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

CLIMATE-SMART COFFEE IN EL SALVADOR

Summary

Coffee is a staple of Central American exports and agricultural production, not least in El Salvador. Coffee is the second-highest export in terms of value at around US$ 113.4 million in annual foreign currency earnings. The coffee sector directly generates over 40,000 jobs in rural El Salvador.

El Salvador exclusively produces high-quality Arabica coffee, cultivated mostly at an altitude ranging between 600 to 900 masl (51%). These features set the future of coffee farming in El Salvador on an increasingly narrow and uneven path. In contrast to Robusta, the Arabica variety is highly vulnerable to climate change, especially at the low altitude at which it is mainly grown in El Salvador. To aggravate this situation, studies show that Mesoamerica, and El Salvador in particular, is the region projected to endure the most severe impacts of increasing temperatures on Arabica production.

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, Salvadorian 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.

Quality and productivity are especially vulnerable to changes in temperatures and precipitation. Coffee areas in El Salvador have become drier and hotter over the past three decades. Annual temperatures have risen across the country by about 0.8°C and during the driest months precipitation was reduced by a third.

Temperatures are projected to further increase by 1.9°C and annual total precipitation is projected to decrease by 180mm under an intermediate impacts scenario. In this sense, our aim is to support efficient adaptation through a coffee specific evaluation of projected climate change impacts. The significant and increasing importance of high-quality coffee in exports reflects the importance of suitable growing conditions.

Drastic changes in climatic suitability for coffee are projected at low and medium altitudes; some areas at high altitudes will retain the climatic characteristics that make them suitable for growing coffee. The departments of Sonsonate and La Libertad will become increasingly suitable while those of La Paz and La Unión, as well as the south and east, will become less suitable. A large share of current coffee farming will be challenged by progressively decreasing suitability. Prospective shifts to Robusta production seem to be of rising interest to stakeholders, though climate projections suggest that this may not a suitable solution for the future.

Adaptation strategies will differ depending on the projected degree of climate change impact. Planting disease-resistant varieties and increasing shade cover are among the climate smart coffee practices recommended at all levels. Early adaptive action at scale with forward-looking approaches will be key in palliating the negative impacts of climate change on coffee production in El Salvador.

Careful consideration of the resources and environment in which smallholder in El Salvador 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.

Since many climate smart coffee practices have long lead-times and coffee farming is a long-term proposition, immediate action should be taken. The overarching goal is to improve the livelihoods and productivity of smallholders, ensure adaptation to climate change, and mitigate the emission of greenhouse gasses. 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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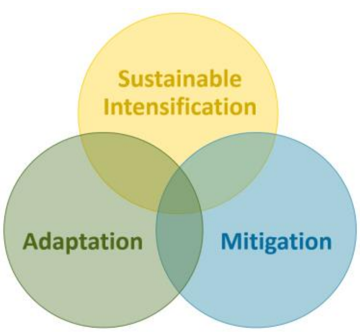
Climate smart coffee

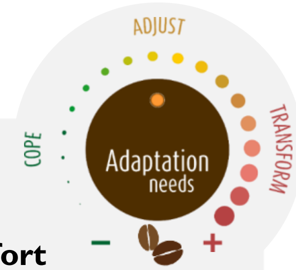
Climate smart coffee production sustainably increases productivity, enhances resilience to climate risk, and reduces or removes greenhouse gas emissions (GHGs). While the concept is new and still evolving, many of the interventions that make up climate smart coffee already exist worldwide and are used 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 climate smart coffee 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 the 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 climate smart coffee. This enabling environment includes policies, institutional arrangements, stakeholder involvement, 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 El Salvador and the potential pathways to mainstream climate smart interventions in the country.



