FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

CLIMATE-SMART COFFEE IN GUATEMALA

Summary

Guatemala is the second-largest coffee producer in Central America after Honduras. The coffee sector is a driver of the rural economy, providing incomes for over 122000 farmers, 98% of whom are smallholders. Guatemalan coffee production generates half a million jobs in the rural economy, nearly 10% of the national active labor force. Approximately 3.3 million 60kg bags of coffee beans are produced annually.

Shade grown high-quality arabica coffee for international markets is the norm in the fields of the caficultores (coffee farmers). Consumer demand has driven the growth of exports of Strictly High Bean, the highest quality produced in Guatemala which accounts for approximately 83% of exports. The total value of exports makes up 14% of the total export value or 651m in USD. It is the second most important agricultural product after sugar in terms of foreign revenue earnings.

Current coffee production areas are projected to experience a gradual increase in temperatures towards more extreme ranges as well as periods of drought and heavy rainfall. Annual temperatures are projected to increase by 1.7°C-2.0°C and total annual precipitation is projected to decrease between 0.8% in the southern coast and 6% in the border between the north and northeastern regions.

Although countries in Central America are relatively small emitters of greenhouse gasses (GHG), they are projected to be among the most affected by climate change. As part of the landscape in this region, Guatemalan coffee farms will become increasingly vulnerable to a series of climatic risks: El Niño Southern Oscillation (ENSO), droughts, storms, strong winds, intensive rainfall, and flooding.

The classification of climate change impacts into an easy to understand gradient which can be superimposed on a map is one of the ways in which effective adaptation can be supported. Our degree-of-impact maps and analysis indicate that most areas will require systemic adaptation, but farms at higher altitudes along the Sierra Madre can achieve climate-smart production with just incremental adaptation. Degrees-of-impact in Southeast Guatemala are more mixed, with the areas near the borders where Chiquimula, Jalapa, and Jutiapa need transformational adaptation, but the remaining areas in these states being incremental or systemic adaptation zones.

Production in agroforestry systems is more resilient than that of unshaded farms. However, agroforestry and management practices are crucial to ensure that a farm is well adapted to future climatic conditions and extreme climatic events. There is still significant leeway for Guatemalan farmers to make their coffee farms resilient while also intensifying production sustainably and mitigating the GHG emissions of their farm.

Different degrees of impact require different adaptation strategies. Adequate varieties, improved shade cover and cover crops are the minimal CSC practices required. With increasing degree of impact mulch, temporary shade, living hedges, windbreaks should be added to the system. Where drought is increasingly problematic drip irrigation, water harvesting, soil enhancing polymers or biochar are recommended. In addition to improved agronomic management, progressive climate change will make a diversified income from alternative crops, off farm income or crop insurance necessary.

Careful consideration of the resources and environment in which smallholder in Guatemala make their decisions is crucial for the success of CSC interventions. Strengthening their access to markets for inputs and credit. Private sector initiatives can boost the capacity of farmer groups and cooperatives to provide technical assistance and financing for the adoption of improved farm management. Gender disparities can pose an additional hurdle for the implementation of CSC in female led farms.

Approaches to scaling CSC practices are the stepping stone toward the long-term sustainability of high-quality coffee from Guatemala. However, investment into coffee production, and CSC in particular is a large investment which can take several decades to bear the expected returns. Multi-stakeholder approaches are the best-bet to achieve CSC objectives because there is no one technology or scaling pathway that can serve the same purpose and have a large enough impact on the decisions of the producers.

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs). While the concept is new and still evolving, many of the practices that make up CSA already exist worldwide and are used by farmers to cope with various production risks. Mainstreaming Climate Smart Coffee (CSC) requires critical stocktaking of the sector fundamentals, already evident and projected climatic developments relevant to coffee production and promising practices for the future, and of institutional and financial enablers for CSC adoption. This CSC profile provides a snapshot of a developing baseline created to initiate discussion, both within countries and globally, about entry points for investing in CSC at scale.

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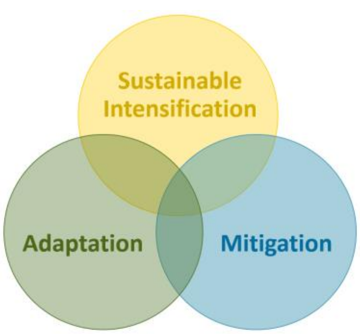
Climate smart coffee

Climate smart coffee (CSC) production sustainably increases productivity, enhances resilience to climate risk, and reduces or removes greenhouse gas emissions (GHGs). While the concept is new and still evolving, many of the interventions that make up CSC already exist worldwide and are used by farmers to cope with various production risks. Interventions can take place at different technological, organizational, institutional and political levels.

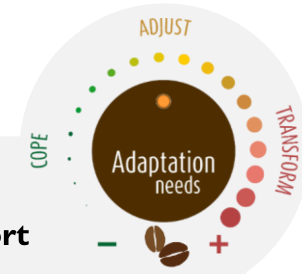
Adaptation to climate change is often understood as a change of production practices at the farm level. We evaluated potential farm-level practices in expert workshops to assess their potential contribution to the CSC pillars. The more benefits a practice provides the higher its climate smartness score. Most practices offer multiple adaptation benefits or raise the ability of the production system to withstand shocks.

With increasing degree of climate impacts, the importance of systems approaches to adaptation and the enabling environment increases. Practice focused adaptation reaches a limit when the climate changes to a degree that makes alternative systems more attractive. In this case, a change in the livelihood strategy may be necessary. Value chain inclusive systems approaches to adaptation, therefore, include a wider range of actors or crops to manage risk from coffee. The chain itself may be made risk proof or more efficient, for example at processing and transport stages, or where farmers and exporters choose to diversify into alternative crops. Such systemic or transformational adaptation may require changes to the framework conditions or enabling environment for CSC. This enabling environment includes policies, institutional arrangements, stakeholder involvement, and gender considerations, infrastructure, credit, insurance schemes, as well as access to weather information and advisory services.



The effective design of such interventions requires an understanding of the climatic changes that are observable in historic weather data, currently perceived by farmers and projected by global climate models. This brief therefore discusses these data for Guatemala and the potential pathways to mainstream climate smart interventions in the country.

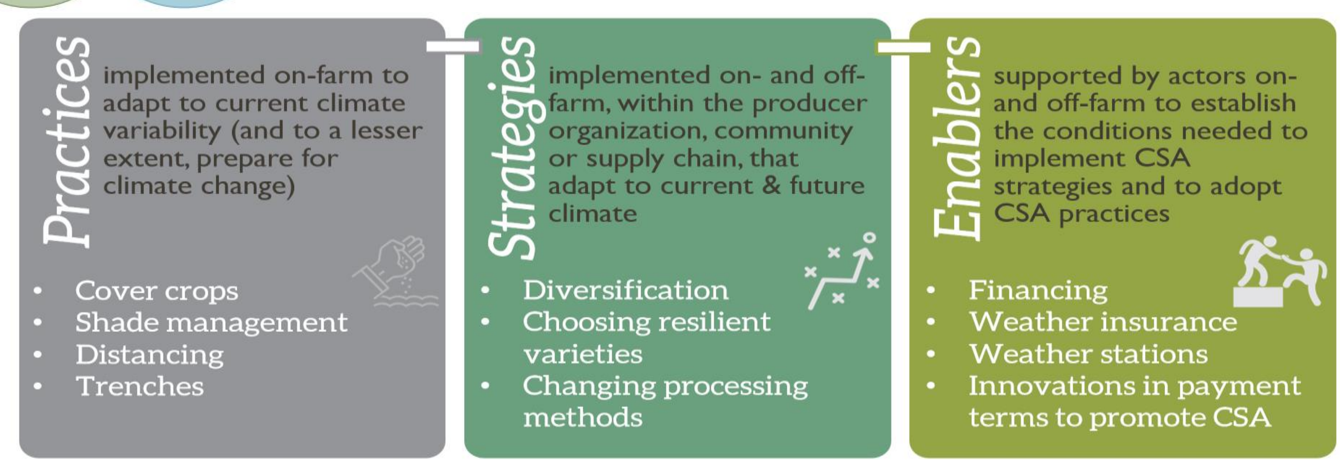
Three degrees of adaptation **effort**



Incremental adaptation where climate is most likely to remain suitable and adaption will be achieved by a change of practices and ideally improved strategies and enablers

Systemic adaptation where climate is most likely to remain suitable but with substantial stress, adaptation will be achieved through a comprehensive change of practices, but also requires a change of strategy and adequate enablers

Transformational adaptation where climate is likely to make coffee production unfeasible, this will require a focus on a change of strategy and adequate enablers as practices alone may be uneconomical

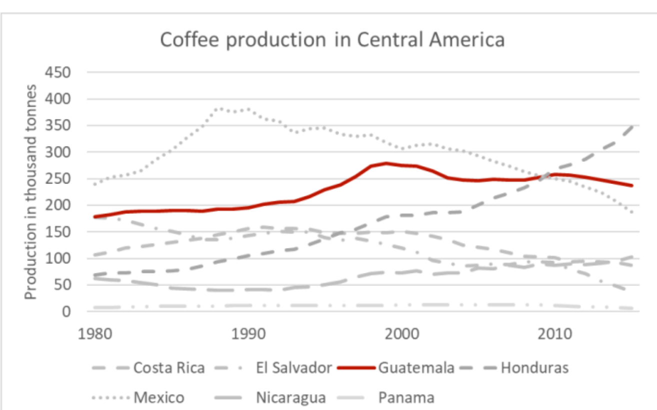


National context

Economic relevance of coffee

Guatemala is currently the second-largest producer of coffee in Central America behind Honduras but before Mexico. For the 2016/17 harvest, Guatemala produced 3.3 million bags [1]. Coffee production in Central America has declined or stagnated for more than 40 years, while other regions significantly increased output. The notable exception is Honduras, which doubled its output in less than two decades, whereas Guatemalan output has decreased during the same period. Until the late '90s productivity was increasing but has since been stagnant and even sharply decreased over the last decade. Total area has been virtually unchanged for decades, all changes in production came from productivity changes [2]. For the last two seasons, productivity has stabilized.

