

Coffee Sector Analysis on Heterogeneity

South and Middle America – Brazil, Colombia, Peru, Mexico and Honduras

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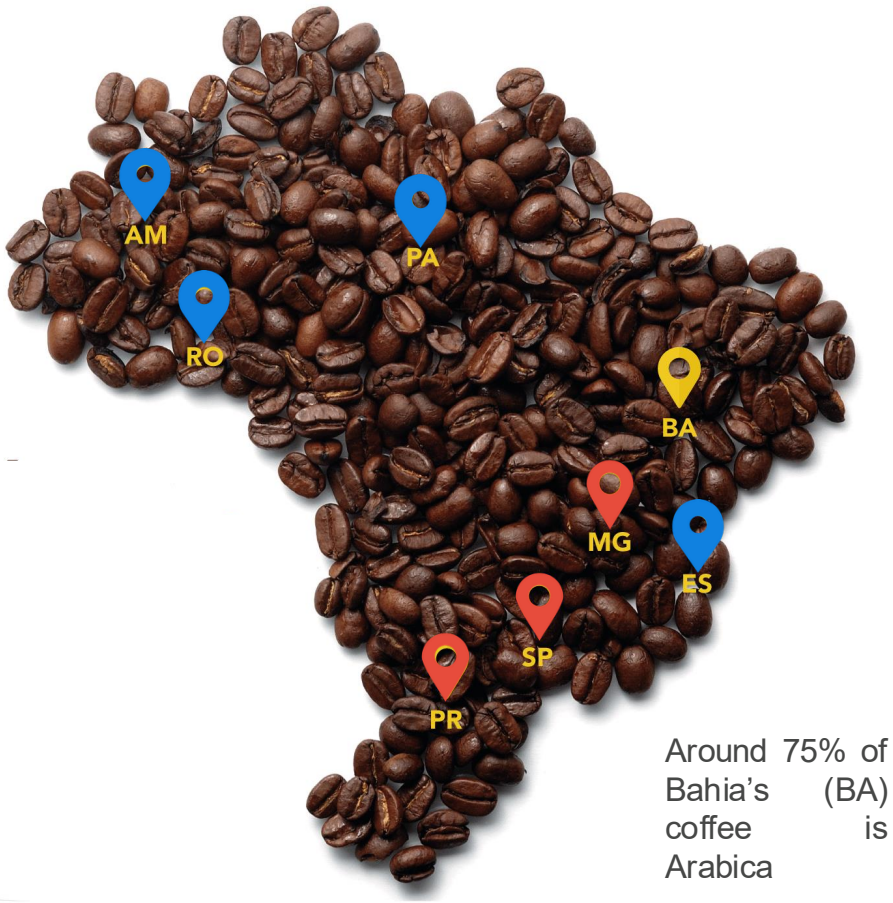
Cologne
7th February 2025

Brazil

Brazil is a leader in coffee-producing technology



Around 75% of Bahia's (BA) coffee is Arabica

Coffee Production

- around 2M hectares of coffee production, of which the vast majority (>70%) is Arabica
- Robusta: Espírito Santo (ES) (~80%), Rondônia (RO), Bahia (BA)
- Arabica: Minas Gerais (MG), São Paulo (SP), Paraná (PR), Bahia (BA)

Minas Gerais is Brazil's top coffee-producing state, divided into five regions: Cerrado Mineiro, Chapada, Matas, Norte, and Sul de Minas.

- farms range in size from small-medium family plantations of less than 10 hectares, up to massive estates of 2000 hectares
- only country to utilize mechanized harvesting tools to assist with the extensive coffee fields
- due to many coffee-growing areas flatter, mechanization is more feasible

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Brazil

Farm Size

Arabica Coffee

- Medium-sized family farms, mostly under 10 hectares, but some between 10 and 100 hectares, contrasting with large farms, as the most significant coffee producers, in Sul de Minas, MG
- Large-scale production of thousands of hectares and fully mechanised to compete on a global scale in terms of production volume

Robusta Coffee

- small-medium properties
- average size of 8 hectares in Espirito Santo (ES), conducted by families

Brazil

Agroforestry Practices

Arabica Coffee

- Arabica coffee is predominantly grown in the southeastern and southern regions of Brazil, such as Minas Gerais and Paraná.
- Shaded monoculture is predominant in small farms. Shade trees like *Grevillea robusta* (Australian silver oak) with Arabica coffee
- Large farms predominantly have a full-sun monoculture
- regenerative methods to reduce the use of chemical Fertilizers and pesticides
- rows of coffee planted with other native trees
- Studies have explored intercropping Arabica coffee with species such as rubber trees (*Hevea brasiliensis*) and *Mimosa scabrella* (bracatinga).

Robusta Coffee

- Robusta coffee is mainly cultivated in the northern regions of Brazil, including Espírito Santo and Rondônia.
- In regions like Bahia, intercropping Robusta coffee with shade-providing trees such as *Grevillea robusta* and banana (*Musa spp.*)
- notable prevalence of **shaded monoculture** in small farms
- Large farms predominantly have a full-sun monoculture

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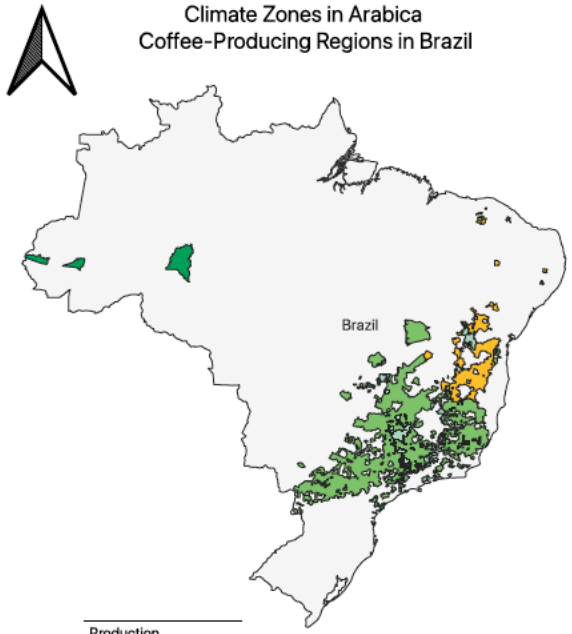
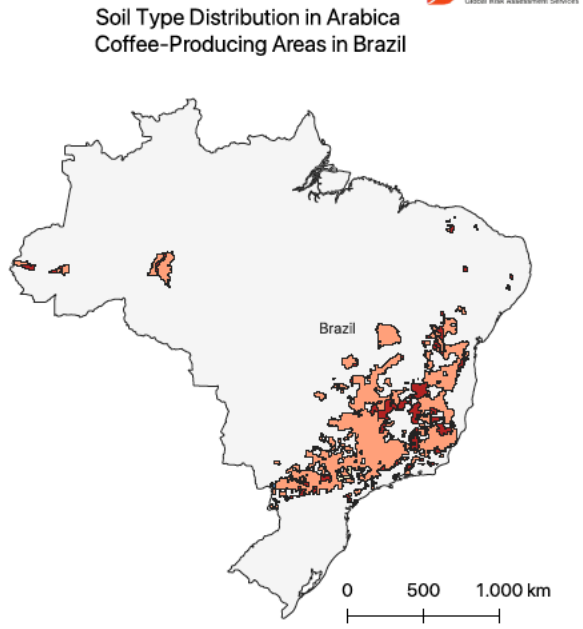
Brazil - Arabica

Climate zone and soil type



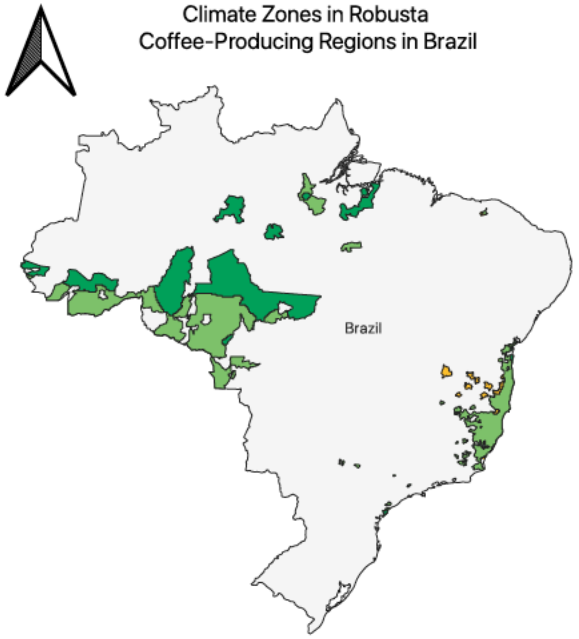
Production Share (%)	Area (%)	Climate Type
52 %	69 %	Tropical Moist
3 %	14 %	Tropical Dry
36 %	7 %	Tropical Montane
<1 %	5 %	Tropical Wet
7 %	1 %	Warm Temperate Moist
<1 %	<1 %	Warm Temperate Dry