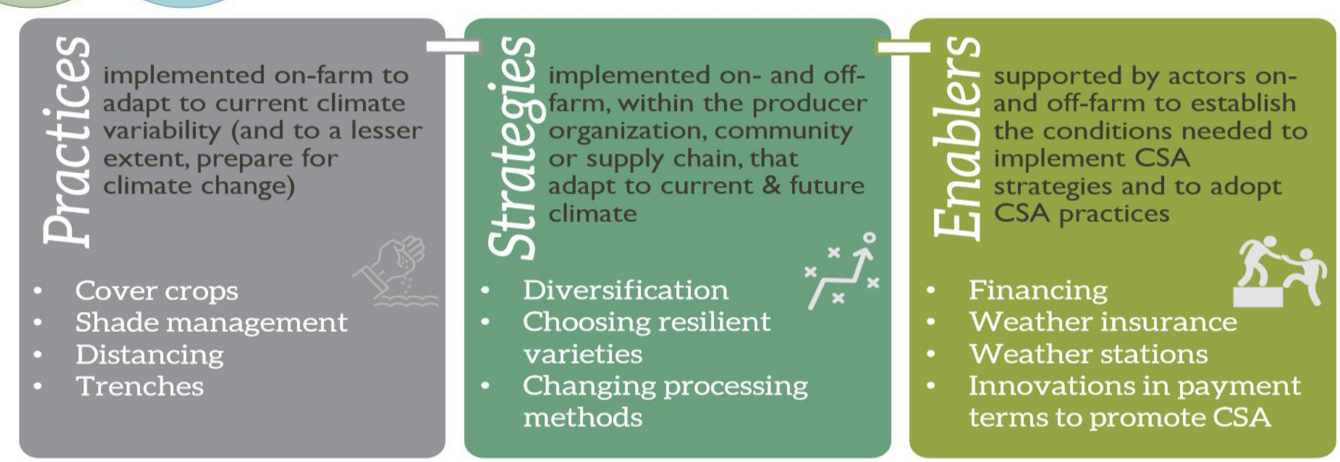


Three degrees of adaptation **effort**

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

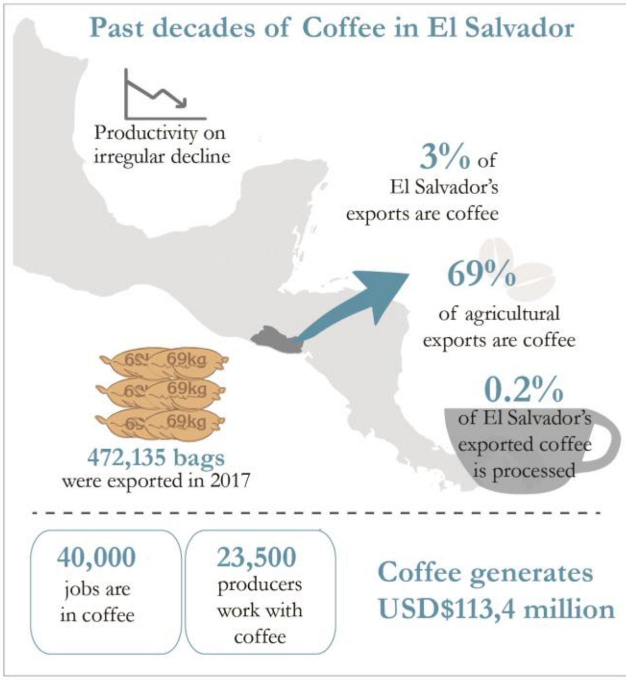
Systemic adaptation where the climate is most likely to remain suitable, but with substantial stress. Adaptation will be achieved through a comprehensive change of practices, but also requires a change of strategy and adequate enablers

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



National context

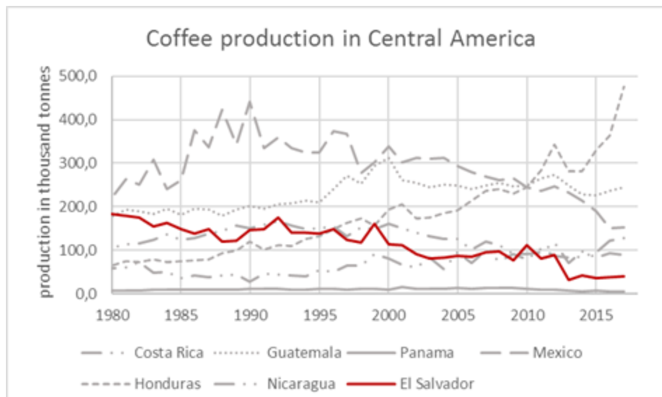
Economic relevance of coffee



Coffee production in El Salvador has been on an irregular decline in the past decades mainly as a consequence of price swings and the spread of pests and diseases. In 1990 the share of coffee production as a percentage of GDP and agricultural GDP was 4.5% and 26.5% respectively. By 2016 these numbers had dropped to 0.56% and 4.7%. Productivity sometimes varies wildly from year to year, according to the FAO data there was an increase in total yields of 47.1% between 2009 and 2010 and a decrease of 63.3% between 2012 and 2013. Moreover, during 11 out of the past 19 years, the change in tonnes produced over the previous year has been above 10%. The area harvested, on the other hand, has remained relatively stagnant and decreased slightly each year (-0.8%) [1].