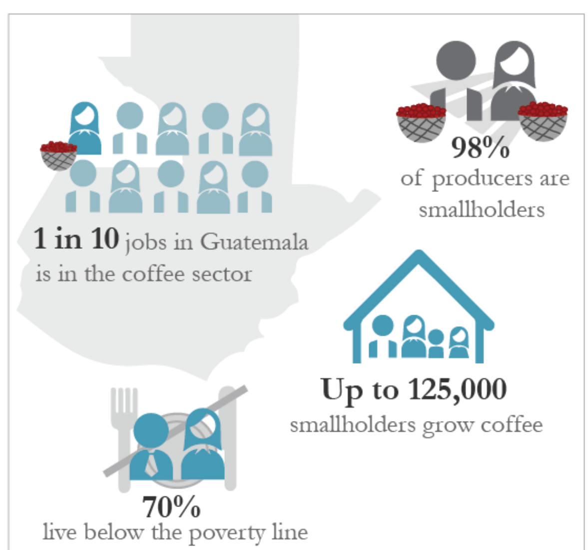
Coffee is Guatemala's third most valuable export commodity behind bananas (including plantain) and cane sugar. In 2016, coffee exports were valued at 651 million USD and made up 14% of the export value of agricultural products or 6% of total exports [3], and 1.04% of total GDP [1]. However, the total export of coffee and its share in exports has been steadily decreasing since the 2011/12 harvest, following the Coffee Rust outbreak and at present it continues to decrease.



Coffee is an export-oriented crop, exports amount to approximately 92% of production from 2015-17 [4]. The top export markets for the 2016/17 harvest were the United States (38%), Japan (15%), Canada (12%) and Belgium (8%) [1].

Coffee production in Guatemala has undergone a drastic transformation in the last 10 years driven by the changes in the precerences of consumers in importing countries. Large landowners used to grow other crops while new smallholder farmers appeared to farm coffee for export at high altitudes. For the 2008/09 harvest, the Guatemalan coffee value chain was estimated to include 74000 smallholder farmers producing approximately 20% of total volume compared to 15000 medium and large farmers producing 80% [5]. By 2016/17, the number of smallholders grew to 122000, making up 98% of production and producing roughly 50% of all coffee in Guatemala [4].

Coffee production is an important activity in the rural economy, generating 500,000 jobs and encompassing 9% of the active labor force [6]. 70% of households in coffee-producing regions live below the poverty line and 20% of households live in extreme poverty [6].



Coffee and land use

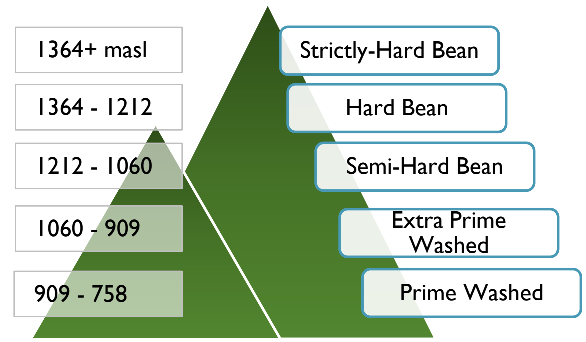
Coffee production occupies 3% of the total national territory of Guatemala [1]. Guatemala has an annual deforestation rate of about 1.2% per year. Between 1990 and 2015 the area under forest cover was reduced from 44% to 33% of the total land surface. Throughout this period the coffee area went through a contraction and expansion cycle. Especially in areas suitable for coffee, the expancion of this crop has been an important factor in forest loss [8]. Besides that, low and volatile prices resulted in a conversion of coffee agroforests to other croplands, usually of lower ecological value. Medium-scale farmers were deemed the most price-sensitive given the total area of conversion with the addition of lower capacities to diversify production [7].

Coffee is grown throughout most of Guatemala mainly along the Sierra Madre mountain range 204 of 340 municipalities and 20 of 22 departments produce coffee. More than half of the coffee produced, however, is grown in just 5 departments: Huehuetenango and San Marcos, comprising the western highlands; and Santa Rosa, Chimaltenango, and Chiquimula, comprising the central-eastern highlands [1].

Within this area, there are an estimated 300 unique microclimates created by a mixture of temperatures and rainfall beneath shade-grown coffee at various altitudes [9]. ANACAFÉ (Asociación Nacional del Café de Guatemala) has divided the country into 7 growing regions, where volume is relatively similar. Each region has a regional office and extension agents who offer technical assistance for the area. Within the main coffee growing regions, 8 specific areas have been selected and marketed by ANACAFÉ for their high-quality cup created by specific microclimates, soil, altitudes, etc.

Coffee production segments

Guatemala has been historically known for its high-quality washed Arabica, a legacy of early German plantations dating back to the 1800s, and still the predominant production system. Guatemala almost exclusively produces Arabica coffee beans, and grades bean quality into 5 categories, each referring to the elevation at which the bean is grown:



Strictly Hard Bean is the primary coffee bean exported at 83% for the 2016/17 harvest [1,4] up from about 40% in the '90s. This expansion was mostly driven by consumer demand for such coffees [10].

No statistics are published about the share of certified producers or the quantity of coffee that is marketed as certified, for example as Rainforest Alliance, Organic or FairTrade [1].

Productivity and poverty indicators

Smallholders make up 98% of producers and produce roughly 50% of all coffee in Guatemala [10]. Smallholders farm on less than 1.2ha [4], however, the majority of smallholders farm on less than a third of a hectare [1]. Estimates of productivity (quintales pergamino/manzana) have been steadily decreasing. ANACAFÉ estimates that productivity has decreased nearly 40% over 10 years with a high of 964 kg/ha in 2006/7 to 638kg/ha in 2015/16 [1].

Guatemalan coffee has traditionally been grown beneath shade, a pattern that still persists today. The national coffee association posits that 98% of coffee is grown under shade. The amount of shade depends on altitude and ranges from 50%-70% shade for low altitudes and 25%-30% for high altitudes [1]. A wide diversity of shade trees is cultivated, including native and promoted varieties. On-farm species diversity is variable and based on access to seed and extension, altitude, and parcel type (new or renovated). Large farms are traditionally

found at lower altitudes while smallholders work higher altitude land. Large farms have diversified plots and grow palm oil and rubber along with coffee.

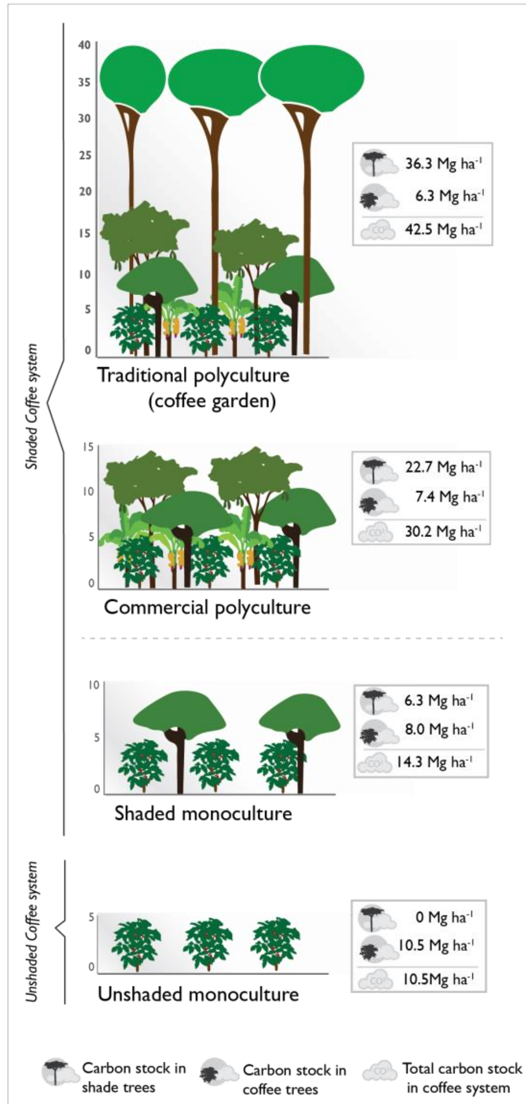
Subsistence farming does occur in smallholder coffee production systems; however, this is not universal. Emerging farmers in the highlands of Huehuetenango and San Marcos expanded from subsistence and day laboring in coffee to producing coffee and continuing to grow subsistence crops such as maize and beans [10]. In predominant coffee growing regions, approximately 20% of food available for poor Guatemalans is generated in subsistence, while 80% is obtained via market purchases. Elsewhere, where coffee is grown along with other crops (for example, cardamom in the Verapaces or food crops in the eastern highlands) poor farmers rely less on market purchases, with subsistence crops making between 30-40% of food consumption [11]. This means that during the recent Rust crisis, and in times of low coffee prices, smallholders don't have access to sufficient and adequate alimentation.

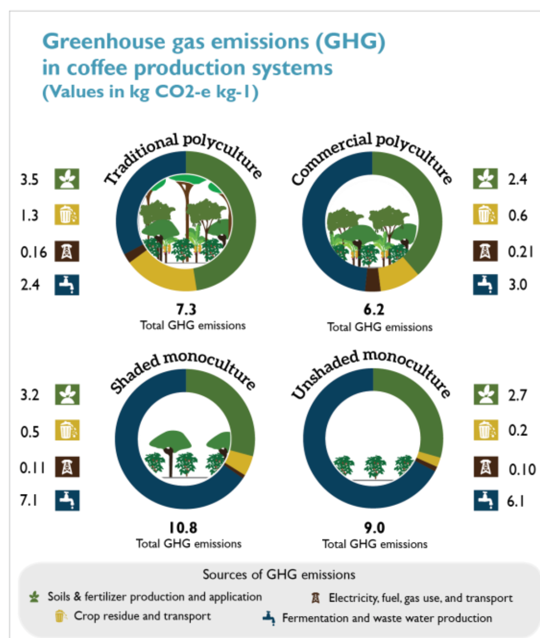
Coffee greenhouse gas emissions

Coffee production is vulnerable to progressive climate change but at the same time contributes by emitting greenhouse gasses. Emissions can be assessed using tools such as the Cool Farm Tool [12].

The most important aspects of the climate impact of coffee production are the standing carbon stocks in the production systems and the product carbon footprint, which measures the GHG emissions per unit weight of coffee produced. The data presented spans across the main production systems in Central America traditional polycultures, commercial, polycultures, shaded monocultures and unshaded monocultures[13].

Polyculture systems have a lower mean carbon footprint, of 6.2–7.3 kg CO2-equivalent kg−1 of parchment coffee, than monocultures, of 9.0–10.8 kg. Traditional polycultures have much higher carbon stocks in the vegetation, of 42.5 Mg per ha, than unshaded monocultures, of 10.5 Mg. Comparing carbon stock and footprint reveals that traditional and commercial polyculture systems are much more climate friendly than shaded and unshaded monoculture systems. Strategies to increase positive and reduce negative climate impacts of coffee production include diversification of coffee farms with productive shade trees (the use of their wood can substitute fossil fuels and energy-intensive building materials), the targeted





use of fertilizer, and the use of dry or ecological processing methods for coffee instead of the traditional fully washed process.