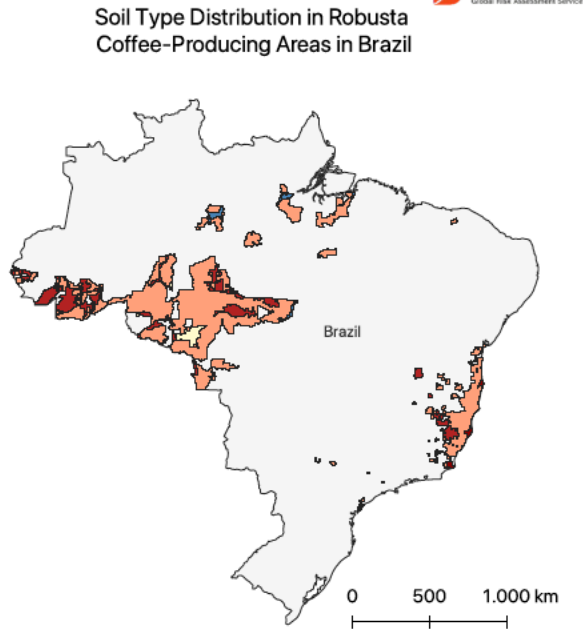
Production Share (%)	Area (%)	Soil Type
84 %	82 %	Low Activity Clay Soils
13 %	16 %	High Activity Clay Soils
<1 %	<1 %	Sandy Soils
<1 %	<1 %	Wetland Soils

Brazil - Robusta

Climate zone and soil type



Production Share (%)	Area (%)	Climate type
83 %	54 %	Tropical Moist
6 %	43 %	Tropical Wet
3 %	2 %	Tropical Dry
3 %	<1 %	Tropical Montane
2 %	<1 %	Warm Temperate Moist



Production Share (%)	Area (%)	Soil Type
68 %	78 %	Low Activity Clay Soils
17 %	16 %	High Activity Clay Soils
2 %	2 %	Sandy Soils
<1 %	<1 %	Wetland Soils
12 %	<1 %	Spodic Soils

Brazil - Robusta

Fertilizer usage

Arabica Coffee

- Around 70% of farms use chemical fertilizers.
- 30% or less use organic or regenerative methods.
- In regions like **Minas Gerais**, particularly the **Cerrado Mineiro** area, there is a notable shift towards regenerative agricultural practices. Farmers here are reducing chemical fertilizer usage and incorporating organic alternatives to enhance soil health and resilience against climate change.
- **Homogeneity Classification**: **High**

Robusta Coffee

- Around 80% of Robusta farms rely on high fertilizer application, both chemical and organic.
- 20% or less use minimal fertilizers.
- In the state of **Espírito Santo**, a major Robusta-producing region, farmers have received assistance in organic fertilizer production and improving processing efficiency, aiming to enhance sustainability and product quality.
- **Homogeneity Classification: Moderate**

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Brazil - Robusta

Land Use Change

Minas Gerais (Largest Coffee-Producing State)

- **Stability:** ~72% of land in Minas Gerais has remained under coffee cultivation.
- Stable coffee production, some areas shifting to mechanised monoculture.

São Paulo (Second Largest Coffee Producer)

- **Stability:** ~65% of São Paulo's coffee-growing areas have remained intact.
- Some regions converted to sugarcane and citrus.

Espírito Santo (Robusta Coffee Region)

- **Stability:** Only ~58% of coffee land remains unchanged.

Bahia (Expanding Coffee Region)

- **Stability:** ~61% of land remains in coffee production.

Paraná

- **Stability:** ~68% of Paraná's coffee farms remain unchanged.

- The **majority of Brazil's coffee land (60-70%) has remained stable**, indicating **a high degree of homogeneity** in long-term coffee-growing regions.

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Brazil - Robusta

Processing

Region	Dominant Coffee Type	Natural Process	Pulped Natural	Wet Process	Key Characteristics
Minas Gerais	Arabica	Highly dominant	Less than 25%	Less than 5%	Largest Arabica-producing region, dominant sun-drying method.
São Paulo	Arabica	Highly dominant	Less than 30%	Less than 5%	Major use of Pulped Natural to improve cup quality.
Espírito Santo	Robusta & Arabica	Highly dominant (Robusta) Dominant (Arabica)	Less than 30% (Arabica)	Less than 10%	High diversity, Wet Processing gaining traction.
Bahia	Arabica	Dominant	Less than 40%	Less than 10%	Mix of Natural and Pulped Natural, some experiments with Wet Process.
Paraná	Arabica	Highly dominant	Less than 15%	Less than 5%	Very homogeneous, mostly Natural Processing.
Rondônia	Robusta	Highly dominant	Less than 15%	Less than 10%	Traditional sun-dried Robusta with some Wet Process trials.

- **Minas Gerais and Paraná** are the most **homogeneous regions**, consistently using **natural processing**.
- **São Paulo and Bahia** show **more variation**, integrating **pulped natural techniques**.
- **Espírito Santo has the most diversified processing** due to both **Arabica and Robusta cultivation**.
- **Robusta-producing regions are less homogeneous**, as they are still **experimenting with wet processing techniques**.

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Brazil - Arabica

- High homogeneity
- Moderate homogeneity
- Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
Medium-sized family farms (<10 ha), some large farms in Sul de Minas	Highly homogeneous in climate (70% Tropical Moist)	Small farm: Shaded monoculture Medium and Large farms: full-sun monoculture	Highly homogeneous in soil (83% Low Activity Clay Soils)	Chemical/Synthetic fertilizer (predominant)	Major arabica producing regions Minas Gerais and São Paulo have remained stable	Highly homogeneous across Minas Gerais, São Paulo, Paraná, and Bahia.
→	↑	↑	↑	↑	↑	↑

Brazil's Arabica regions are highly homogeneous in soil (83% Low Activity Clay soil) and climate (70% Tropical Moist). Medium farm sizes dominate, with the notable prevalence of **shaded monoculture and full-sun monoculture** in small and large farms, respectively. **High homogeneity in Fertilizer use**, **low land use change (LUC) in established regions**, and **dominant natural processing (65-80%).** Considering the regional production size, a sample size of ~500 can capture diversity effectively.

High homogeneity	**>60% of the area or production share falls under a single category (systems where a single category dominates)**
Moderate homogeneity	**30%-60% of the area or production share is in the leading category (where multiple categories coexist but one is still slightly dominant)**
Low homogeneity	**<30% of the area or production share falls under a single category (highly diverse systems with no single category significantly dominating)**

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Brazil - Robusta

- ↑ - High homogeneity
- → - Moderate homogeneity
- ↓ - Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
Small to medium size farm predominant	Highly homogeneous (83% of robusta come from tropical moist climate)	Small farm: Shaded monoculture Medium and Large farms: full-sun monoculture	Highly homogeneous in soil (78% Low Activity Clay Soils)	A mix of Organic and Chemical/Synthetic fertilizer	Significant recent shift in land conversion. Majority of farms still stable	Highly homogeneous across regions
→	↑	↑	↑	→	→	↑

Robusta regions show high homogeneity in soil (78% Low Activity Clay soil) and climate (54% Tropical Moist). Small-medium family farms with notable dominance of shaded monoculture. Moderately diverse **Fertilizer input**, **moderately high LUC stability**, and **highly homogeneous processing methods with 60-75% natural processing** suggest representative sampling can be achieved using a sample size of ~500.

High homogeneity	**>60% of the area or production share falls under a single category (systems where a single category dominates)**
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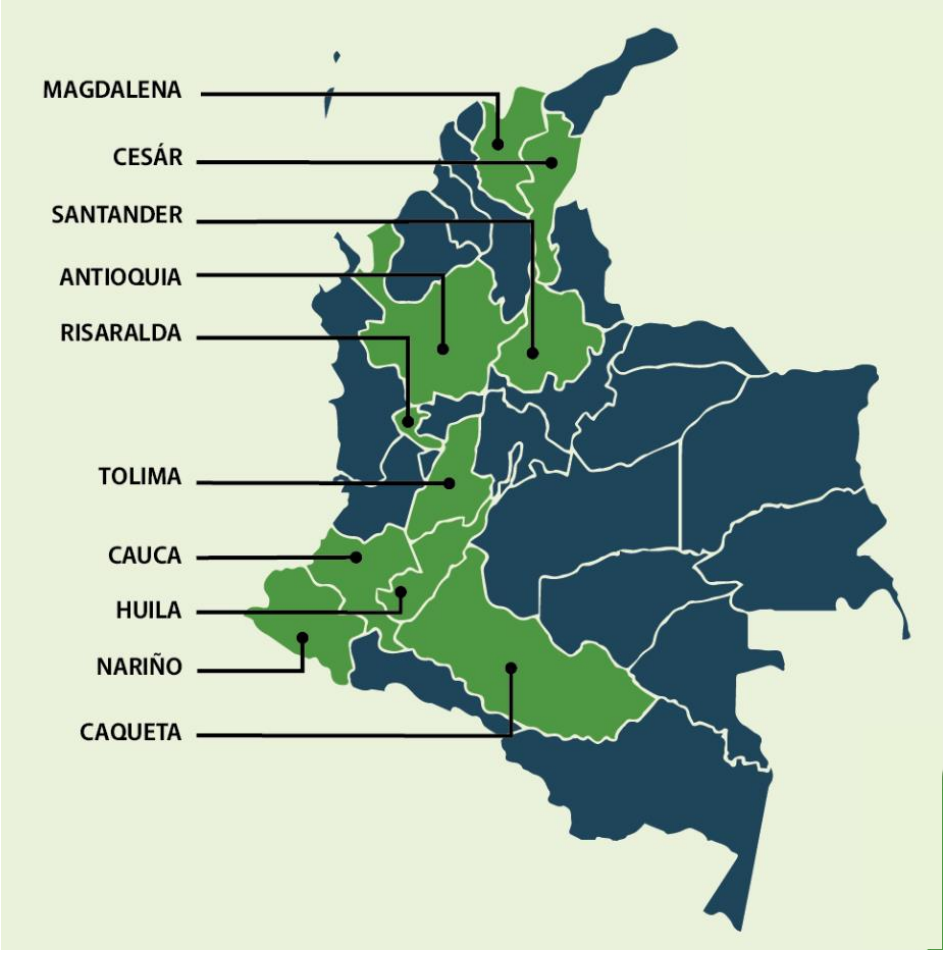
Colombia