Coffee constitutes 3% of total exports, but approximately 69% of agricultural exports, however, only 0.2% is exported as processed coffee. 472.135 bags of 69Kg were exported in 2017, half of them to the United States, and substantial amounts to Germany and Japan [2]. Coffee generates US$ 113,4 million in foreign currency and it is associated with the direct creation of 45000 jobs, 23500 of which are producers [3,4].

Falling coffee prices reduce the incentives for farmers to invest and manage their farm properly. Lack of investment leads to plant stress due to unsuitable climatic conditions and greater vulnerability to pests and diseases. Around the 2010s, a series of hurricanes created amenable conditions for the rapid and devastating spread of coffee rust, known locally as "Roya". Between 2012 and 2014 coffee rust affected 20 to 50% of production or 70% of the coffee area [5] especially at low and mid-level altitudes. As prices fall, management deteriorates and losses in productivity increase the cost per bag of coffee further diminishing the marginal benefits of producers. In addition to prices, the investment attitudes of farmers are influenced by the cost of inputs, public policy and government programs, security, and labor availability, none of which have been able to steer back production to pre-2012 levels.



At present, many farmers consider that producing more coffee leads to more economic losses. Production at current prices is not profitable. For many, growing coffee is an endeavor rooted in tradition and not a way to make profits. While small batches of coffee can be sold at high prices, finding the right buyer can be a difficult task, particularly for remote or poor farmers. Buyers of coffee in volume may overlook El Salvador as other countries, such as Honduras or Nicaragua, produce larger quantities. Crucially for farmers facing economic losses from growing and selling coffee, they have some diversification of production with other crops which lend them food security and income.

Climate change is projected to induce further economic losses to the production of coffee. Carrying into the future business-as-usual farm management practices is estimated to lead to a total loss of 22,093,083 USD in transformation zones [6] (see *Coffee and climate change* section).

Impact zone	% of production	Value USD
Incremental	11%	11,786,484
Systemic	69%	77,212,029
Transformation	20%	22,093,083

Coffee and land use

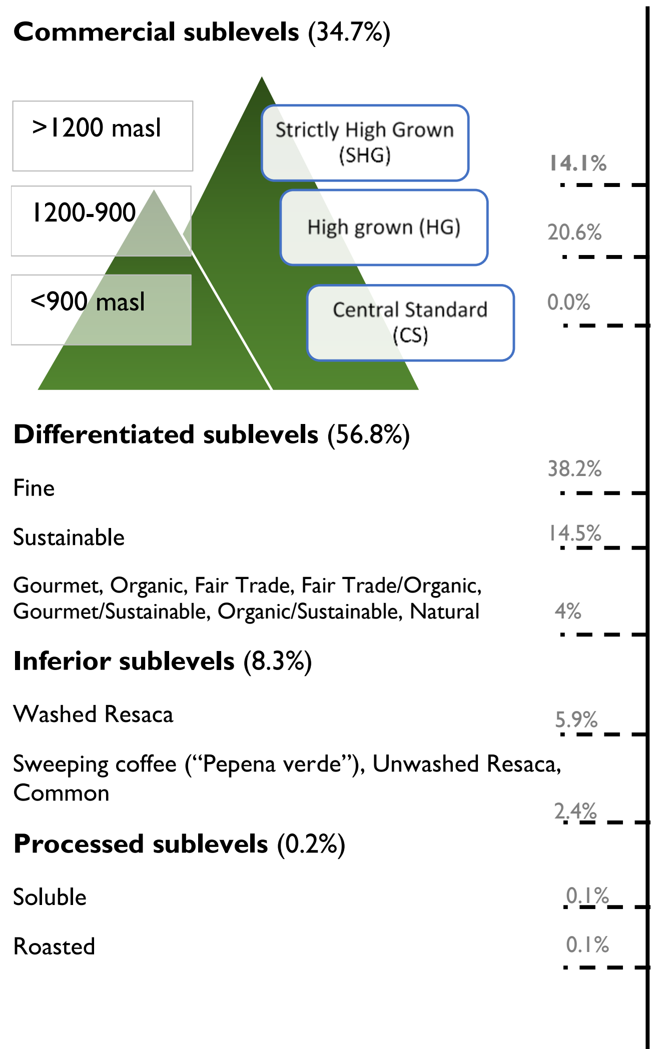
Deforestation is forbidden by law, yet the equivalent of 4500 hectares of forest is lost each year -an annual rate of 1.4%. Since 2000, 7.2% of tree cover of El Salvador has been lost and only 5000 ha of primary forest are left in the country [7]. Shifting agriculture is the principal cause for this loss. Coffee farmers historically tended to replace forest species with plants of the Inga genus which are favorable to coffee. Nowadays, the decrease in coffee farms is also having a negative impact on forestation and water retention[3]. Some authors have described coffee farming in El Salvador as a "bulwark" against deforestation [7]. During the period of falling prices in the 90s, many farmers sought to earn more income by converting their shaded coffee farms to unshaded row agriculture production of corn, for example, or for livestock.