Challenges for coffee production

One of thes main challenges facing coffee production in Guatemala is the renovation of coffee farms. ANACAFÉ estimates 50% of farms need to be renovated (see also section below). USAID reports that 169 thousand hectares (70%) require renovation and replanting [14]. There is some disagreement on varieties for re-planting, between resistant, productive, and cup-quality varieties.

Commonly grown high-cupping specialty varieties include Caturra, Catuaí, and Bourbon when grown at high altitudes (more than 1400 masl). These varieties are also among the most vulnerable to rust with an incidence at 43.2%, 41%, and 7.6% respectively [1]. Additionally, Bourbon is particularly vulnerable to heavy rains as the variety often drops its fruit. While these varieties can receive a higher price for their improved cup quality, they are more susceptible to disease and are often sold in cherry, unable to reach specialty markets.

Currently, in Guatemala, prices do not cover costs for small farmers, leading to frequent reduction of inputs and discounted labor [15]. A smallholder producing on 1.7 manzanas (1.2 ha) with good agricultural practices would receive a yearly income of approximately USD 3000 (GTQ 22100), at a yearly loss of USD 240 (GTQ 1800). However, few smallholders reach that income level and USD 1870 (GTQ 14000) may be a more conservative estimate [16]. Furthermore, the minimum wage in Guatemala has grown 95% more than the price of coffee. At USD 420 per month, Guatemala has the highest minimum wage among coffee-producing countries in Latin America [16]. Large farmers, too, have been affected by the diminishing profit margin due to rising labor costs and continue to diversify assets, often farming African palm, rubber, bananas or moving to pasture depending on altitude [7].

Limiting inputs to stay competitive and profitable can place small farmers in precarious situations for pests and diseases. Regular fertilization supports leaf development and avoid crop loss, however with reduced profitability and inputs to cope come more ideal conditions for rust severity [17].

Gender disparity is a known and observed reality in not only the production of coffee, but it also permeates the entire value chain. Guatemala-specific public data concerning women's ownership and participation are uncommon. In informal interviews, smallholding women farmers, list *machismo* as a challenge to producing coffee. Not only does it limit on-farm decision-making power of women, but it also reduces the opportunities for capacity development--whether that be visiting demonstrative parcels or attending training.

In impoverished regions, underage adolescents often work on the family farm to pick coffee, or even work as hired labor. This is more common among boys than girls [18].

Pest and Diseases

Three main pests and diseases affect coffee production in Guatemala: Coffee leaf rust, or la roya (CLR, *Hemileia vastatrix*); American leaf spot disease, or ojo de gallo (*Mycena citricolor*), and the coffee berry borer, or la broca (CBB, *Hypothenemus hampei*).

Guatemala was hit hard by the **coffee leaf rust** crisis (2012/13) in Central America, affecting 70% of total cultivated area and reduced yields in the country by between 20 and 25% [1,15]. Favorable conditions including an increasing minimum temperature and an early rainy season are plausible drivers of this outbreak [17]. In Guatemala, rust outbreaks were reported with equivalent attack intensity between 400 and 1400 masl [17]. Following the outbreak, the region reacted by massive breeding and replanting efforts with rust-resistant varieties. By 2017, 15860 hectares had been renovated costing roughly USD 84 million. Additionally, Guatemala set a USD 100 million trust fund to support production for medium-to-large producers [17]. Between 2015 and 2016, the presence of rust grew 5%, notably affecting Chiquimula where 53% defoliation among coffee trees can be found--aided further by climate and market stress [11].

The **coffee berry borer** is the primary pest affecting coffee production, attacking the bean directly and using it for reproduction. The highest incidence occurs at the onset of the wet season and management is mostly manual. Higher temperatures are predicted to increase the latitudinal and altitudinal range, in other words, the area of incidence is expected to expand and move higher, as well as and increase of coffee berry borrer occurrence at different stages of development per fruiting season [19].

Coffee leaf spot is a fungal disease that affects coffee production, specifically in moist, dense, conditions. It has been specifically a problem for rust-resistant varieties such as IHCAFE 90 and Lempira [20].

The dry season provides amenable conditions for **Araña roja**, a species of spider mite (*Oligonichus yothersi*) which sucks the sap and damages coffee leaves as well as the leaves of shade trees including Mango (*Manguifera indica*) and Eucalyptus (*Eucalyptus sp.)* [21].

Mealybugs (*Pseudococcidae*), locally known as *Cochinillas* attack the root of the coffee plant. Their secretions attract ants which protect them against natural enemies. When the roots are damaged, the leaves begin to lose color and the coffee plant eventually dies off. These insects are more commonly found during the first five years after planting. Low and mid-level altitudes, acidic and sandy soils and a somewhat humid environment favor their development and spread.

Coffee and climate change

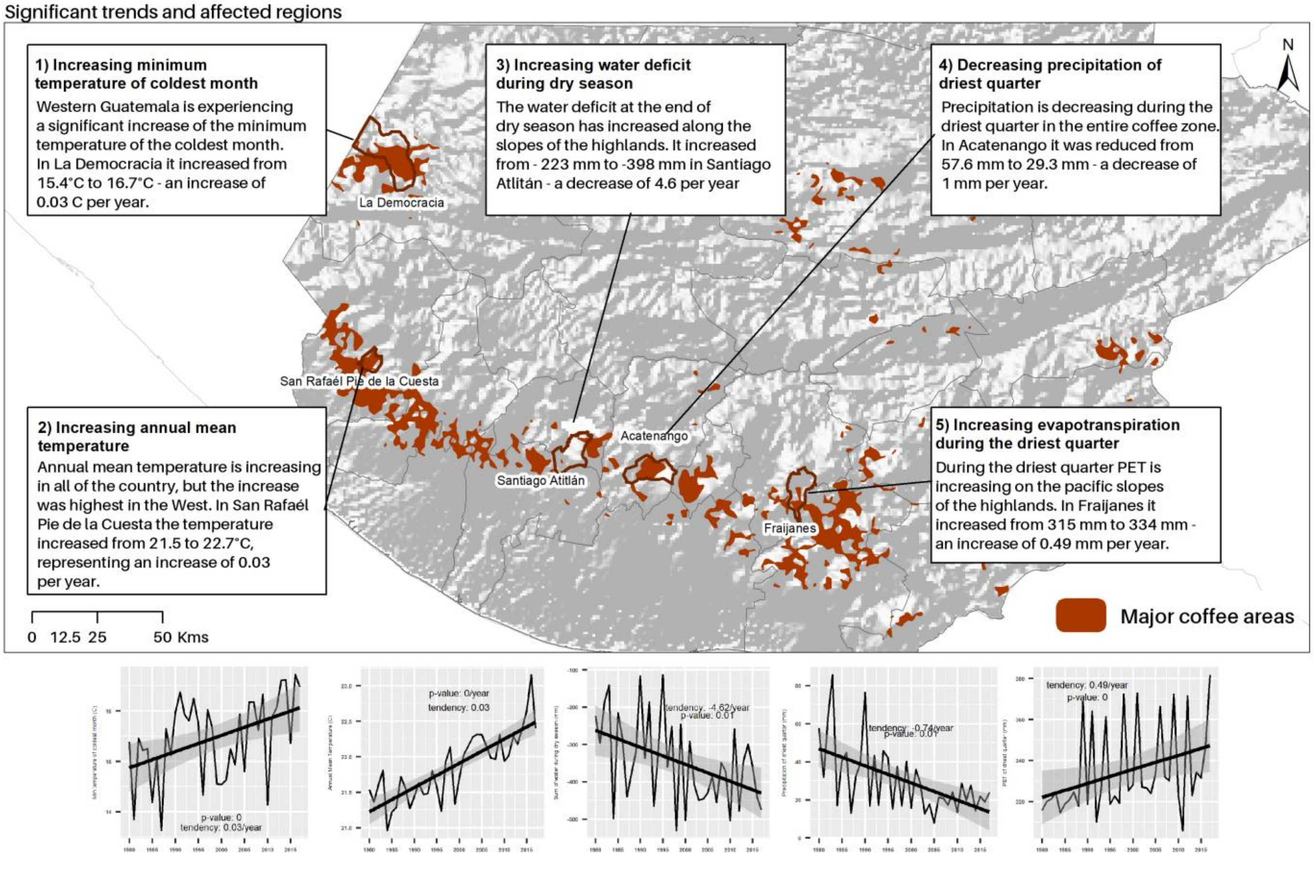
Coffee experts and producers report that they already perceive a change in climate and an increase in adverse climatic events such as storms, irregular rainfall, increasing temperature range, drought, high temperatures, and high winds. Farmers perceived precipitation to be less frequent but with an increased volume of rain. These trends are said to be of high or very high impact on coffee production by changing pests, diseases and weeds, post-harvest risks, soil erosion, fruit drop and causing irregular flowering. The recent coffee rust epidemic was generally attributed to conducive weather conditions and regional experts claim that climatically Central America has become more extreme with a tendency to more drought, heavier rainfalls, and higher temperatures. In this section, we will first describe climatic changes that we could find in observed climate data from 1980 until 2017. Next, we will report changes that were projected by global climate models in a climate change scenario of intermediate severity.

Observed climate risk and trends

Coffee presences in Guatemala are primarily located along the Sierra Madre mountain range, which extends from Mexico all the way to Honduras. These areas in Guatemala have become drier and hotter over the past three decades. Annual temperatures have risen across the country, potential evapotranspiration increased, and the distribution of precipitation has become more variable. The extent of these developments varied across the country. For some variables, we could not identify significant developments, e.g. total annual precipitation remained unchanged in all of Guatemala. However, higher temperatures and reduced cloud cover will increase the water needs of the coffee crop, in which case water stress may rise despite unchanged water availability.

Climate trends in Guatemala (1980 - 2017)

Significant trends and affected regions



What is a "significant" trend?

The definition of "significance" of a climate trend by coffee practitioners is usually different from the scientific definition. A local coffee expert may claim that a trend was significant if in recent seasons weather events deviated from customary expectations, and this had an impact on crop management and yields. The scientific method was invented to test such hypotheses using systematic observation and measurement because human perception may be flawed by a few recent events that do not amount to a trend that will continue into the future, or the causality may be biased by our limited senses. However, given the urgency of climate action scientific significance has limitations itself: a trend in climate data may be statistically significant, but meaningless to the practitioner; limited data may sometimes not allow the rigorous testing of statistical significance, especially of rare but impactful "once in a century" events. Start and endpoint of trend analysis may affect the detection of trends, or they may be a function of natural variability over decades. It is thus not good practice to assume they will continue into the future without strong evidence to support this. Last, not all local trends were caused by global warming, but are the result of deforestation, urbanization or similar localized developments.