Coffee Production

Focused on the Arabica Coffee

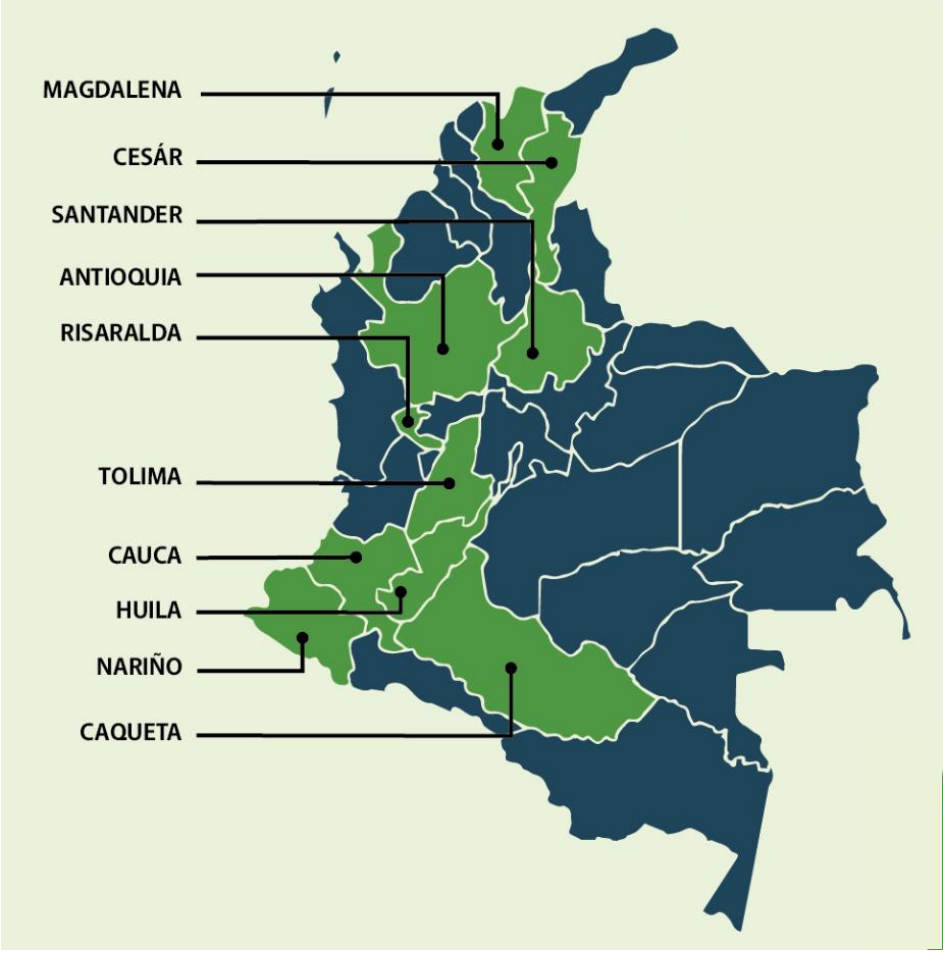
- roughly 875,000 hectares planted with coffee across 590 municipalities and 14 coffee-growing regions, offering a hugely diverse coffee production with an array of flavours, processing methods, and cultivars
- cultivated along the three different mountain ranges of the Andes as well as in the Sierra Nevada of Santa Marta, from the Atlantic coast in the North to the border between Colombia and Ecuador in the South
- coffee regions are characterized by the differences between their rain patterns and their harvest cycles, and the altitude and temperature at which their coffee is produced

	Main Crop	Fly Crop
Antioquia	November - February	April - June
Caldas	September - December	March - May
Cauca	April - September	October - February
Huila	October - January	April - August
Nariño	May - October	November - April
Risaralda	October - December	April - June
Santander	September - February	May - June
Tolima	May - September	October - December

Colombia

Coffee Production

Focused on the Arabica Coffee



- Antioquia: mountainous region, fertile soil
- Cauca: high peaks, situated on the “Macizo Colombiano” (the Colombian Plateau), mountainous and volcanic region, smallholder farmers, soils rich in nutrients due to volcanic ash
- Huila: productive valleys and snowed volcanoes
- Nariño: south of Colombia, bordering Ecuador in the high peaks of the Andes; high altitudes, located mainly on mountainsides above 2000m, cooler-than-average temperatures, reliable and well-distributed rainfall, high percentage of organic material soil
- Santander: shade-grown coffee, large amount of organic production, certified, drier micro-climate and lower growing latitude, warmed dry sunny area
- Sierra Nevada: mountain region of over 5000m, isolated from the Andes, at the north coast; farmers are part of native tribes, growing coffee organically

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Colombia

Farm Size

Focused on the Arabica Coffee

Arabica Coffee

- smallholder farmers: less than 2 hectares, with 60% less than 1 ha
- small part of producers: more than 5 hectares
- only 5% cultivates more than 20 hectares
- typical family farming model
- cooperatives and coffee associations

Colombia

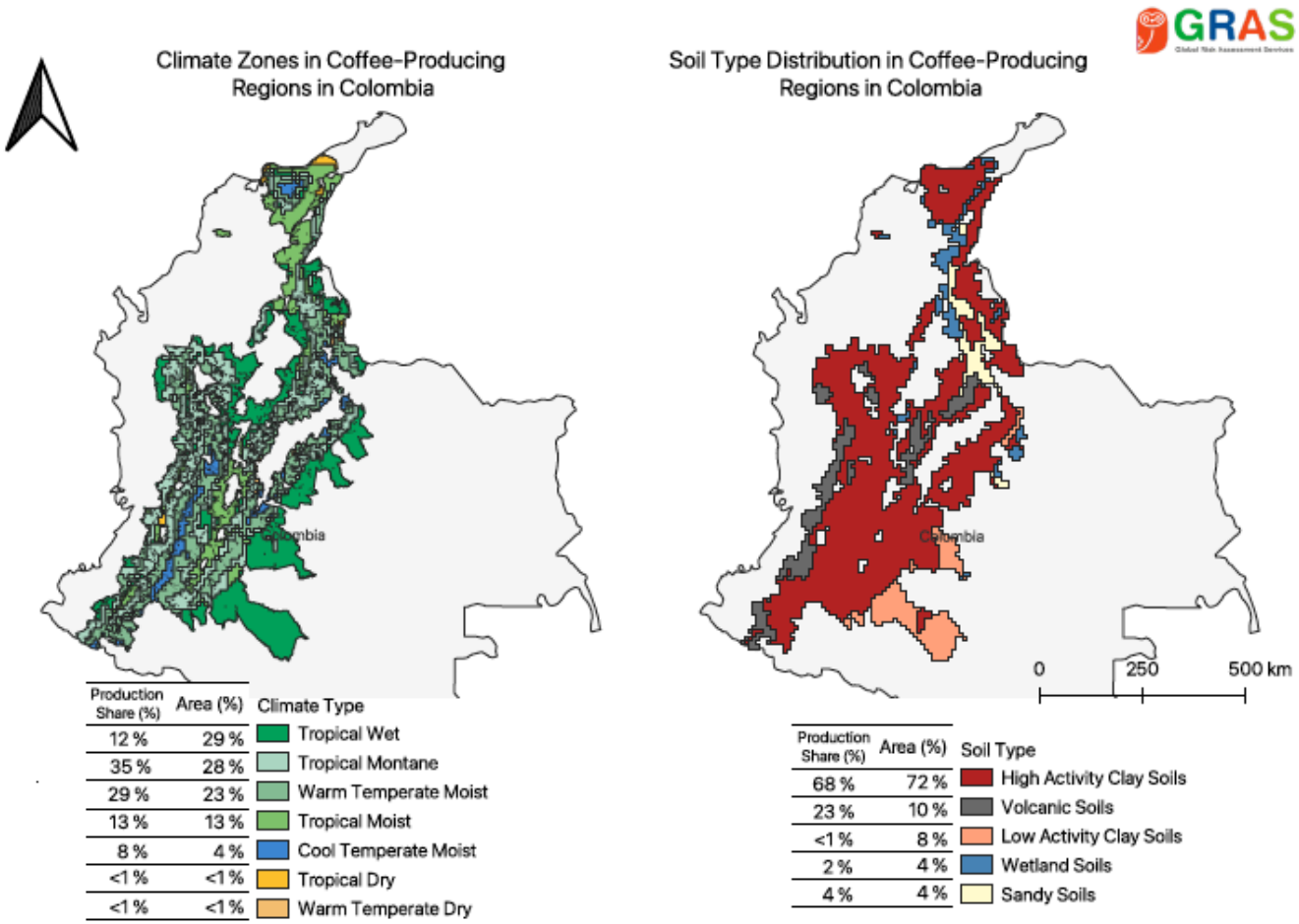
Agroforestry Practices

Arabica Coffee

- Traditional Polyculture (High Shade) is commonly practiced among small-scale farmers in Colombia.
- Commercial Polyculture (Medium Shade) present however adopted by farmers seeking additional income streams alongside coffee production. This type of agroforestry not so prevalent.
- Shaded monoculture systems are part of Colombia's coffee production landscape as well. Less dominant than traditional polyculture.
- Integrated forests for shade-grown coffee in regions like Santander