Making shaded coffee farms sustainable is a key element of maintaining forest cover, especially since El Salvador is the only country in Central America without a Sustainable Forest Management Plan at any level of government. The relatively recent inclusion of the Ministry for the environment in the board of the Salvadorian Coffee Council may prove to be a promising step in the right direction.

Although coffee may be grown alongside banana ("guineos") for temporary shade, and other fruit trees and timber species for permanent shade, these species are not as common on coffee farms as they should be. Farmers will cite security and theft as the reason for the lack of fruit species in their farms, and too much bureaucracy as the reason for choosing not to plant timber species. Felling shade trees or coffee plants on coffee farms is exempt from the provisions of the Forestry Law (Ley Forestal), however, authorization by the landowner or person in charge of the management of the farm is required. In addition to the authorization, the law mandates that a document must be held describing the quantity, species, weight, volume, origin, destination and "other data the forestry authorities consider necessary or convenient". The relevant authority in rural areas is the Ministry of Agriculture and Livestock (MAG), in urban areas it is the municipal government, and in protected natural areas and mangroves it is the Ministry of the Environment and Natural Resources (MARN). Felling, cutting, or pruning shade trees is exempt from forestry laws as long as the aim is to preserve the coffee farm and the tree species are not listed as endangered or historic.

Coffee production segments

The Salvadorian Coffee Council segments exports on four levels and 18 sublevels. The main levels are Commercial (34.7% of the total export volume) and Differentiated (56.8%). Processed coffee has a very low share of total exports (0.2%) but makes up all imports. In terms of volume, more soluble coffee is imported than is produced in the commercial sublevels. While a relatively large share of production is classified as fine



or sustainable, Fair Trade and organic certification are quite limited. The price differential between certified and uncertified is not fixed, making it difficult for farmers to evaluate whether it would be beneficial for them.

To differentiate production further, the Salvadorian Coffee Council promotes the distinction between natural, honey, washed, and semi-washed fermentation processes. To promote denomination of origin projects, for each of the six mountain ranges -Alotepec Metapán, El Bálsamo Quezaltepec, Apaneca Ilamatepec, Chichontepec, Tecapa chinameca, and Cacahuatique- a Mountain Range Cup Profile was evaluated according to five parameters: fragrance, aftertaste, body, flavor, and acidity.

Productivity and poverty indicators

According to the Salvadorian Coffee Council, 14% of area farmed with coffee is managed by 75% of farmers who own less than 3.5ha [2]. Most coffee farms are in the departments of Santa Ana, La Libertad, and Ahuachapán. However, the distribution of land between smallholder and owners of large estates is not fully homogenous. Coffee farms in Chichontepec and Alotepec-Metapan are held mostly by smallholders, while farmers in Bálsamo-Quezaltepeque have larger farms.

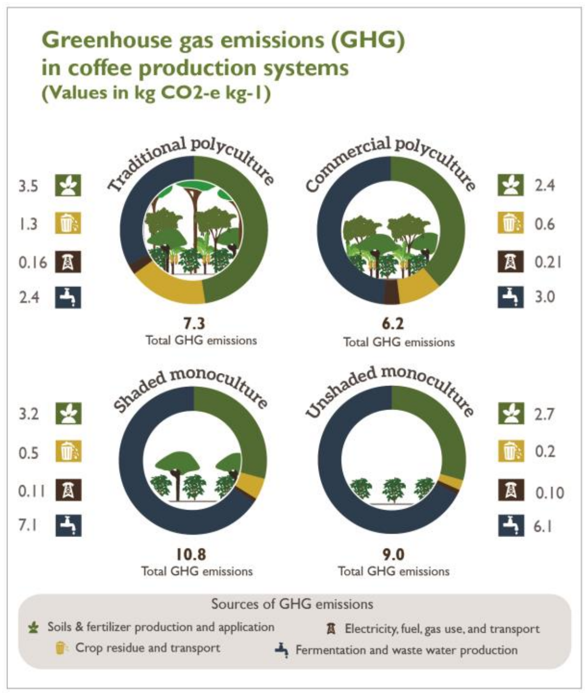
The productivity of smallholder plots ranges from 300 to 420 kg per hectare while the yields of large coffee plantations range from 480 to 720 kg/ha. Smallholder farms have 3000 plants on average per hectare. The difference in productivity can be partially attributed to larger plots having 500 to 1000 more plants per hectare and being slightly better managed [2]. 20% of coffee is produced by 86% of smallholders with plots smaller than 7ha. 40% of production comes from owners of large estates (>70ha), including companies, who grow 28% of total production [8].