How was the trend analysis done?

We first calculated bioclimatic indicator variables for the years 1980-2016 and then used the Theil-Sen estimator to fit a trend to the data. This method fits a line by choosing the median of the slopes of all lines through pairs of points. The Theil-Sen estimator is more accurate than least squares regression for heteroscedastic data and insensitive to outliers. We considered a trend significant if the 95% confidence interval did not include zero. We used Terraclimate [30] interpolated monthly climate data for temperature, precipitation and potential evapotranspiration. We defined the cropping year to start with the three months that are the driest of the year on the multi-decadal average and the following 9 months. For each cropping year, we derived 31 bioclimatic variables that describe annual and seasonal patterns. For each 0.05° grid cell of Guatemala we evaluated the significance of the trend and estimated the slope. We picked bioclimatic variables with trends in coffee regions that could potentially have a biophysical impact. Finally, in regions with significant changes we picked a representative coffee location to determine the absolute change, p-value and slope.

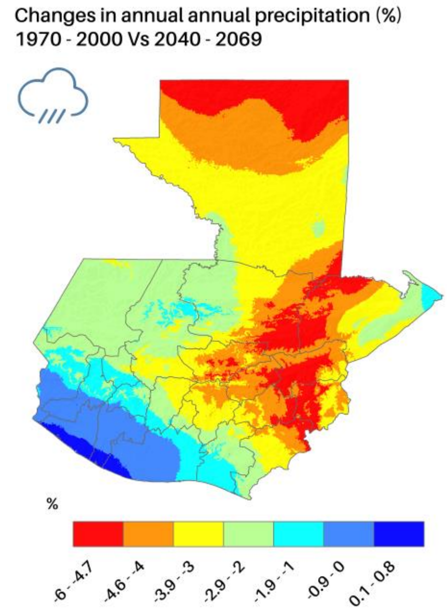
What is potential evapotranspiration?

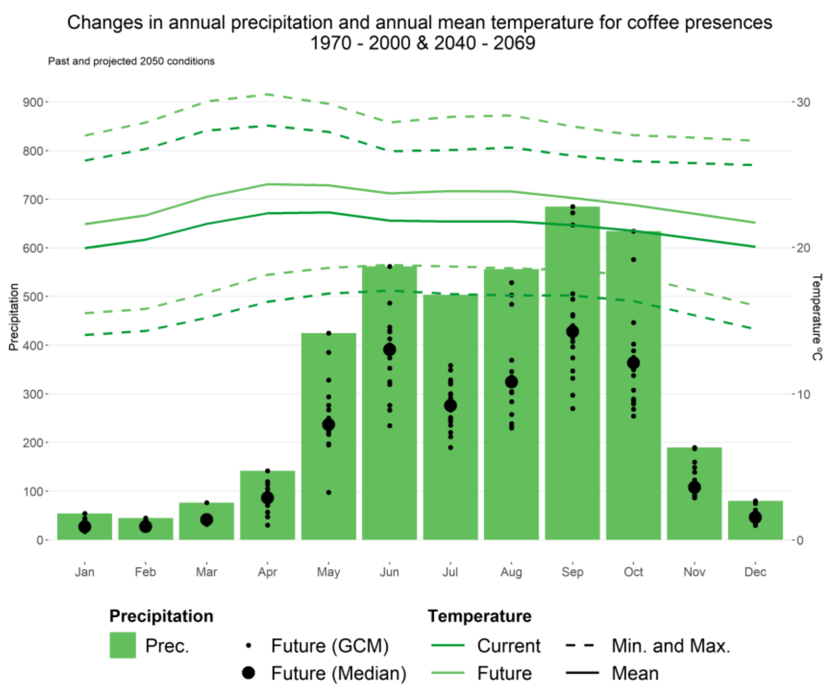
Evapotranspiration is the combined process of evaporation from the Earth's surface and transpiration from vegetation. Potential evapotranspiration (PET) is the amount that would occur if sufficient water were available. It is estimated using average, minimum and maximum air temperature and solar radiation in the Hargreaves method [31]. The cumulative water deficit at the end of the dry season is the cumulative excess PET over precipitation.

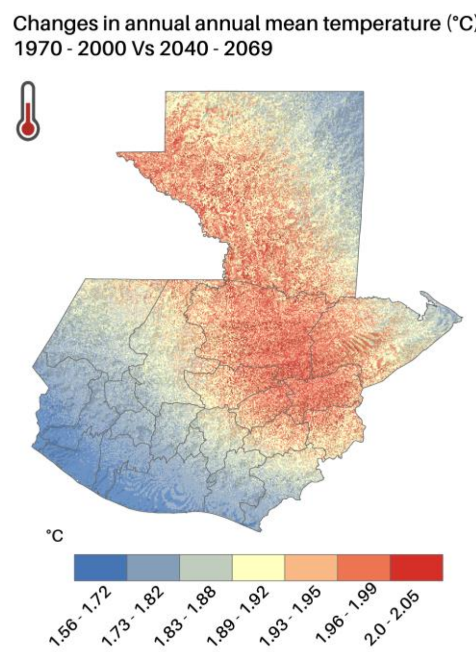
Projected climatic changes

Global climate models projected the annual mean temperature to increase by 1.7°C-2.0°C until mid-century. Temperature changes are projected to be higher in the central states Alta and Baja Verapaz as well as eastern Peten, Izabal, and Zapaca. Rainfall will exacerbate the effects of higher temperatures as parts these states were projected to have a decrease in total annual precipitation of 6%.

Central America has been repeatedly hit by droughts in the past, most notably in the late 90s and turn of the century[23]. Coffee yields are very sensitive to these events which are projected to become more frequent and intensive in the coming decades as climate change progresses. Additional extreme climatic events potentially damaging for coffee in Central America include the El Niño Southern Oscillation, strong winds and intensive rainfall, and flooding. The damage caused by these events is compounded in the face of low prices or periods of price volatility as the incentive for farmers to renovate and replant or take other farm management measures to recuperate production decreases[23].





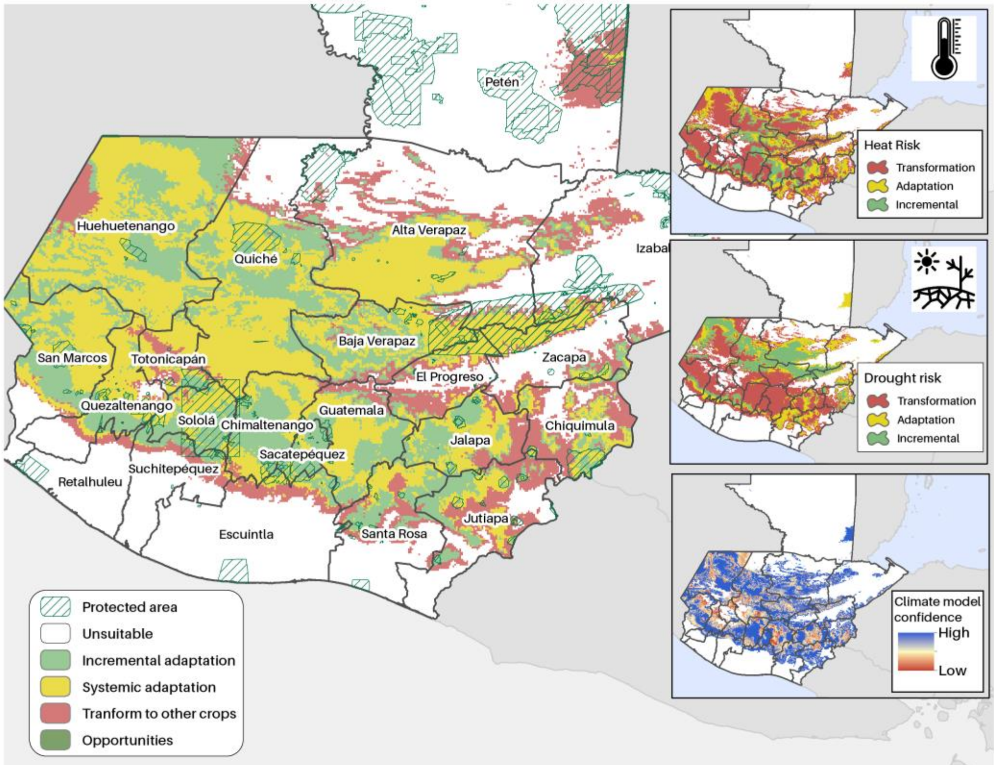


How are future climate projections generated?

A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs), generally derived using global climate models. A global climate model (GCM) is a representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes. Climate projections depend on the emissions scenario used, which is in turn based on assumptions concerning future socio-economic and technological developments.

GCM outputs have a coarse resolution of 100 or 200km, which is not practical for assessing agricultural landscapes. We therefore use downscaled climate projections. For each GCM anomalies are calculated as the delta between modeled baseline climate and future prediction. These anomalies are interpolated and added to the baseline climate data. Key assumptions of this approach are that changes in climate only vary over large distances and the relationship between variables in the baseline are maintained into the future.

Gradient of climate change impacts



To support effective adaptation, we developed a gradient of climate change impacts for coffee production. The gradient is a coffee-specific evaluation of the projected climatic changes described above. Otherwise identical climatic changes may result in severe or irrelevant impacts depending on historical climate conditions. For example, a reduction of 50mm precipitation may be critical to the coffee crop at locations with low water availability but would be irrelevant where rainfalls are abundant throughout the year. Depending on the degree of impact, diferent packages of adaptive practices are recommended.

Incremental adaptation	Systemic adaptation	Transformation
These areas are most likely to remain suitable. Focus should be on the sustainable intensification of production and incremental adaptation by enlarging farmers' portfolio to manage climate risk. CSA practices with high mitigation and productivity potential should be prioritized: **Minimum CSA coffee practices:** Use of permanent shade **Additional coffee practices:** Use of temporary shade Native cover crops Selection of rust resistant varieties Windbreaker curtains **Optional:** Grafting Arabica onto Robusta rootstock Drip irrigation Water harvesting Canals for drainage	These areas remain suitable but with substantial stress. Comprehensive adaptation of the production system will be necessary. CSA practices with high mitigation and adaptation potential should be prioritized and combined with systems change: **Minimum CSA coffee practices:** Use of permanent shade Use of temporary shade Native cover crops Selection of resistant varieties Organic barriers **Additional coffee practices:** Grafting arabica onto Robusta rootstock Deeper bags and deeper holes for planting Canals (acequias) for drainage Water harvesting Drip irrigation Biochar Gypsum Leguminous cover crops Windbreaker curtains **Systems strategy:** Crop diversification (on-farm) Income diversification (off-farm) Insurance	Increasing climatic stress makes adaptation or a strategy change indispensable. Without comprehensive adaptation coffee production will be unfeasible. CSA practices with high adaptation and livelihoods potential should be prioritized: **Transformation strategy:** Crop diversification (on-farm) Income diversification (off-farm) Insurance **Minimum CSA coffee practices:** Use of permanent shade Use of temporary shade Native cover crops Selection of resistant varieties Water harvesting Water retention polymers Drip irrigation Mycorrhiza Trichoderma (fungicide) Biochar Leguminous cover crops Gypsum Windbreaker curtains

The gradient shows the most likely degree of necessary adaptation effort across several potential future climate pathways. The impact gradient indicates that most of the Guatemalan coffee production can be sustained with adequate effort. Currently, about half the area in the country has suitable climate conditions for coffee production but most of the suitable area is in need of substantial adaptation effort. Of the current Arabica area, 20% will require transformational adaptation, 30% systemic change, and almost 50% will remain suitable using current production practices. Areas below 800 masl will require transformational change, for example to Robusta or other crops. In the future, most Arabica area will be at 1200m and above. Previously unsuitable areas above 1800m will see improved conditions.

