglietti, and Chiara Scaraggi (UNIDO), and Carole Hemmings, Sabrina Troster, and Mei Tercek (TechnoServe).

Lead Authors

Paul Stewart
Global Coffee Director
TechnoServe

pstewart@tns.org

Myriam Sainz
Senior Director
Strategic Initiatives
TechnoServe

msainz@tns.org

Contributors

Andrea De Marco
ACT Programme Manager
and Partnership Advisor
UNIDO

a.demarco@unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TechnoServe
Business Solutions to Poverty™