From a historical perspective, productivity was very high at the end of the 90s, but it fell substantially with the crash in coffee prices at the end of the decade and the trend continued through the turn of the millennium. With slowly increasing prices, productivity picked up again until a severe outbreak of coffee leaf rust hit Central America in 2012. An estimated 60% of plants were affected by the fungus. Production in El Salvador was one of the worst-hit due to the susceptibility of its varieties and the old age of its plantations [3].

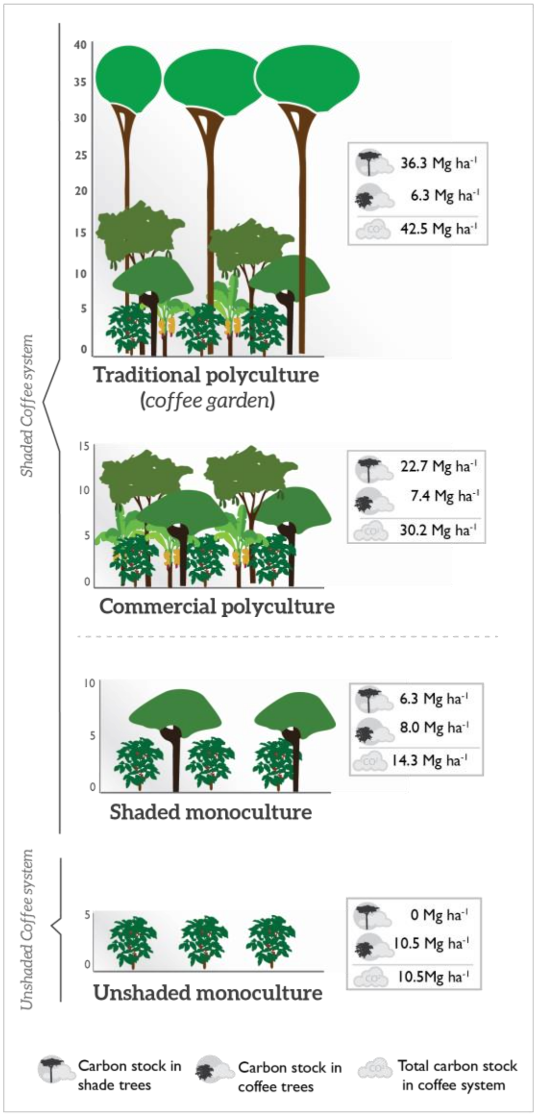
In terms of poverty, at the national level, the share of the population living on less than 5.50 USD a day is 29%, a percentage similar to Vietnam or Colombia and significantly lower than neighboring Central American countries. This indicator has been decreasing since 2008, briefly plateauing in 2010 and 2013 [9]. Poverty indicators are higher for rural than urban areas.

Coffee greenhouse gas emissions

Coffee production is vulnerable to progressive climate change, but at the same time contributes to it through on-farm emissions of greenhouse gasses. Deforestation and the use of chemical fertilizers and pesticides contribute, among other factors, to these emissions. Emissions can be assessed using tools such as the Cool Farm Tool [10]. Still, coffee farms in El Salvador are considered crucial for the conservation of tropical forests and the preservation of aquifers. They also contribute to the conservation of biodiversity and other ecosystem services.



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[11].



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.

Perhaps the largest challenge relating GHG emissions and coffee production is the transformation of coffee farms to unshaded row agriculture and their abandonment due to unsustainable losses from low prices and plants affected by pests and diseases.

Ideally, coffee plants would be renovated if they are old or ridden with diseases and grown under polyculture. While traditional Inga species are beneficial for the coffee plant, diversified systems with multiple strata and tree species store the most carbon, yield high-quality coffee, and increase and stabilize incomes. Deciduous trees and perennial trees should be combined, the first will increase soil organic matter through leaf fall and the second ensure sufficient shade. To incentivize the adoption of multistrata agroforestry systems, security fears need to be addressed and enabling environments created (e.g. distribution of plants and/or seeds, adequate extension services, market links to sell timber and fruit production, etc.)

Challenges for coffee production

Low international coffee prices are the primary concern of stakeholders in El Salvador. High prices are a key incentive for farmers to invest their time and money into the coffee farm. The view of the stakeholders is reflected historically between 1997 and 2003: as coffee prices gradually fell by 65%, productivity decreased 30% and total production dropped 35% [1]. As low prices are coupled with a greater incidence of pests and diseases and plant stress due to climate change, the challenges of coffee production become ever more difficult to overcome.