Altitude in m.a.s.l.	Adaptation strategy	Guatemalan grade
758 - 909	Transformation	Prime washed
909 - 1060	Systemic adaptation	Extra prime washed
1060 - 1212	Systemic adaptation	Semi-hard bean
1212 - 1364	Systemic adaptation	Hard bean
>1364	Incremental adaptation	Strictly hard bean

Impacts follow an altitudinal gradient and little regional difference could be found. Low lying areas that historically used to produce coffee will become unsuitable. Coffee production in Guatemala is already confined to optimal area in high altitudes because of a demand for high quality beans. In the future, this geographical limit will reflect the projected stress from climate change. The lowest suitable altitude will rise by at least 200m.

Regional differences were projected for the importance of drought stress. In the Coban and Huehue areas heat stress was found to be relatively more important. Along the pacific range both heat and drought were projected to increase to levels that would be considered unsuitable under current conditions. Thus, even though large areas in Guatemala will likely remain suitable, adaptation to such hazards will be a precondition.

Previously sub-optimal sites will likely become uneconomical for coffee. This trend is already evident in the gradual disappearance of lower grades qualities in the last decades. Hard bean grade coffee will in part struggle to remain productive unless comprehensive adaptation measures are implemented. Strictly hard bean grade will require incremental management changes to remain productive.

How certain is the projection?

As any future outlook our model has a considerable degree of uncertainty and should be considered projections, not predictions. Uncertainty in our model also comes from emissions scenarios, climate models and the crop model. Emissions scenarios uncertainty were discussed above, and of course, reducing emissions globally is the most promising adaptation option. We used 19 global climate models as equally valid projections of future climate. These models show a high level of agreement on an increase of temperature, but disagreement about the regional and seasonal distribution of precipitation. The resulting consensus model of the independent projections is therefore to a large degree influenced by the temperature increase while disagreement from precipitation is masked. Nevertheless, an increase in temperature implies increased water needs of agriculture. Last, our model is an "all other things equal" model that only considered a change of climate. Our statistical approach is designed to avoid overfitting and deliberately also includes marginal locations for coffee. This should be considered "friendly" uncertainty because it means through guided adaptation the worst impacts will be avoidable.

Climate smart coffee in Guatemala

Farm level adaptation

Climate Smart Coffee recommends a series of agricultural practices that fulfill one or more of the key objectives of Climate Smart Agriculture. Because of the urgent need for high adoption, an obvious approach to CSC development is to promote the scaling of no-regret farmer coping strategies within suitable decision domains. The following list consists of expert validated practices. They can serve as a starting point to develop portfolios for each of the risk zones. Additional information about the practices can be found in the annex or at Coffee & Climate [10].

CSC practices	Adaptation level	Adaptation benefit	Total Climate Smartness
Use of permanent shade	1	FDHR	5
Use of temporary shade	1	FHR	4.6
Grafting Arabica Scion onto Robusta rootstock	2	DR	2.9
Native cover crops	2	FDHR	2.5
Organic barriers	2	HR	3.1
Canals (Acequias)	2	HR	1.1
Planting Sarchimor varieties	2	R	2.3
Planting Catimor varieties	2	R	2.1
Planting climate-tolerant varieties	2	FDHR	3.1
Water harvesting	3	FDHR	1.1
Use of deeper holes and bags	3	DR	2.2
Drip irrigation	3	FDR	2.7
Water retention polymers	3	DR	0.7
Use of mycorrhiza and/or trichoderma	3	DR	1.3
Biochar	3	DHR	1.9
Leguminous cover crops	3	FDHR	2.8
Graminillas cover crops	3	FDHR	2.5
Gypsum application to soil	3	FDR	2

F– Flood/torrential rain/erosion; D – drought; H – Heat; R – Resilience.
1–Incremental adaptation; 2– Systemic adaptation; 3– Transformation

Renovation with adapted varieties

Due to climate change and the massive impact caused by coffee rust in Guatemala from which it has not yet fully recovered, there is a need for renovation and rehabilitation (R&R). USAID estimates that almost 70% of the total area planted with coffee should have R&R [14]. Yields could increase between 5 and 25% if R&R is carried out.

Farmers often replant with low-quality seeds from their own plot. ANACAFE produces a variety called Anacafe 14 which is resistant to coffee rust, though currently insufficient quantities are produced.

The priority of variety development in Guatemala has been resistance to coffee rust. Lately, the planting of Catimores and Sarchimores has been on the rise. These hybrid varieties are resistant to coffee rust and are commercially known in Guatemala by the names: Anacafé 90, Catimor T-8667, Costa Rica 95, among others. Other varieties such as Anacafe 14, Icatú, and Obatá are resistant to coffee rust and are also drought and nematode tolerant. Detailed information on coffee varieties is made available by ANACAFE [24].

An initiative by World Coffee Research (WCR) to promote seedling gardens and field trials with improved

and certified varieties is taking place in Guatemala from 2016 to 2020.

Systems approaches

Climate-smart coffee plans must consider the systems or environments in which coffee farmers make their investment and management decisions. Lack of access to credit markets, inputs, and a low share of gains from higher quality as well as gender considerations are powerful disincentives for the implementation of CSC practices. In many cases, the small size of the farm does not warrant investing in expensive equipment, moreover, the steep slopes on which coffee is grown in Guatemala make the use of heavy machinery very difficult.

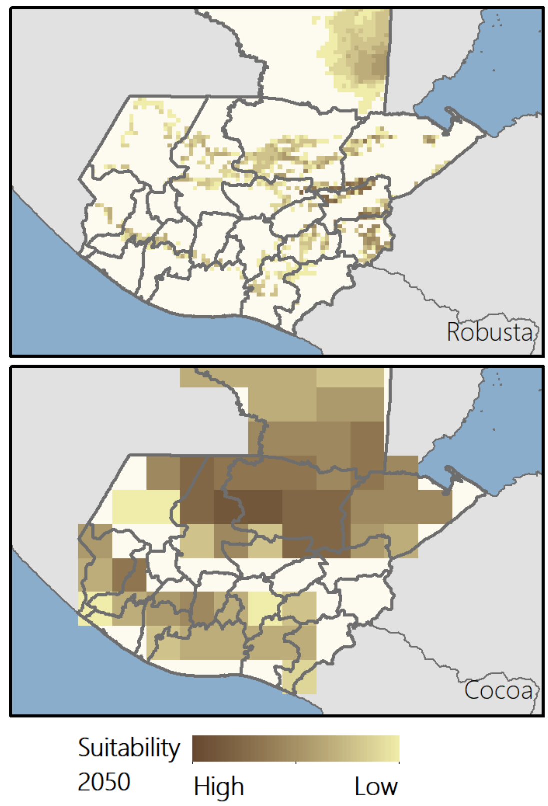
Stronger links to the markets both for inputs and for selling production are required to make sure that farmers can invest in their farms adequately and gain reasonable returns. Many smallholders currently depend on so-called *coyotes* or loan-sharks who charge very high-interest rates for their access to the market. Farmers are tied to their respective value chains either too loosely or too tightly. Around 70% of coffee farmers have links to cooperatives or some form of an organized group based on coffee, however, these groups are not able to provide their members with access to finance or training [14].

Gender disparities and instances of *machismo* are a problem not only within households, but also for coffee growing households lead primarily by women.

The **Hanns R. Neumann Stiftung (HRNS)** supports the Mujeres en Café Guatemala, an association dedicated to improving the status of women at all steps in the value chain of coffee production in Guatemala.

The Trifinio Plan, which is also sponsored by the HRNS is centered around **Ecosystem-based adaptation** (EbA). Coffee farms under agroforestry are providers of ecosystem services, the Trifino Plan implemented at the border between El Salvador, Guatemala, and Honduras seeks to prevent encroachment of coffee farms into the rainforest. EbA is a strategy to increase the tolerance to the negative impact of climate change through improved biodiversity and ecosystem services. Land restoration and riparian vegetation buffers are examples of such measures which can increase the resilience of yields in coffee farms while raising external benefits.

The recommendation for coffee farming households in transformation areas is to strongly consider the transition to a different crop, preferably one grown under agroforestry to ensure ecosystem services are sustained. Growing coffee may become uneconomical in the medium- to long-term in these areas. **Diversifying production** with nuts and avocados, for example, is not only an option to ease this transition for coffee growers in transformation zones, but it is also recommended for farms in incremental and systemic adaptation areas. Climate or price shocks can severely reduce the food security of poor farming households, therefore participating in additional value chains reduces the risk of losing coffee incomes.



Two such widely discussed options are Robusta coffee and Cocoa. These crops are similarly climate sensitive as Arabica but may sustain higher temperatures. However, where drought threatens Arabica, cocoa is unlikely to be a good choice because of its high precipitation requirements [11], but climate was projected to be suitable for both crops in some of Guatemala's current coffee areas [12].

Enabling interventions

To facilitate the adoption of CSC practices enabling interventions need to be expanded and enacted. These types of interventions are designed to provide farmers with finance options and the necessary services to make their investment and farm management decisions.

Due to the insufficient fund of the State Trust (*Fideicomiso*), many farmers are still reliant on local lenders are known as *coyotes* who charge extremely

high-interest rates on loans. Because coffee is such an important crop for the livelihoods of farmers, they are very risk-averse and trust in new solutions or technologies needs to be built up through the observation of clear impacts.

A smart alignment of management practices with seasonal patterns can avoid losses of input and labor due to untimely weather events. **Weather-related management alerts** combine season-based cropping calendars with weather station data to trigger mobile service messages. Instead of initiating management following the normal seasonal rhythm, the alerts advise practices such as planting or fertilization when the observed weather suggests a suitable crop development state.