Colombia

Climate zone and soil type



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Colombia

Fertilizer usage

- **Antioquia, Eje Cafetero, Huila**: High fertilizer input (450-700 kg/ha), dominated by NPK blends (20-10-10, 18-6-18), phosphates, and urea, with growing adoption of biofertilizers.
- **Tolima:** Moderate fertilizer use (500-600 kg/ha), relying on a mix of synthetic NPK, rock phosphate, and poultry manure.
- **Cauca & Nariño:** Lower fertilizer application (~400-500 kg/ha), favoring compost, biofertilizers, and reduced synthetic input.
- **Santander & Norte de Santander:** Lower fertilizer dependency (~350-450 kg/ha), with lime, manure, and some synthetic fertilizers to improve less fertile sandy soils.
- **Colombia's coffee sector is highly homogeneous**, with well-established coffee belts **showing consistency in fertilizer use**, while **expanding regions are adopting diverse and dynamic** cultivation strategies.

Colombia

Land Use Change

- **Antioquia & Huila:** Minimal land use change (LUC), stable coffee-growing regions with established plantations.
- **Eje Cafetero (Caldas, Quindío, Risaralda):** Moderate LUC due to urban expansion and farm diversification, but traditional coffee remains dominant.
- **Tolima:** Ongoing LUC as pastureland transitions into coffee plantations, driven by economic incentives.
- **Cauca & Nariño:** High LUC, expanding high-altitude coffee farms, replacing natural vegetation and some pastureland.
- **Santander & Norte de Santander:** Significant LUC due to pastureland conversion and some deforestation to accommodate new coffee farms.
- At a **national level**, Colombian coffee cultivation **demonstrates regional variability** in **land use change (LUC)** but **evident homogeneity in established coffee zones**

Colombia

Processing

- **Washed Processing (Wet Process) dominates**
  - Nationwide, 85-90% of coffee is wet-processed.
  - The regions of Eje Cafetero, Cauca, Nariño, and Huila have the most uniform adoption of Wet Processing (>85%).
  - This method is favored for preserving acidity, reducing defects, and maintaining quality for export markets.
- **Natural Processing (Sun-Dried) is increasing in some regions**
  - Santander & Norte de Santander lead in Natural Processing (~15%) due to drier climate conditions.
  - Due to climate adaptation and speciality coffee trends, Tolima and Antioquia are increasing Natural Process production (10-12%).
- **Pulped Natural is minimal**
  - Only 4-7% of coffee is processed via the Honey Method due to Colombia's humid climate, which makes drying difficult.
  - Santander and Antioquia are leading regions in Honey Processing (7% & 5%, respectively).
- **Colombia's coffee sector is highly homogeneous in processing techniques**, with **wet processing dominating (~85-90%) across regions**.

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Colombia

- High homogeneity
- Moderate homogeneity
- Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
Smallholder farms less than 2 ha dominates	Diverse climate zones with comparable share of tropical wet, tropical montane and warm temperate moist	Shaded monoculture (predominant)	Highly homogeneous in soil (72% High Activity Clay Soils)	NPK fertilizer (predominant used in high coffee production region) and Organic in some parts	Homogeneity in established coffee zones	Highly homogeneous, wet processing dominates
↑	↓	→	↑	→	→	↑

Due to **low to moderate homogeneity** in **climate zones, agroforestry practices, fertilizer use, and LUC**, a **sample size of ~600** is needed for accurate representation of **Colombia's Arabica coffee systems**. While **LUC remains low in traditional regions**, **fertilizer use varies (400-650 kg/ha), and wet processing (~85-90%) dominates, with rising natural drying methods.**

High homogeneity	**>60% of the area or production share falls under a single category (systems where a single category dominates)**
Moderate homogeneity	**30%-60% of the area or production share is in the leading category (where multiple categories coexist but one is still slightly dominant)**
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Peru

Coffee Production

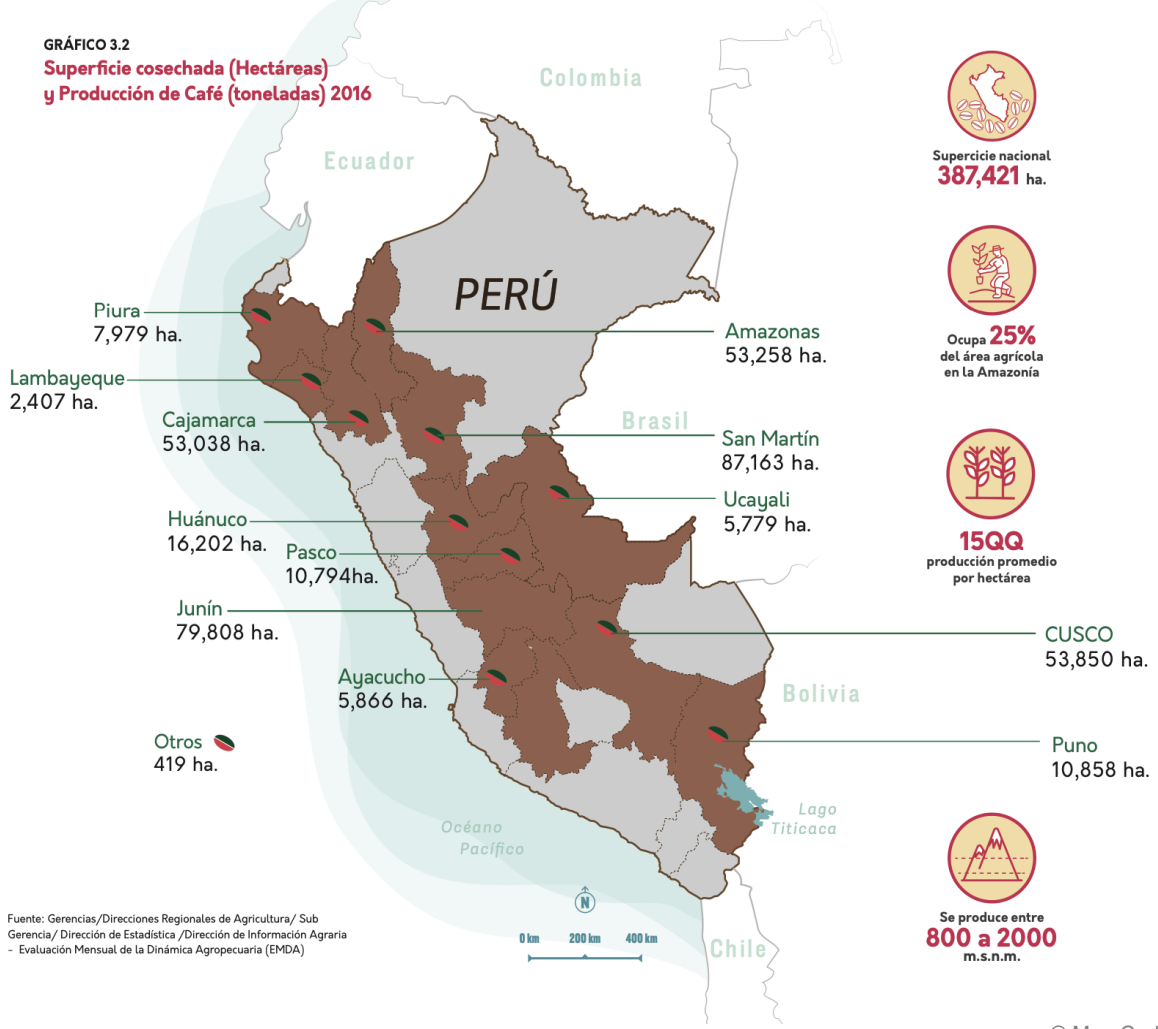
Arabica Coffee x Robusta Coffee

~100% **~0%**

PLAN NACIONAL DE ACCIÓN DEL CAFÉ

GRÁFICO 3.2

Superficie cosechada (Hectáreas) y Producción de Café (toneladas) 2016



Fuente: Gerencias/Direcciones Regionales de Agricultura/ Sub Gerencia/ Dirección de Estadística /Dirección de Información Agraria - Evaluación Mensual de la Dinámica Agropecuaria (EMDA)

Supercicie nacional **387,421** ha.