The coffee production area of El Salvador is located within the Central American Dry Corridor. These regions cover most of El Salvador and Honduras, as well as parts of Guatemala, Nicaragua, Costa Rica, and Mexico. This region is characterized by the frequent occurrence of droughts, excessive rainfall, and flooding [12]. The incorporation of irrigation systems in coffee farms is uncommon. In 2016 a severe drought brought about crop losses between 50 and 90% (20% for coffee in El Salvador), which in turn led to 190000 food-insecure people and 192000 needing humanitarian assistance in El Salvador. The 2016 drought generated US$ 29 million in agricultural investment losses[12]. Moreover, the climate in the Trifinio region located in El Salvador, Guatemala, and Honduras, is particularly unstable for farming this crop [15].

Coffee farms are generally located on steep terrain, making coffee forests crucial to reduce the high susceptibility to erosion. Forested coffee farms are also contributors to aquifers[3]. Most production systems are diversified agroforests. Productive trees planted alongside coffee protect farmers against falling prices or yields which would threaten their food security. Smallholder coffee farmers across Central America suffered the consequences of the coffee crisis caused by falling prices in the years preceding and after 2000, many abandoned their farms and migrated to the cities.

The coffee sector is in dire need of renovation and replanting with resistant varieties. During the period the coffee leaf rust crisis materialized (2012/13), production fell 70%, sharply accelerating the trend in decreasing production. Coffee related employment fell from 85000 in the 2012/13 season to 35000 in the 2013/14 season. Unlike other Central American producers, such as Honduras, Nicaragua, and Guatemala, Salvadorian production has not yet fully recovered.

Soil composition poses an additional challenge. Inadequate nitrogen management, high aluminum content, and leaching and extraction of nutrients has led to soil acidification. High acidity negatively affects plant development (less growth and inadequate absorption of nutrients) and favors the apparition of diseases (e.g. "Rosilinea") [13]. Soils are often also lacking in organic matter content. To manage soils, producers often are limited to the application of lime to reduce soil acidity and recover some of their productivity.

Climate change is a driver of changing pest and disease dynamics. Coffee leaf rust which is now widespread initially only affected farms at low altitudes, for example. The main pests and diseases affecting coffee plants in El Salvador are the aforementioned coffee leaf rust ("Roya de café" – Hemileia vastatrix), anthracnose ("Antracnosis" - Colletotrichum coffeanum), and the coffee berry borer ("Broca del café" - Hypothenemus hampei). Other pests and diseases worth mentioning are the "piojo blanco", "araña roja", "gallina negra", "chancuate", and "langosta". Stakeholders mentioned that pests were previously found at the same developmental stage (larva, worm, or butterfly, for example) whereas now they are harder to combat because at any given time individuals are at different stages of development.

Anthracnose is a fungal disease that thrives under low temperatures and very humid conditions. Inadequate shade and excessive soil moisture also favor its capacity to damage the crops and, ultimately, the quantity and quality of yields.

Pests can also negatively impact production in a significant way. Chief among these is the coffee berry borer which is a costly plight for farmers since it requires mostly manual management. The coffee berry borer causes the most damage at the beginning of the wet season and spreads more rapidly under higher temperatures. Coffee at high altitudes is being gradually more affected by this pest.