Index-based weather insurance offers a new promise for reducing climate risks. Pay outs are triggered by pre-determined weather events and thus do not require verification of losses. Such index insurance may avoid problems of adverse selection and moral hazard. It also has minimal transaction costs, which helps the insurance market reach poor people. A properly designed index could address the wide variation in yields and quality that is so central to coffee profits. However, index insurance has met with low uptake among intended beneficiaries, particularly small-scale farmers. An index-based insurance contract targeting at the group level, such as a coffee cooperative, could be a potential solution to the problem of low uptake.

Adoption and scaling business cases

Active efforts to scale out climate smart practices are a priority to secure long-term sustainability of the coffee sector. Because coffee production is an investment of several decades and many CSA practices have a long lead-time, adaptive action needs to be taken immediately with forward-looking thinking. A multi-stakeholder approach will be required as no single technology or scaling pathway may account for the diversity of decision environments of the actors involved. Together with organizational development, we suggest complementary scaling pathways for climate smart coffee that respond to business incentives: Voluntary certification, carbon in-setting, impact investing, sustainability branding.

Management practices such as shade use, and reforestation influence have the double benefit of both reducing climate vulnerability and increasing carbon stocks in coffee. In some cases, these synergies can be used to incentivize and subsidize adaptation actions through carbon accounting for mitigation actions. Carbon in-setting offers to offset GHG emission in the coffee supply chain or processes.

Therefore, roasting and trading companies can offset their GHG foot print by investing in carbon sequestering activities at farmer level that at the same time support the adaptation of farmers to progressive climate change. A study in Nicaragua showed that afforestation of degraded areas with coffee agroforestry systems and boundary tree plantings resulted in the highest synergies between adaptation and mitigation [25]. Financing possibilities for these joint adaptation mitigation activities can arise through carbon offsetting, carbon in-setting, and carbon footprint reductions.

The interest of companies to invest in CSC depends on their business model and the scale of their operations. Companies that work closely with farmers tend to not separate efforts into climate or sustainability efforts, but rather focus on holistic programs to increase productivity and make coffee farming attractive. Large brands source large quantities and choose to invest in climate change activities out of a volumes-based business case. “Front-runner” companies are concerned about supply volumes, but in addition generate value from brand reputation. Last, the value of smaller brands is often based on social and environmental reputation. Therefore, the latter have a higher capacity to develop solutions in direct contact with their smallholder base than the larger companies. They can therefore act as catalysts to innovate CSC approaches that can be mainstreamed by the more risk-adverse large brands with their large constituencies to achieve CSC adoption at scale (See case study below for a practical example).

Social investment funds seek to maximize positive social and environmental effects of investments by providing finance for rural small businesses for both short- and long-term investments. Private investors are more able to act on novel information than governmental organizations but some degree of certainty about the efficacy of practices is required. Working with producer organizations rather than individual farmers may provide efficient incentives for adoption of financeable CSC. However, currently incentive investors have a limited scope.

Policy Environment

Institutions

The **Guatemalan Ministry of Agriculture, Livestock, and Food (MAGA)** sets the standards and norms for agricultural production to promote efficiency, competitiveness, and the protection of the environment. Creating policies for agricultural training, international commerce of agricultural production and boosting the capacity of agricultural organizations to achieve their objectives are also among the duties of MAGA[27].

The **National Association of Coffee (ANACAFE)** was established in 1960 with the Coffee Law though it is now a private institution. Its main objective is to improve the national production and export of coffee. It is the main representative group of the Guatemalan coffee sector and is in charge of allotting export licenses, promoting national coffee internationally and developing and implementing policy related to coffee. Representatives of cooperatives and associations are members of the board of directors.

The **Federation of Agricultural Cooperatives of Coffee Producers (FEDECOCAGUA)** has over 20000 members from 148 cooperatives and farmer groups across Guatemala. The mission statement of this organization is to close the gap between smallholder farmers who have limited resources and importers in the countries where the coffee is consumed. To fulfill its mission, FEDECOCAGUA provides technical assistance, finance, and supports commercialization. It has five regional bodies: in Huehuetenango, Suroccidente, Centro, Noroccidente, and Cobán[28].

The **Center Research on Coffee (Cedicafé)** aims to increase coffee profitability in the face of adverse circumstances. It relies on field- experimentation of innovative approaches, improved agronomic practices, post-harvest processing, and mechanization. The center publishes technical reports twice a month on topics ranging from quality monitoring to the detection and management of spider mites (Araña roja, *Oligonichus yothersi*) [29].

85% of Guatemalan coffee is exported through the **Coffee Exporters Association (ADEC)**. It was founded in 1965 and currently has 33 members. Through this association, members advocate for export regulation and provide training and support on logistics, marketing, and post-harvest processing among others[30].

Coffee Women (Mujeres Café) is an association of female producers created to strengthen the competitiveness, sustainability, and profitability of coffee farms managed by women. The association also seeks to incentivize the participation of women in the Guatemalan coffee sector and improve their quality of life, for example, through coffee grafting competitions open only to women and workshops[31].

The **Federation for Commercializing Specialty Coffee of Guatemala (FECCEG)** is an NGO constituted by 12 smallholder farmer cooperatives. Its aim is to develop and implement programs related to gender equality, sustainable development, and strengthening institutions. It supports smallholder members through help in administration, diversification, and access to credit. It also improves access to international markets through the Specialty Coffee Exporter Association of Guatemala, which focuses on the export of high quality, coffee with organic and Fairtrade certification.

The **Ministry of Economy (MINECO)** designs the policies for international commerce of agricultural production alongside the Guatemalan Ministry of Agriculture, Livestock, and Food. It is also at the table during discussions on the creation and extension of agricultural policies such as the provision of funds to the Fideicomiso and the *Law for the economic reactivation of coffee* [32].

The **Chamber of Agriculture (CAMAGRO**) was established in 1973 and it currently unites 13 agricultural associations, including ADEC and ANACAFE. Its focus is to coordinate the programs and aims of its members to increase their efficiency and the value-added of the agricultural sector. It also supports policymaking through technical reports on law initiatives[33].

Previously known as the National Commission for the Environment (CONAMA), the **Guatemalan Ministry of Environment and Natural Resources (MARN)** was created to assist and coordinate national policies to protect and improve the environment in Guatemala. Currently, it manages environmental policies and promotes sustainable development [34].

The **Foundation of Coffee for Rural Development (FUNCAFE)** started operating in 1994 to boost human development in rural areas. It is founded on three pillars, food and nutrition security, health, and education.

Policies

In 1969 the Coffee Law was passed (decree 19-69) which was regulated again in 1970 (decree13-70) and regulates coffee production and commercialization and delegates to ANACAFE an advisory position to the Guatemalan government. Decrees were passed in 1972 (37-72 and 74-72) which set tax exemptions for the purchase of farming equipment and fertilizers. In 2013 the Guatemalan coffee Trust Fund was extended until 2026 and it received a futher extension in 2019 until 2051 providing debt restructuring for expired debts and tax credit return for exports[15].

The **Law for the Economic Reactivation of Coffee (Decree 4-2019)** was approved mid-2019. Its directed to smallholder farmers to facilitate access to credit for investment into their coffee plots by financing and prolonging the Fideicomiso and restructure their debts. 6 to 8 years are required for renovating a coffee farm, therefore access to credit is crucial [35].

Although most coffee farmers in Guatemala are reliant on their own savings or lending from intermediaries. Many smallholders do now have land titles they could use as collateral. The **Fideicomiso (Trust)** serves as a basis for lending to small to large coffee farmers individually or organized as legal groups. Micro and smallholder farmers pay interest rates of 2% on the loans, one percentage points lower than medium and large producers. Repayment periods are dependent on the investment plan (semi-permanent diversification 15 years, renovation of coffee 7 years). It currently manages US$ 100m. There are two Trusts: *Fideicomiso Apoyo Financiero para los Productores del Sector Cafetalero Guatemalteco*, and the *Fideicomiso Mejoramiento del Pequeño Caficultor*[22].

Existing initiatives

A joint initiative by ANACAFE and USAID called the **Rural Value Chains project** lead the renovation of over 3000 ha between 2012 and 2017. 129 farmer organizations and around 7000 coffee households benefited and reportedly yields increased over 60% in renovated and replanted plots.

The **Seed Verification Program** was designed and implemented by World Coffee Research (WCR) in 2016 and is expected to continue until 2020. The goal of this program is to provide farmers with better varieties for their plots. WCR helps local nurseries in the selection of plants and planting of improved coffee varieties.

The **Trifinio Plan** is an international effort lead by the Hanns R. Neumann Stiftung and the Mesa de Café Trinacional (MCT) to protect the watershed located in the border between Guatemala, Honduras, and El Salvador. The idea behind this initiative is to "smooth" the transition between natural rainforest and land used for agriculture. Additionally, the plan contributes improved varieties and training for farmers to raise their productivity and incomes without encroaching on the rainforest[36].

Increasingly, agricultural tourism is promoted in coffee farms, for example in the Atitlan Lake Basin. Along coffee tasting in specialty coffee shops, visitors learn how coffee is grown and the ecological services coffee farms provide[15].

Outlook

Raising productivity, adaptation to climate change and extreme climatic events, and mitigation the emissions of GHG at the farm level are positive outcomes for all actors on the value chain. Still, it is mainly poor farmers who carry the majority of the cost and the risk when attempting to implement new practices. Both the public and the private sector should promote a favorable decision environment and access to training and finance to facilitate the adoption of practices that are in the common interest.

Improving the access to markets for inputs and finance is key to increase investment but being able to reap the benefits of their investments through higher prices is just as important. Initiatives targeting farmer groups and cooperatives will have the advantage of reaching a far larger number of coffee growers and enabling the cooperation between these groups will increase their efficiency.

The wide adoption of agroforestry systems is an invaluable stepping stone toward further CSC objectives. For further progress to be made, the trust of farmers in new approaches needs to be gained and their decision environments understood. The ecosystem services provided by coffee farms in Guatemala should be rewarded while acknowledging that they are at risk of being diminished by climate change.

Private sector initiatives must continue to engage in climate smart programs, encourage smallholders to participate and avoid their exclusion. This requires that all value chain actors, not just the producers or processors, share costs and risks.

CASE STUDY:
INTEGRATING CSA PRACTICES

Santos Castillo Gutiérrez has grown up cultivating coffee from an early age, at the age of 12 he was already helping his father Rufino Castillo on their farm. Little by little, he began to learn more about coffee while working as a day laborer and in 1987 at the age of 33, he planted his first coffee seedling.