Ocupa **25%** del área agrícola en la Amazonía

15QQ producción promedio por hectárea

Se produce entre **800 a 2000** m.s.n.m.

281 mil toneladas producidas el 2016

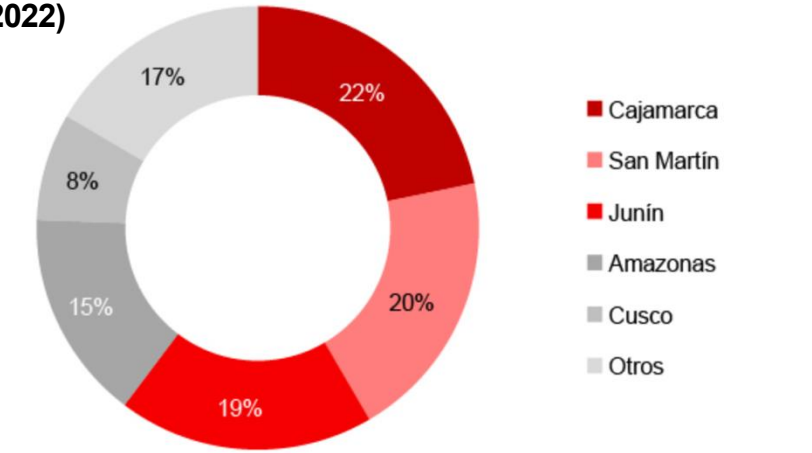
(2016)

16 regions, standing out:
San Martin, Cajamarca, Junin, Amazonas, Cusco, Pasco and Huanuco

- Peru is reducing the farms on country level

Participación departamental en la producción de café

(2022)



Fuente: Midagri. Elaboración: ComexPerú.

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Peru

Farm Size

Arabica Coffee

- smallholder farmers dominate
- often solely with family labour
- 2 to 5 hectares (more 2 to 3)
- part of them are grouped in associations or cooperatives

Due to higher market value and adaptability to higher altitudes, Peruvian farms concentrate in the arabica coffee, with the unroasted becoming almost 90% on average of traditional exports.

Peru

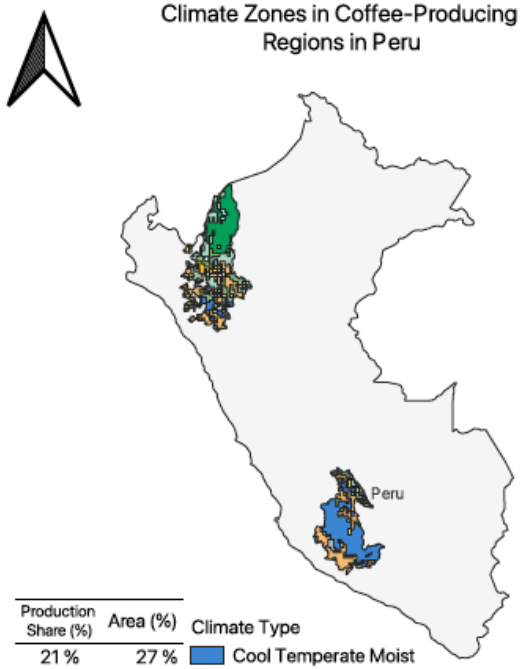
Agroforestry Practices

Arabica Coffee

- Historically, coffee in Peru was traditionally cultivated under a dense and diverse canopy of native shade trees.
- Commercial Polyculture (Medium Shade) systems are present in Peru's coffee-growing regions
- The dominance of traditional polyculture and shaded systems is evident
- Agroforestry-based restoration at Forest Frontiers

Peru

Climate zone and soil type



Production Share (%)	Area (%)	Climate Type
21 %	27 %	Cool Temperate Moist
35 %	25 %	Warm Temperate Dry
<1 %	16 %	Tropical Wet
12 %	15 %	Tropical Montane
17 %	10 %	Warm Temperate Moist
5 %	2 %	Tropical Moist
4 %	2 %	Cool Temperate Dry
2 %	2 %	Tropical Dry

Production Share (%)	Area (%)	Soil Type
99 %	99 %	High Activity Clay Soils
<1 %	<1 %	Wetland Soils

Peru

Fertilizer usage

- **Organic and Conventional Practices**: Coffee farming in Peru is largely **organic**, with minimal use of synthetic fertilizers. Many farmers rely on compost and **guano-based fertilizers**.
- **Regional Variations**: In regions like **Cajamarca and San Martín**, farmers integrate agroforestry systems, naturally enriching soil fertility.
- **Chemical Dependency**: Some producers in high-yield areas use **NPK fertilizers**, but adoption remains limited due to cost.
- **Environmental Concerns**: Studies highlight **soil nutrient depletion** due to the lack of balanced fertilizer application, affecting long-term productivity.
- **High homogeneity**, dominant use of **organic fertilizers**, with low reliance on synthetic fertilizers across all regions. Some **variation in input intensity** between high and low-production areas.

Peru

Land Use Change

- **Deforestation in the Amazon**: Coffee expansion in **San Martín and Puno** has led to **high deforestation rates**, with over **120,000 hectares** lost in the past decade.
- **Agroforestry as a Solution**: Some farmers use **shade-grown coffee** to maintain biodiversity, but economic pressures drive land conversion to **full-sun monoculture**.
- **Climate Vulnerability**: Higher altitudes are now being converted for coffee farming due to **rising temperatures**, leading to potential **soil erosion** risks.
- **Moderate homogeneity**, **deforestation-driven expansion** in the Amazon (San Martín, Puno) contrasts with stable agroforestry coffee in **Cajamarca**.

Peru

Processing

- **Wet Processing Dominates**: The **washed method** is widely used, contributing to **high water usage**.
- **Water Pollution**: Many farms **discharge wastewater** into rivers, leading to contamination.
- **Eco-Friendly Trends**: Some regions have adopted **fermentation tanks and improved drying techniques** to reduce environmental impact.
- **High homogeneity**, **washed processing** dominates (~80-90%), but some regions (Amazon, Puno) are adopting Natural and Honey Processing.

Peru

- High homogeneity
- Moderate homogeneity
- Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
Smallholder farms less than 3 ha dominate	Diverse climate zones with comparable share of tropical and temperate	raditional polyculture and shaded monoculture (predominant)	Highly homogeneous in soil (99% High Activity Clay Soils)	High homogeneity, dominant use of organic fertilizers	Moderate homogeneity deforestation-driven expansion	High homogeneity, washed processing dominates
↑	↓	→	↑	↑	→	↑

Due to **low homogeneity** in **climate and moderate homogeneity in LUC and agroforestry practices**, a **sample size of ~600** is needed for an accurate representation of **Peru's Arabica coffee systems**. While **organic fertilizers dominate, LUC varies (Amazon deforestation vs. stable agroforestry), and processing remains mostly washed (~80-90%) with rising natural processing methods.**

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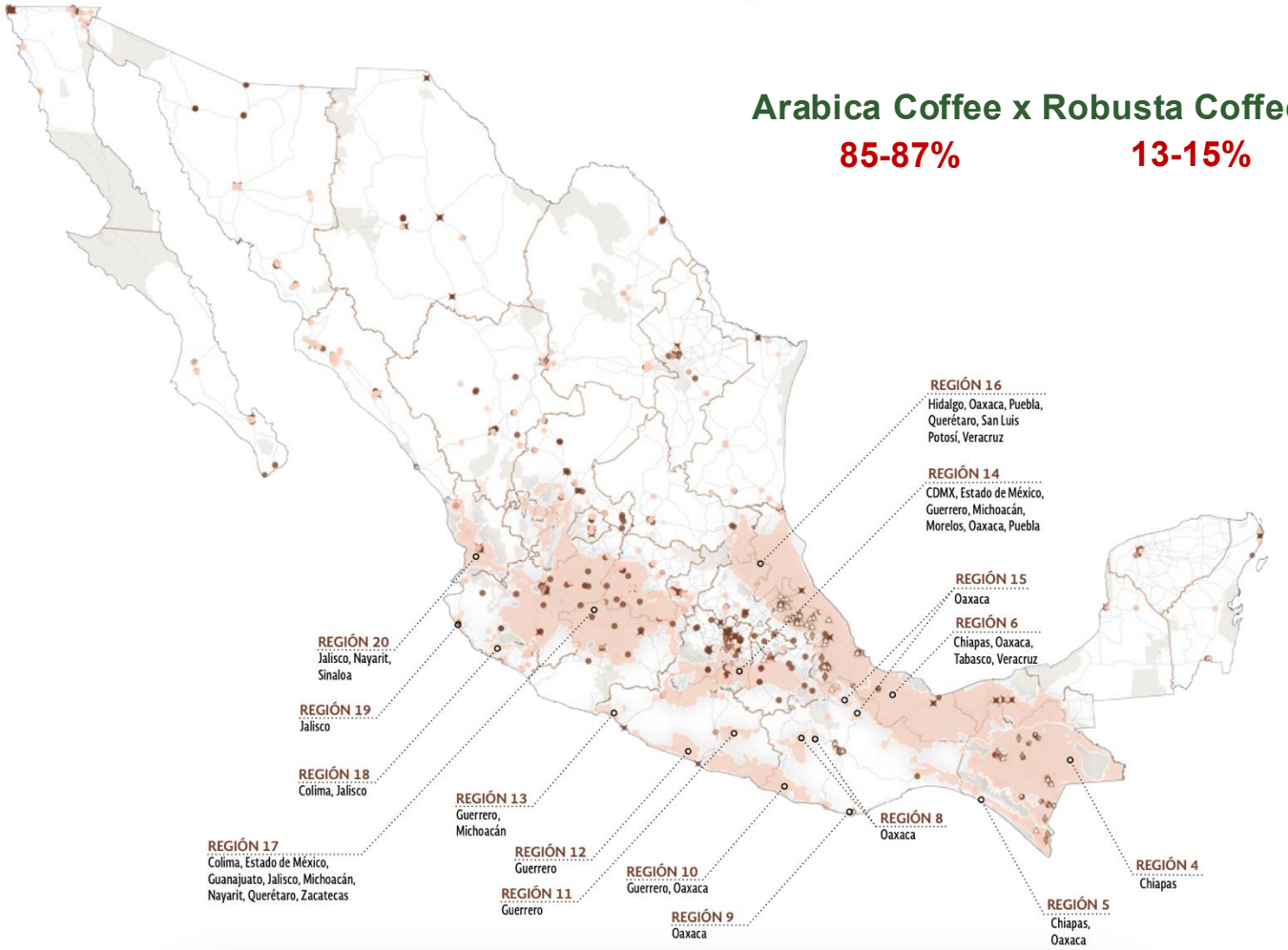
Mexico