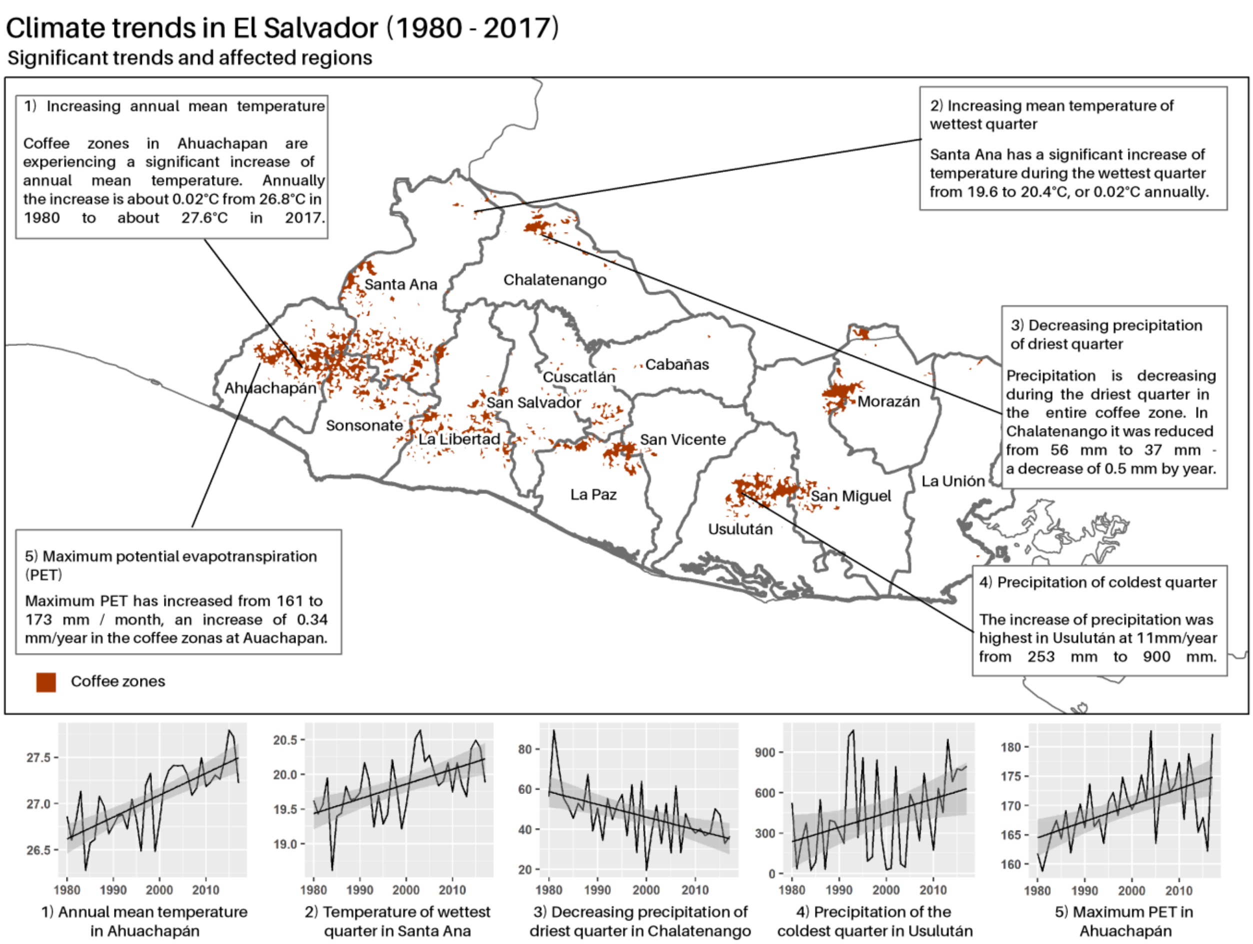
Finally, there is inequality the ownership of coffee farms. 60% of coffee farm owners are men, 35% are women and 5% are companies or groups. As farm size increases these shares gradually shift in favor of companies; more than 50% of owners of farms of more than 70 ha are companies, men and women only hold 27 and 19% of these large farms respectively [8]. Access to markets and agricultural services is skewed in favor of large farms. Some smallholder farmers, on the other hand, are insufficiently linked to or have erratic links with the market. Moreover, the average age of farmers is increasing as their offspring are tending toward more lucrative crops or off-farm employment.

Coffee and climate change

Technicians, as well as producers, are aware of the fact that the low productivity of coffee farms in El Salvador is a consequence of pests and diseases, inadequate soil management, but also climate change. Perceptions of climate change include an increase in average temperatures and the temperature range, increasingly irregular/erratic rainfall as well as a greater occurrence of extreme climatic events including storms, droughts, and floods both in terms of frequency and strength. In addition to changing the suitability for growing Arabica coffee, a changing climate also drives changes in pest and disease dynamics which poses a further challenge for production. The recent coffee leaf rust crisis in Central America which, it is argued, spread more easily due to amenable weather conditions is a prominent example of changing pest and disease dynamics. 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 occurrences in El Salvador are primarily located along the Southern volcano chain but can also be found along the Sierra Madre mountain range towards the border with Honduras. These areas in El Salvador 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 El Salvador. 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.



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 but not least, not all local trends are caused by global warming, but may be the result of deforestation, urbanization or similar localized developments.

How was the trend analysis done?