Today, Santos Castillo has a 7 ha farm in the state of Chiquimula in southeastern Guatemala. Different coffee varieties such as Anacafe 14, Catimor, Catuai and Castillo, grow alongside Congo grass (Bracharia ruziziensis) and under the temporary shade of Pidgeon Pea (Cajanus cajan).

He is already implementing many practices that can be classified as CSC on his plot: contour lines, shade management, organic nutrition, among others. Recently he started incorporating cover crops and better distancing to improve the development of his coffee plants. Unfortunately, Mr. Castillo is only able to sell his harvest to intermediaries in the cities. He tells us that intermediaries will set the prices and this makes adding value to his production difficult .

Aside from low selling prices, pests and diseases like coffee leaf rust (Hemileia vastatrix) and anthracnose (Glomerella Cingulata) are also taking a toll on his production. These are not, however, the only challenges he faces.

Santos Castillo notes that compared to ten years ago "the dry season is longer and more severe, and as a result plants wilt and coffee beans fall prematurely". Extreme climate events are also becoming more intensive: "During 2018 we suffered one of the most severe droughts I can remember". Under these prospects, improved varieties and farming practes are his way of fending off the external risks threatening his farm.

CSC practices are already proving advantageous, the cover crops he planted helped regulate soil temperatures and maintain moisture. Mulching of cover crops then increased the organic matter on his farm. Though seed costs and access are still a problem, he is clear about the effects of this practice "I saw the differences during the drought of 2018, my plantation performed better where I established cover crops".

Presently, he is supported by the Hanns R. Neuman Stiftung and the Trifinio Commission. Extension agents have helped him invest better in his farm and he wishes more would come to teach him new management practices and receive investment guidance. He would also look forward to the development of a farmer organization to teach young people about coffee and spark their interest in growing it. For now, however, Santos Castillo is hoping coffee prices recover so he can continue to invest in coffee.

Mr. Gutiérrez trusts that CSC practices and better prices will improve his families livelihoods and the recommendations he has implemented until now are promising. He declares repeatedly that "Coffee is important to our family. ***We live from coffee! We are not making enough money for our life expenses"***

Literature

1. ANACAFE. Asociación Nacional del Café [Internet]. 2018 [cited 24 Jan 2019]. Available: http://www.anacafe.org/

2. FAO. FAOSTAT [Internet]. 2019 [cited 24 Jan 2019]. Available: http://www.fao.org/faostat/en/#data/QC

3. World Trade Organization. Trade Profile Guatemala [Internet]. 2019 [cited 24 Jan 2019]. Available: http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=GT

4. USDA FAS. Guatemala annual coffee production: no longer business as usual [Internet]. 2017 May. Report No.: 17005. Available: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Coffee%20Annual_Guatemala%20City_Guatemala_5-15-2017.pdf

5. Muñoz CY. Aproximación a la cadena de valor del café de Guatemala. Infome Final. 2010;

6. World Bank. ADN economico de Guatemala. 2014.

7. Haggar J, Medina B, Aguilar RM, Munoz C. Land use change on coffee farms in southern Guatemala and its environmental consequences. Environ Manage. 2013;51: 811–823.

8. Schmitt-Harsh M. Landscape change in Guatemala: Driving forces of forest and coffee agroforest expansion and contraction from 1990 to 2010. Appl Geogr. 2013;40: 40–50. doi:10.1016/j.apgeog.2013.01.007

9. Hempstead W. Green book of Guatemalan Coffees. Guatemala, Guatemala: Guatemalan National Coffee Asociation (ANACAFÉ); 2010.

10. Fischer EF, Victor B. High-end coffee and smallholding growers in Guatemala. Lat Am Res Rev. 2014;49: 155–177.

11. FEWSNET. Informe especial: America Central [Internet]. FEWSNET; 2017 Aug. Available: https://fews.net/sites/default/files/documents/reports/Centroamerica%20-%20Informe%20Especial%20-%20Sector%20Cafetalero%202017.pdf

12. Cool Farm Tool | An online greenhouse gas, water, and biodiversity calculator [Internet]. [cited 12 Apr 2018]. Available: https://coolfarmtool.org/

13. van Rikxoort H, Läderach P, van Hal J. The Potential of Mesoamerican Coffee Production Systems to Mitigate Climate Change1. 2011;

14. USAID. Country data sheets for coffee renovation and rehabilitation [Internet]. Nov 2017 [cited 31 May 2019]. Available: https://www.sustaincoffee.org/assets/resources/20171109_Country_data_sheets_vFinal.pdf

15. Guatemala: Coffee Annual | USDA Foreign Agricultural Service [Internet]. [cited 17 Jul 2019]. Available: https://www.fas.usda.gov/data/guatemala-coffee-annual-4

16. de Leon P. La Importancia del Café en la Economía Guatemalteca y el Estado Actual de su Productividad. 28 Congreso de la Caficultura; 2017; Guatemala.

17. Avelino J, Cristancho M, Georgiou S, Imbach P, Aguilar L, Bornemann G, et al. The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. Food Secur. 2015;7: 303–321.

18. Marin C, Antonio RNG. Gender differences in time use among indigenous adolescents in Boca Costa region, Guatemala. 2018;

19. Jaramillo J, Muchugu E, Vega FE, Davis A, Borgemeister C, Chabi-Olaye A. Some Like It Hot: The Influence and Implications of Climate Change on Coffee Berry Borer (Hypothenemus hampei) and Coffee Production in East Africa. Thrush S, editor. PLoS ONE. 2011;6: e24528. doi:10.1371/journal.pone.0024528

20. World Coffee Research. Arabica Coffee Varieties. In: Variety Catalog [Internet]. 2019 [cited 8 Apr 2019]. Available: https://varieties.worldcoffeeresearch.org

21. Almengor OGC. Manejo Integrado de la Araña Roja del Café. : 7.

22. Guzman Silva VH. Diagnostico de la cadena de café [Internet]. 2016. Available: http://www.marn.gob.gt/Multimedios/9809.pdf

23. Eakin H, Tucker CM, Castellanos E. Market Shocks and Climate Variability: The Coffee Crisis in Mexico, Guatemala, and Honduras. Mt Res Dev. 2005;25: 304–309. doi:10.1659/0276-4741(2005)025[0304:MSACVT]2.0.CO;2

24. ANACAFE. Guía de variedades [Internet]. 2016 [cited 16 Jul 2019]. Available: https://www.anacafe.org/uploads/file/9a4f9434577a433aad6c123d321e25f9/Gu%c3%ada-de-variedades-Anacaf%c3%a9.pdf

25. Rahn E, Läderach P, Baca M, Cressy C, Schroth G, Malin D, et al. Climate change adaptation, mitigation and livelihood benefits in coffee production: where are the synergies? Mitig Adapt Strateg Glob Change. 2014;19: 1119–1137.

26. 2018 State of the Sector | CSAF [Internet]. [cited 27 Sep 2018]. Available: https://www.csaf.net/state-of-the-sector/

27. Ministerio de Agricultura Ganadería y Alimentación. obj-estra17.pdf. In: Objetivos estratégicos, operativos y acciones [Internet]. [cited 15 Jul 2019]. Available: https://www.maga.gob.gt/wp-content/uploads/2018/11/obj-estra17.pdf

28. ¿Quiénes Somos? – Fedecocagua : : Bienvenidos [Internet]. [cited 17 Jul 2019]. Available: http://www.fedecocagua.com.gt/quienes-somos/

29. Cedicafé [Internet]. [cited 4 Jul 2019]. Available: http://demo.anacafe.org/Servicios/Cedicafe/

30. About Us – Welcome to ADEC [Internet]. [cited 5 Jul 2019]. Available: http://adecgt.com/index.php/about-us/

31. Mujeres Café Guatemala - Asociación - Todos Los Rubros En Café. In: Mujeres Café Guatemala [Internet]. [cited 5 Jul 2019]. Available: https://mujerescafeguatemala.org/

32. Dan dictamen favorable a iniciativa de reactivación económica de la caficultura | MINECO [Internet]. [cited 15 Jul 2019]. Available: https://www.mineco.gob.gt/dan-dictamen-favorable-iniciativa-de-reactivaci%C3%B3n-econ%C3%B3mica-de-la-caficultura

33. Misión – Cámara del Agro Guatemala [Internet]. [cited 15 Jul 2019]. Available: https://www.camaradelagro.org/acerca/mision/

34. Misión y Visión :: Ministerio de Ambiente y Recursos Naturales :: [Internet]. [cited 15 Jul 2019]. Available: http://www.marn.gob.gt/paginas/Misin_y_Visin

35. Decreto 4-2019 -Ley para la Reactivación Económica del Café [Internet]. [cited 5 Jul 2019]. Available: http://demo.anacafe.org/articles/decreto-4-2019-ley-para-la-reactivacion-economica-del-cafe/

36. Central America. In: Hanns R. Neumann Stiftung [Internet]. [cited 16 Jul 2019]. Available: https://www.hrnstiftung.org/central-america/

37. Impacto ASS Agência, Cafeicultura R. Sarchimor IAC 125 RN (IBC 12 o café Uva), resistente a roya y nematódos. In: Revista Cafeicultura [Internet]. [cited 11 Jul 2019]. Available: https://revistacafeicultura.com.br/?mat=61483

Acknowledgments

The Feed the Future Alliance for Resilient Coffee is a consortium of non-governmental organizations and research institutions working at the intersection of climate change and coffee production. Our vision is to improve the livelihoods and resiliency of coffee farmers and promote better environmental stewardship by having the private sector fully support and allocate resources to the implementation of climate-smart agriculture in coffee landscapes globally.

This publication is a joint product of the International Center for Tropical Agriculture (CIAT), the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and Hanns R. Neumann Stiftung. The International Center for Tropical Agriculture (CIAT) – a CGIAR Research Center – develops technologies, innovative methods, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. Eco-efficient agriculture reduces hunger and poverty, improves human nutrition, and offers solutions to environmental degradation and climate change in the tropics. Headquartered near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia. **www.ciat.cgiar.org**

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Original graphics, design and layout: Gutiérrez N (CIAT)

The impact gradient icon is an adaptation of “Setting” by Juan Pablo Bravo, The Noun Project.