Coffee Production



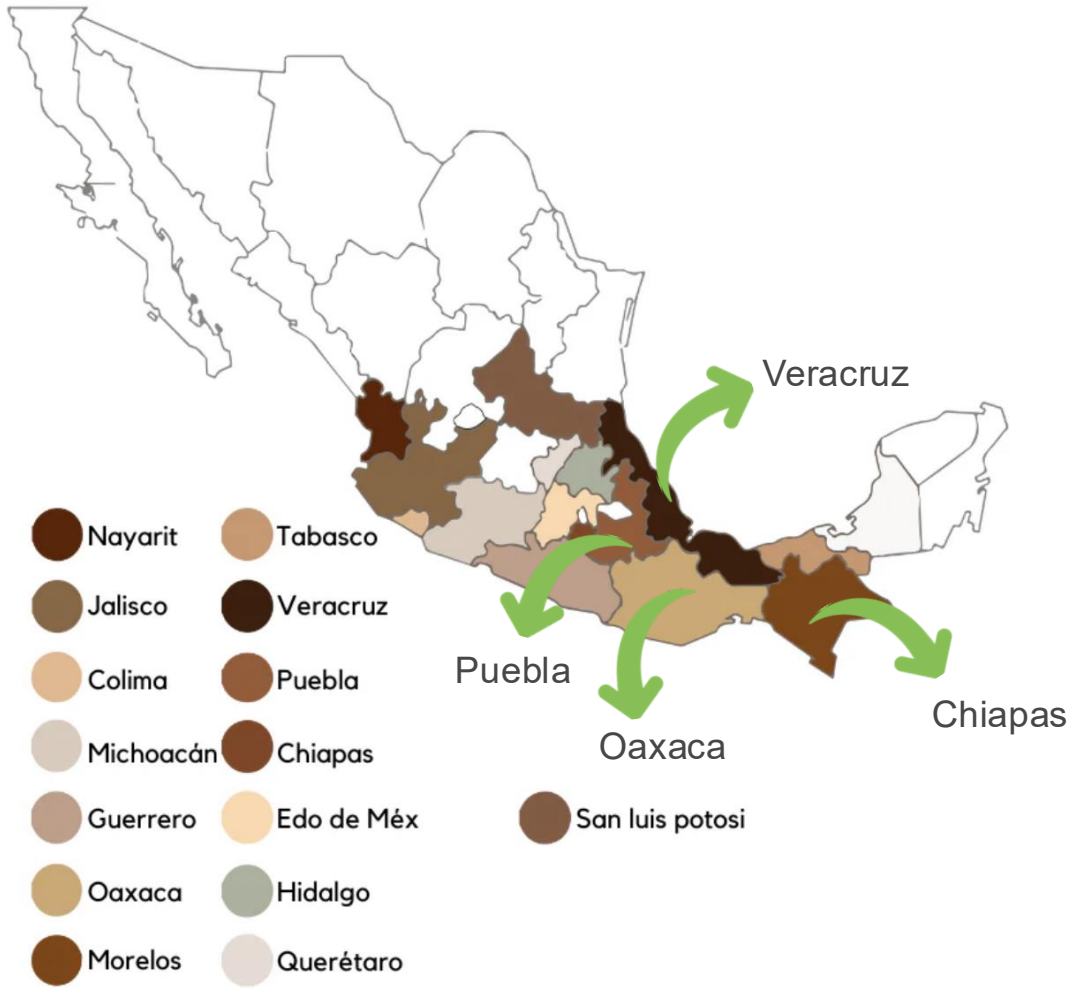
Arabica Coffee x Robusta Coffee

85-87% **13-15%**

16 strategic regions standing out:
Chiapas, Veracruz and Puebla

21 potential regions

Mexico



Coffee Production

Chiapas:
- country's biggest coffee producer (around 38% of the annual crop)
- mountains
- high rainfall, with moist volcanic soils
- arabica coffee (highlands) x robusta coffee (lowlands)

Veracruz:
- 26% of the country's coffee
- coastal plains into an elevated mountainous terrain
- nutrient-rich, dark volcanic soils
- arabica coffee (highlands) x robusta coffee (lowlands)

Oaxaca:
- Produces 9% of Mexico's coffee
- lower elevations
- terrain with volcanic nutrients and plenty of moisture
- arabica coffee (highlands) x robusta coffee (lowlands)

Puebla:
- Produces 18% of Mexico's coffee
- highlands and medium altitudes
- influenced by elevation and diversity of nutrients from this volcanic terrain
- arabica coffee

Mexico

Farm Size

Arabica Coffee

- smallholder farmers
- family labour, lack of mechanization
- less than 5 hectares
- cooperatives (majority) and civic organizations

Mexico

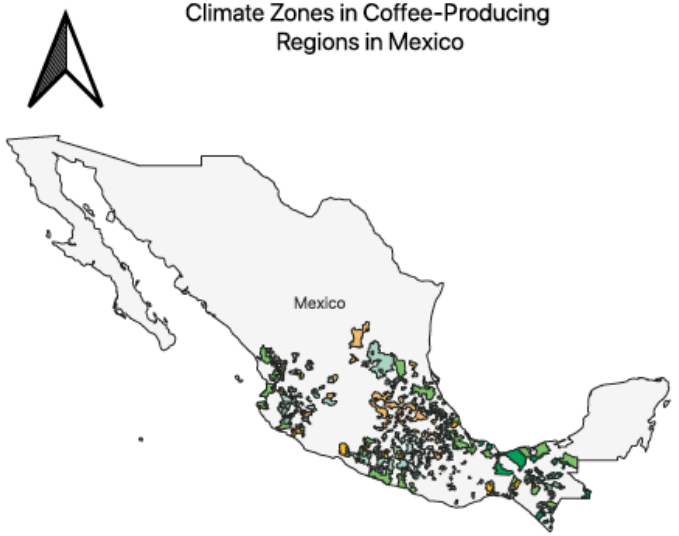
Agroforestry Practices

Arabica Coffee

- Traditional polyculture is a common practice in Mexico's coffee-growing regions, particularly among smallholder farmers.
- Commerical polyculture, where coffee is intercropped with economically valuable shade trees, such as timber or fruit species, providing moderate shade, is present in selective regions.
- Unshaded monoculture is less common in Mexico due to increased vulnerability to pests and climate variability. Plants with more disease-resistant trees.

Mexico

Climate zone and soil type



Production Share (%)	Area (%)	Climate Type
29 %	31 %	Tropical Montane
18 %	30 %	Tropical Moist
19 %	16 %	Warm Temperate Dry
6 %	9 %	Tropical Wet
9 %	7 %	Tropical Dry
13%	5 %	Warm Temperate Moist
<1%	<1%	Cool Temperate Moist

Production Share (%)	Area (%)	Soil Type
93 %	88 %	High Activity Clay Soils
<1 %	5 %	Wetland Soils
5 %	5 %	Low Activity Clay Soils
<1 %	1 %	Volcanic Soils

Mexico

Fertilizer usage

- **Shift from Organic to Synthetic**: Traditional shade-grown coffee farms in **Chiapas and Veracruz** used organic manure, but recent trends indicate a **higher dependency on synthetic Fertilizers**.
- **High Input Usage**: In **high-intensity farming zones**, nitrogen-based Fertilizers are heavily applied, **increasing soil acidity**
- **Impact on Coffee Rust (CLR)**: A study by Castillo et al. (2020) found that Fertilizers play a role in controlling **coffee leaf rust (Hemileia vastatrix)**.
- **Sustainability Challenges**: Overuse of Fertilizers contributes to **water contamination and loss of biodiversity** in certain areas.
- **Moderate homogeneity**, transition from **organic to synthetic Fertilizers**, but **significant regional variability**. Chiapas and Oaxaca maintain **traditional organic practices**, while Veracruz and Puebla have shifted to **high-input synthetic Fertilizers**.