Spanish version of this document: https://hdl.handle.net/10568/103989

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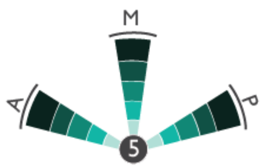
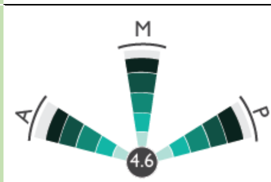
This document should be cited as:

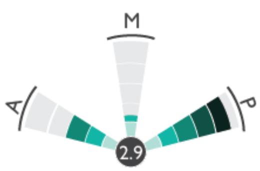
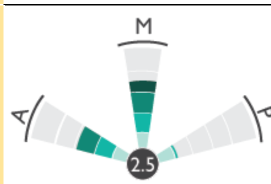
Bunn, C., Lundy, M., Läderach, P., Castro-Llanos, F., Fernandez-Kolb, P., Rigsby, D. 2019. Climate Smart Coffee in Guatemala. International Center for Tropical Agriculture (CIAT), Cali, CO. 28 p.
Permanent link to cite or share this item: https://hdl.handle.net/10568/103771

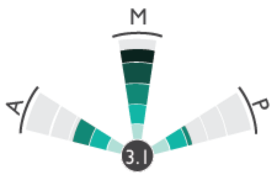
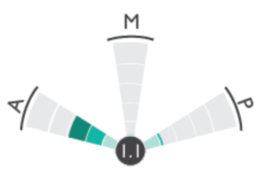
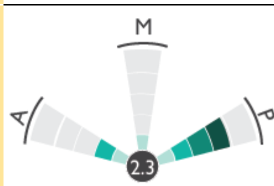
This study is made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the Feed the Future initiative. The contents are responsibility of CIAT and do not necessarily reflect the views of USAID or the United States Government.

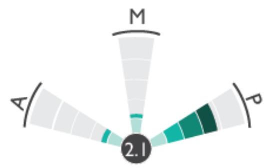
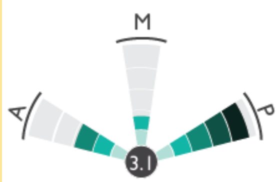
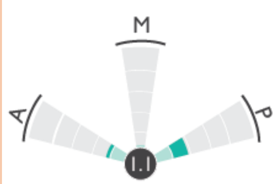
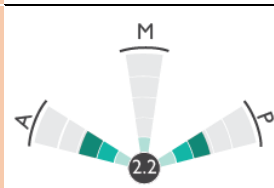
Annex

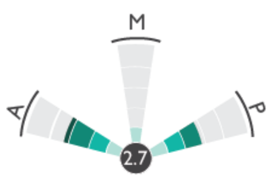
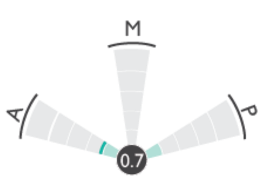
CLIMATE SMART COFFEE PRACTICES FOR GUATEMALA

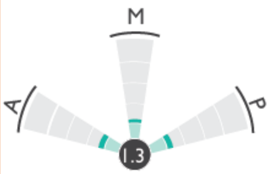
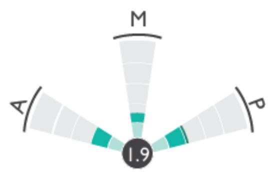
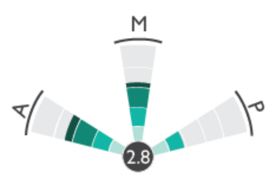
CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)
Permanent shade *Planting and pruning of permanents shade trees* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Buffers intensive rainfall damage -Sustains yields in the face of extreme events -Protects against strong winds -Improves soil structure -Extends the life-cycle of the crop -Reduces soil erosion and/or runoff -Improves soil fertility -Higher drought tolerance -Reduces the incidence of pests and diseases	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces need for fossil fuels -Reduces deforestation and loss of wetlands -Reduces GHG emissions through less or no burning -Carbon stocks of biomass increase -Carbon stocks of soil increase	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases -Improves quality
Temporary shade *Planting of productive shade trees during nursery and establishment* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Buffers intensive rainfall damage -Sustains yields in the face of extreme events -Protects against strong winds -Improves soil structure	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces need for fossil fuels -Reduces deforestation and loss of wetlands -Reduces GHG emissions through less or no burning -Carbon stocks of biomass increase	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases -Improves quality

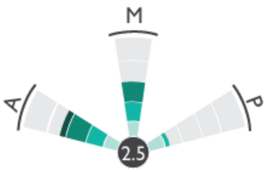
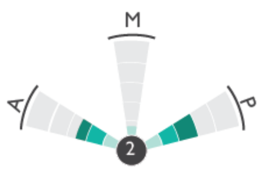
		-Extends the life-cycle of the crop -Reduces soil erosion and/or runoff -Improves soil fertility -Higher drought tolerance -Reduces the incidence of pests and diseases	-Carbon stocks of soil increase	
Grafting *Grafting arabica coffee on robusta stock to obtain the quality of arabica and the resilience of robusta* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Sustains yields in the face of extreme events -Extends the life-cycle of the crop -Higher drought tolerance -Reduces the incidence of pests and diseases	-Slightly lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Carbon stocks of soil increase slightly	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases -Reduces post-harvest losses
Native cover crops *Cover crops help reduce soil erosion, evapotranspiration, and increase the nutrient content of the soil*	 High knowledge intensity	-Buffers extreme temperatures -Buffers intensive rainfall damage -Protects against strong winds -Improves soil structure -Reduces soil erosion and/or runoff -Improves soil fertility -Higher drought tolerance	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces deforestation and loss of wetlands -Reduces GHG emissions through less or no burning -Carbon stocks of biomass increase -Carbon stocks of soil increase	-Improves crop growth

Organic barriers *Biological/organic barriers are a useful alternative to artificial barriers. They protect coffee farms from extreme winds, flooding, and other climatic events* *Read more*	 High cost High knowledge intensity	-Buffers intensive rainfall damage -Sustains yields in the face of extreme events -Protects against strong winds -Reduces soil erosion and/or runoff	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces need for fossil fuels -Reduces deforestation and loss of wetlands -Reduces GHG emissions through less or no burning -Carbon stocks of biomass increase -Carbon stocks of soil increase	-Improves crop growth
Trenches (Acequias) *Trenches on the plot serve to accumulate rainfall and increase soil water infiltration. The also reduce soil erosion.* *Read more*	 High cost	-Increases water infiltration and water retention -Buffers intensive rainfall damage -Prevents flooding -Reduces soil erosion and/or runoff	No impact	-Improves crop growth slightly
Planting Sarchimor variety *Establishment or replanting with Sarchimor coffee reduces coffee rust and nematode damage*[37]		-Sustains yields in the face of extreme events -Higher drought tolerance -Reduces the incidence of pests and diseases	-Slightly lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Carbon stocks of biomass increase slightly	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases

Planting Catimor variety *Establishment or replanting with Catimor can help reduce the impact of coffee rust*		-Reduces the incidence of pests and diseases	-Carbon stocks of biomass increase slightly	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases -Reduces post-harvest losses
Planting climate-tolerant varieties *Establishment or replanting with coffee varieties that are drought and heat-tolerant* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Sustains yields in the face of extreme events -Extends the life-cycle of the crop -Higher drought tolerance -Reduces the incidence of pests and diseases	-Carbon stocks of biomass increase	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces losses due to pests and diseases -Reduces post-harvest losses
Water harvesting *Conservation and collection of water from rainfall, reservoirs, wells, etc.* *Read more*	 High cost	-Sustains yields in the face of extreme events -Reduces soil erosion and/or runoff	No impact	-Improves crop growth slightly -Reduces post-harvest losses slightly
Improved planting *Coffee planted in deeper bags and deeper holes* *Read more*	 High cost	-Buffers extreme temperatures -Increases water infiltration and water retention -Buffers intensive rainfall damage -Sustains yields in the face of extreme events	-Slightly lower emissions of GHG because of the reduced use of fertilizers and/or pesticides	-Improves crop growth

		-Protects against strong winds -Extends the life-cycle of the crop -Improves soil fertility -Higher drought tolerance -Reduces the incidence of pests and diseases		
Drip irrigation *Water management and irrigation systems to reduce the negative impact of droughts and dry periods* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Sustains yields in the face of extreme events -Protects against strong winds -Improves soil structure -Extends the life-cycle of the crop -Improves soil fertility -Higher drought tolerance -Reduces the incidence of pests and diseases	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces deforestation and loss of wetlands	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses -Reduces post-harvest losses
Water retention polymers *Polymers (synthetic plastic compounds) and biopolymers (plant fibers) improve soil properties and reduce water evaporation*	 High cost High knowledge intensity	-Increases water infiltration and water retention -Higher drought tolerance	No impact	-Slightly improves crop growth

Mycorrhiza and/or Trichoderma *Application of mycorrhiza and/or Trichoderma to coffee nurseries and seedbeds* *More on Mycorrhiza* *More on Trichoderma*		-Extends the life-cycle of the crop -Improves soil fertility -Higher drought tolerance	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Carbon stocks of biomass increase	-Improves crop growth -Reduces losses due to pests and diseases
Biochar *Application of biochar improves soil conditions and resource use efficiency* *Read more*		-Increases water infiltration and water retention -Improves soil structure -Extends the life-cycle of the crop -Improves soil fertility -Higher drought tolerance	-Carbon stocks of soil increase	-Improves crop growth
Leguminous cover crops *Leguminous species fixate nitrogen in the soil and can be used for mulching* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Buffers intensive rainfall damage -Sustains yields in the face of extreme events -Protects against strong winds -Improves soil structure -Reduces soil erosion and/or runoff -Improves soil fertility -Higher drought tolerance	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces deforestation and loss of wetlands -Reduces GHG emissions through less or no burning -Carbon stocks of biomass increase -Carbon stocks of soil increase	-Improves crop growth -Increases carrying capacity-Reduction of post-harvest losses

Graminillas cover crops *Non-leguminous crops have vigorous root systems which help to penetrate compacted soils, increase rainwater infiltration and increase soil organic matter* *Read more*	 High cost High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Buffers intensive rainfall damage -Protects against strong winds -Improves soil structure -Reduces soil erosion and/or runoff -Higher drought tolerance	-Lower emissions of GHG because of the reduced use of fertilizers and/or pesticides -Reduces GHG emissions through less or no burning -Carbon stocks of soil increase	-Improves crop growth -Increases carrying capacity-Reduction of post-harvest losses
Gypsum Application to soil *With certain types of soil, application of large quantities of gypsum (calcium sulfate) to the soil causes coffee roots to row deeper, enabling them to access more moisture during dry seasons and prolonged periods of drought.* *Read more*	 High knowledge intensity	-Buffers extreme temperatures -Increases water infiltration and water retention -Improves soil structure -Extends the life-cycle of the crop -Improves soil fertility -Higher drought tolerance	No impact	-Improves crop growth -Improves flowering -Increases carrying capacity-Reduction of post-harvest losses

Smartness score

Transformation

Systemic adaptation

Incremental adaptation