Mexico

Land Use Change

- **Chiapas and Veracruz: Hotspots for LUC**: Traditional **shade-grown coffee systems** are being replaced by **intensive monoculture**.
- **Urban Expansion**: Research by Rice (1997) highlights **urban encroachment** into coffee lands, particularly in **central Veracruz**.
- **Illegal Deforestation**: The conversion of land for coffee cultivation in **Oaxaca and Guerrero** has increased deforestation **by 34%** in the last 15 years.
- **Soil Erosion and Water Issues**: The removal of forest cover has increased **soil erosion rates**, affecting watershed ecosystems.
- **Moderate regional homogeneity, high LUC in Veracruz and Oaxaca**, **urban encroachment in Chiapas**, but **stable traditional coffee systems in southern regions**.

Mexico

Processing

- **Traditional Sun Drying and Washed Processing**: In **Chiapas and Veracruz**, coffee is processed using **sun drying**, while some farms use **mechanical dryers**.
- **Waste Management Issues**: Improper disposal of **coffee pulp and wastewater** has led to **localized pollution**.
- **Sustainable Processing Efforts**: Some cooperatives are adopting **zero-waste coffee processing**, utilizing **biogas digesters**.
- **Moderate homogeneity, traditional sun-drying in Chiapas and Oaxaca**, while **mechanical drying & modern washed processing** are prevalent in **high-production zones (Veracruz, Puebla).**

Mexico

- High homogeneity
- Moderate homogeneity
- Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
Smallholder farms less than 5 ha dominates	Diverse climate zones with share of tropical montane and tropical moist covering more than 60 % of the area	Traditional polyculture common and unshaded monoculture negligible	Highly homogeneous in soil (88% High Activity Clay Soils)	Moderate homogeneity, transition from organic to synthetic Fertilizers	Moderate regional homogeneity	Moderate homogeneity
↑	→	→	↑	→	→	→

Due to **moderate homogeneity** in **climate, agroforestry practices, Fertilizer use, LUC, and processing**, a **sample size of ~600** is needed for accurate representation of **Mexico's Arabica coffee systems**. **LUC varies (urban expansion in Chiapas, stable polyculture in Oaxaca), Fertilizer use is shifting from organic to synthetic, and processing remains highly diverse (sun-dried, washed, mechanical drying).**

High homogeneity	**>60% of the area or production share falls under a single category (systems where a single category dominates)**
Moderate homogeneity	**30%-60% of the area or production share is in the leading category (where multiple categories coexist but one is still slightly dominant)**
Low homogeneity	**<30% of the area or production share falls under a single category (highly diverse systems with no single category significantly dominating)**

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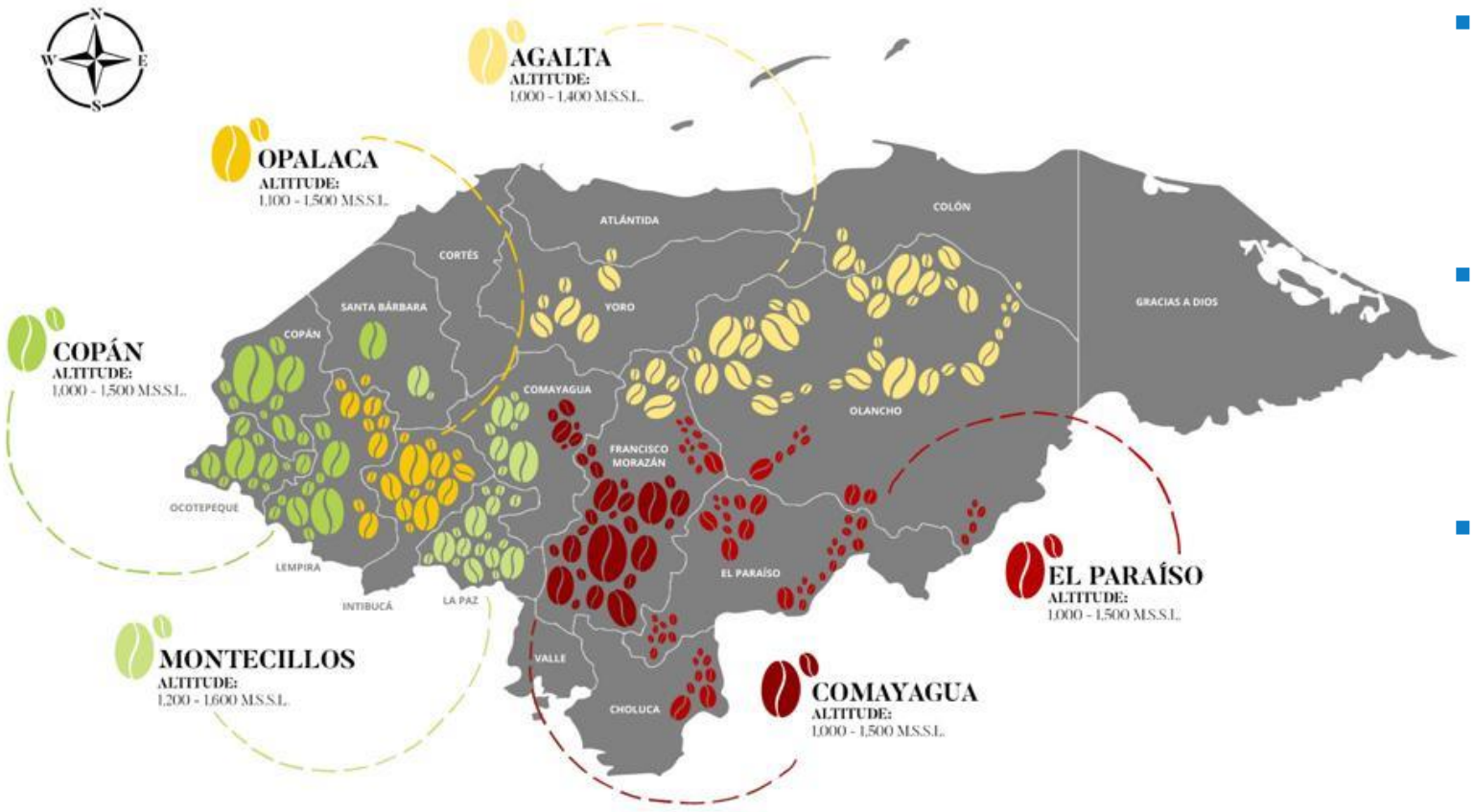
Honduras

Coffee Production



- coffee is produced in 15 of the 18 departments in Honduras, with 210 out of 298 municipalities producing coffee
- six distinct regions for coffee production: Copán, Comayagua, Montecillos, Opalaca, Agalta and El Paraíso
- 2022–23 harvest: highest numbers of producers in the departments of El Paraíso, Santa Bárbara (Copán), Comayagua and Lempira (Copán)

Honduras

Farm Size

- 95% are smallholder farmers, usually operated by families
- producer’s organizations as intermediaries for exporting
- trade associations (90-95%) and local cooperatives (5%)
- less than 2 hectares (typically 0.5 to 1.5 ha)

Honduras

Agroforestry Practices

- More than 95% of coffee is shade-grown
- Traditional polyculture is common among smallholder farmers in Honduras, promoting biodiversity and ecological balance.
- Commercial polyculture systems are present in Honduras's coffee-growing regions.
- Shaded monoculture systems are implemented in some Honduran coffee plantations, though precise statistics on their prevalence are scarce.
- Unshaded monoculture is less common in Honduras due to increased vulnerability to pests and climate variability.

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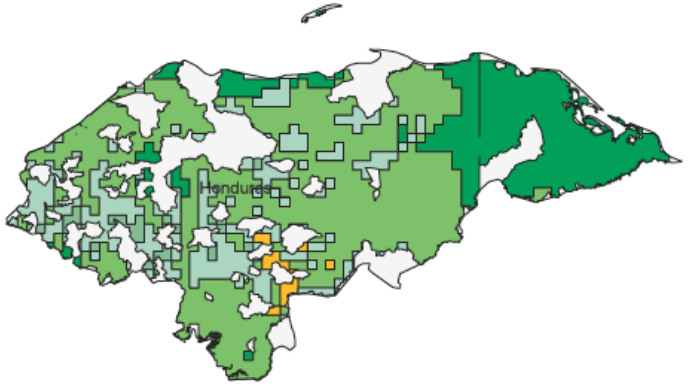
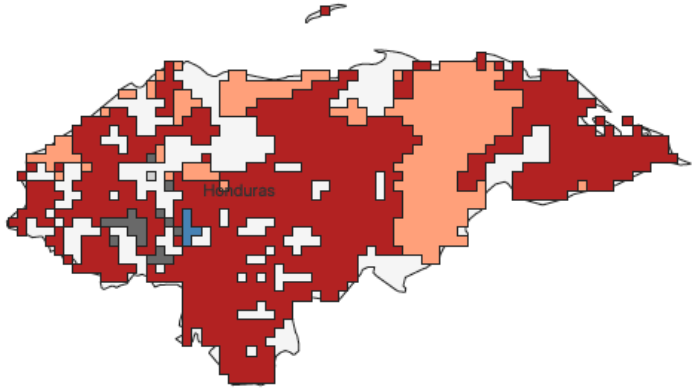
Honduras

Climate zone and soil type



Production Share (%)	Area (%)	Climate Type
37 %	53 %	Tropical Moist
11 %	24 %	Tropical Wet
33 %	17 %	Tropical Montane
7 %	2 %	Warm Temperate Moist
2 %	1 %	Tropical Dry



Production Share (%)	Area (%)	Soil Type
68%	72 %	High Activity Clay Soils
10 %	24 %	Low Activity Clay Soils
10 %	1 %	Volcanic Soils
1 %	<1 %	Wetland Soils

Honduras

Fertilizer usage

- **Intensive Use of Fertilizers**: Among the Latin American countries, **Honduras** has the highest rate of chemical fertilizer application.
- **Government Support**: Policies supporting **subsidized fertilizers** have increased productivity in **Copán and Santa Bárbara**.
- **Soil Degradation Issues**: Excessive use of **urea and phosphates** is leading to **soil degradation** and loss of organic matter.
- **Organic Alternatives**: Some cooperatives promote **biofertilizers and mycorrhizal fungi**, but large-scale adoption remains slow.
- **Moderate to high homogeneity: High fertilizer dependency** in **Copán and Santa Bárbara**, while smaller farms in **Lempira and Intibucá** rely more on **organic and biofertilizers**.

Honduras

Land Use Change

- **Protected Area Encroachment**: Deforestation linked to coffee production is threatening **Reserva de la Biosfera del Río Plátano**.
- **Expansion into Highlands**: Farmers are moving coffee plantations to **higher elevations** (1,200m-1,800m) due to climate-induced shifts, increasing **habitat destruction**.
- **Carbon Footprint Increase**: LUC from **forests to coffee plantations** is a major contributor to **CO_2 emissions** in Honduras.
- **High homogeneity across country: Deforestation and expansion into highlands** seen **nationwide**, indicating a uniform trend of land conversion.

Honduras

Processing

- **High-Volume Processing Mills**: Honduras has **large-scale wet mills** that consume significant amounts of **water and energy**.
- **Government Regulations**: New laws enforce **wastewater treatment**, but compliance remains low.
- **Innovation in Processing**: **Honey and natural processing** methods are gaining popularity to reduce **water consumption**.
- **High homogeneity: Washed processing (~85-90%) is dominant nationwide**, with **some new adoption of Natural Processing** for specialty markets.

Honduras

- High homogeneity
- Moderate homogeneity
- Low homogeneity

Farm Size	Climate Zone	Agroforestry Practices	Soil Types	Fertilizer Usage	Land Use Change	Processing
95% smallholder farms less than 2 ha	Moderately diverse climate zones with share of tropical wet and tropical moist covering more than 70 % of the area	Traditional polyculture common and unshaded monoculture negligible	Highly homogeneous in soil (72% High Activity Clay Soils)	Moderate to high homogeneity	High conversion across country	High homogeneity, washed processing dominant
↑	→	→	↑	→	↑	↑

While **LUC is uniformly driven by deforestation and highland expansion, fertilizer use, agroforestry practices, and climate vary.** Due to **moderate to high homogeneity** in **farm size, soil type, LUC,** and **processing**, a **sample size of ~600** is needed to represent **Honduras's Arabica coffee systems**.

High homogeneity	**>60% of the area or production share falls under a single category (systems where a single category dominates)**
Moderate homogeneity	**30%-60% of the area or production share is in the leading category (where multiple categories coexist but one is still slightly dominant)**
Low homogeneity	**<30% of the area or production share falls under a single category (highly diverse systems with no single category significantly dominating)**

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Limitations of the Research

- Differentiate harvesting characteristics and practices from arabica and robusta crops in **Brazil**
- Data on farm size for robusta production in **Brazil**
- Finding information about robusta coffee production both in **Peru and Mexico**. Peru was the hardest since approximately 100% of the output is from the variety of arabica
- Going deep into the agroforestry practices for **Peru and Mexico**, as they were just generally mentioned, without detailed examples or more information
- Obtaining official up-to-date data from the government (e.g. the last national census in **Peru** was done in 2012)
- Limited reliable literature and country datasets for all the countries
- **Regional Processing Diversity Not Fully Captured:** While national trends indicate high wet-processing dominance, **local variations in drying and fermentation techniques remain underreported**.
- **Limited Data on Water Usage & Waste Management:** Environmental impacts of processing, particularly regarding **wastewater management in wet processing**, need further investigation.

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Limitations of the Research

- **Data and Methodological Constraints**
  - **Limited Regional Data Availability:** Some regions, especially remote coffee-growing areas, lack updated or detailed records on **fertilizer usage, LUC trends, and processing methods**.
  - **Variability in Data Sources:** Inconsistencies between **government reports, academic studies, and industry sources** may affect accuracy in regional comparisons.
  - **Time Lag in Land Use Change (LUC) Data:** LUC trends rely on satellite imagery and historical data, which may not fully reflect **current expansion rates or reforestation efforts**.
  - **Sampling Bias:** The studies primarily focus on **commercially significant regions**, possibly **underrepresenting smallholder and indigenous coffee farms**.
- **Land Use Change (LUC) Limitations**
  - **Deforestation Attribution Issues:** While LUC is documented, **distinguishing coffee-driven deforestation from other agricultural expansion (e.g., cattle ranching, logging)** remains challenging.
  - **Uncertain Climate Adaptation Impacts:** Predictions about **coffee expansion into higher altitudes** due to climate change lack **long-term empirical validation**.

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Proposed sampling numbers

Country	Representativeness risk factor	Mitigating factor	Final sample no.
Brazil (Robusta)	Low (4 out of 7 characteristics homogeneous)	1.3	370 X 1.3 ~ 500
Brazil (Arabica)	Low (6 out of 7 characteristics homogeneous)	1.3	370 X 1.3 ~ 500
Colombia	Moderate (3 characteristics have high homogeneity, 3 moderate and 1 low)	1.6	370 X 1.6 ~ 600
Honduras	Moderate (4 characteristics have high homogeneity while the other 3 are moderate)	1.6	370 X 1.6 ~ 600
Peru	Moderate (4 characteristics have high homogeneity, 2 moderate and 1 low)	1.6	370 X 1.6 ~ 600
Mexico	Moderate (2 characteristics have high homogeneity while the other 5 are moderate)	1.6	370 X 1.6 ~ 600

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Other Secondary Data Resources

COUNTRY	INSTITUTION	YEAR OF DATA	SOURCE LINK
BRAZIL	CONAB - Companhia Nacional de Abastecimiento (EN: National Company of Supply)	2022	https://portaldeinformacoes.conab.gov.br/produtos-360.html
	Instituto Brasileiro de Geografia e Estatística (EN: Brazilian Institute of Geography and Statistics)	2022	https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9117-producao-agricola-municipal-culturas-temporarias-e-permanentes.html?=&t=resultados
	ABIC - Associação Brasileira da Indústria de Café (EN: Brazilian Coffee Industry Association)	2023	https://www.abic.com.br/estatisticas/producao-agricola-2/
COLOMBIA	Federacion del cafe Colombiano (EN: Colombian Coffee Federation)	2022	https://federaciondecafeteros.org/app/uploads/2023/08/Precios-area-y-produccion-de-cafe2.xlsx
	Agronet - Ministerio de agricultura y desarrollo rural (EN: Ministry of Agriculture and Rural Development)	2022	https://www.agronet.gov.co/estadistica/Paginas/home.aspx?cod=1
	UPRA - Unidad de Planificación Rural Agropecuaria, Ministerio de Agricultura (EN: Rural Agricultural Planning Unit, Ministry of Agriculture)	2022	https://www.agronet.gov.co/estadistica/Paginas/home.aspx?cod=2
HONDURAS	IHCAFE - Instituto hondureno del cafe (EN: Honduran Coffee Institute)	2022	https://www.ihcafe.hn/produccion-nacional/
MEXICO	Servicio de Información Agroalimentaria y Pesquera - Gobierno de Mexico (EN: Agri-Food and Fisheries Information Service - Government of Mexico)	2022	https://nube.siap.gob.mx/cierreagricola/
PERU	Cámara Peruana del Café y Cacao (EN: Peruvian Chamber of Coffee and Cocoa)	2021	https://camcafeperu.com.pe/ES/cafe-peruano-estadisticas.php
	INEI - Instituto Nacional de Estadística e Informática (EN: National Institute of Statistics and Informatics)	2022	https://www.gob.pe/inei/ https://www.inei.gob.pe/media/MenuRecursivo/indices_tematicos/cap13002_3.xls
	Ministerio de desarrollo agrario y riego (EN: Ministry of Agrarian Development and Irrigation)	2022	https://app.powerbi.com/view?r=eyJrIjoiYjYwYTk5MDgtM2M0MS00NDMyLTgzNDEtMjNhNjEzYWQyOTNlIiwidCI6IjdmMDg0NjI3LTdmNDAtNDg3OS04OTE3LTk0Yjg2ZmQzNWYzZiJ9

Many thanks for your attention!

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