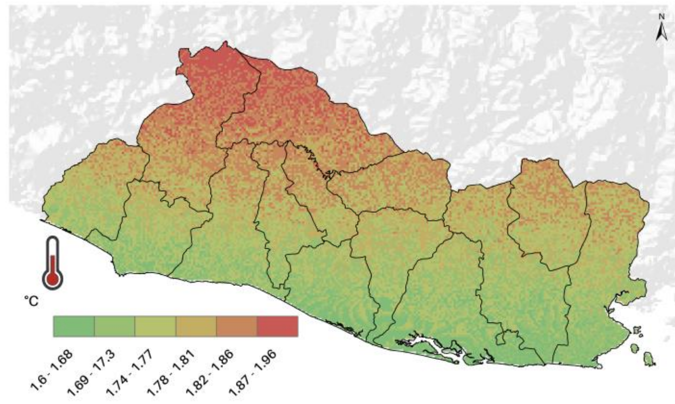
We first calculated bioclimatic indicator variables for the years 1980-2016 and then used the Theil-Sen estimator to fit a trend to the data. This method fits a line by choosing the median of the slopes of all lines through pairs of points. The Theil-Sen estimator is more accurate than least squares 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 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 El Salvador 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?

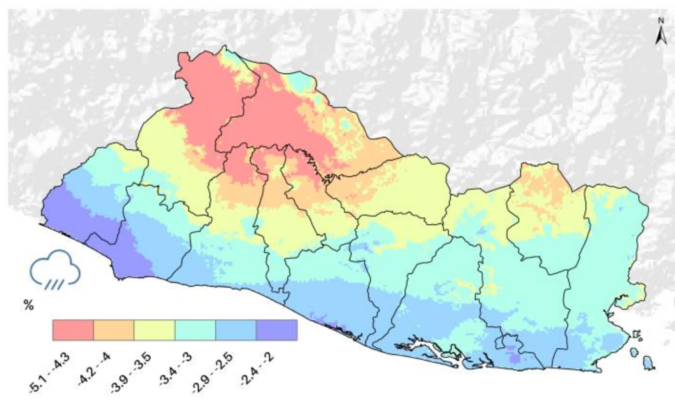
Evapotranspiration is the combined process of evaporation from the Earth's surface and transpiration from vegetation. Potential evapotranspiration (PET) is the amount that would occur if sufficient water were available. It is estimated using average, minimum and maximum air temperature and solar radiation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

Projected climatic changes

At present, El Salvador has, perhaps, the largest share of area suitable for growing coffee -in terms of agroecological zones- of any Central American country. These zones are primarily hot and dry with the exception of the Alotepec Metapán mountain range which is colder and more humid. Global climate models project sizeable reductions the share of suitable areas in the future. The location of suitable agroecological zones will likely be confined more strictly to the six main mountain ranges. Temperatures are projected to increase by 1.9°C and precipitation is projected to decrease by 180mm under an intermediate impacts scenario.

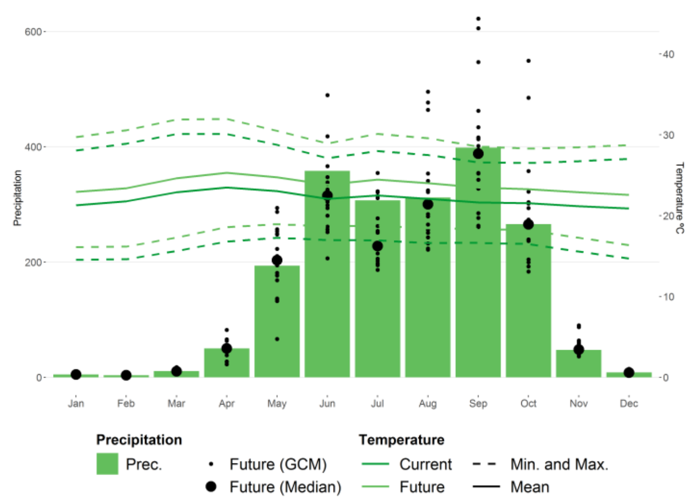


Central America has been repeatedly hit by droughts in the past, most notably in the late 90s and turn of the century [14]. Coffee yields are very sensitive to these events which are projected to become more frequent and intensive in the coming decades as climate change progresses. Additional extreme 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 [14].



Gradient of climate change impacts

To support effective adaptation, we have developed maps displaying the gradients of climate change impacts for coffee production in El Salvador. This gradient is coffee specific and can be used to evaluate the projections of climate change indicated previously. Historical climate conditions will determine whether otherwise identical climatic changes with have severe or irrelevant impacts on production. To provide a brief example, a reduction in precipitation by 50mm could be critical for coffee farms located in areas with low water availability, however, it would be irrelevant in those areas where rainfalls are common throughout the year. Each color of the map represents a different degree of impact and adaptation effort that is deemed likely necessary for farms located in that area.



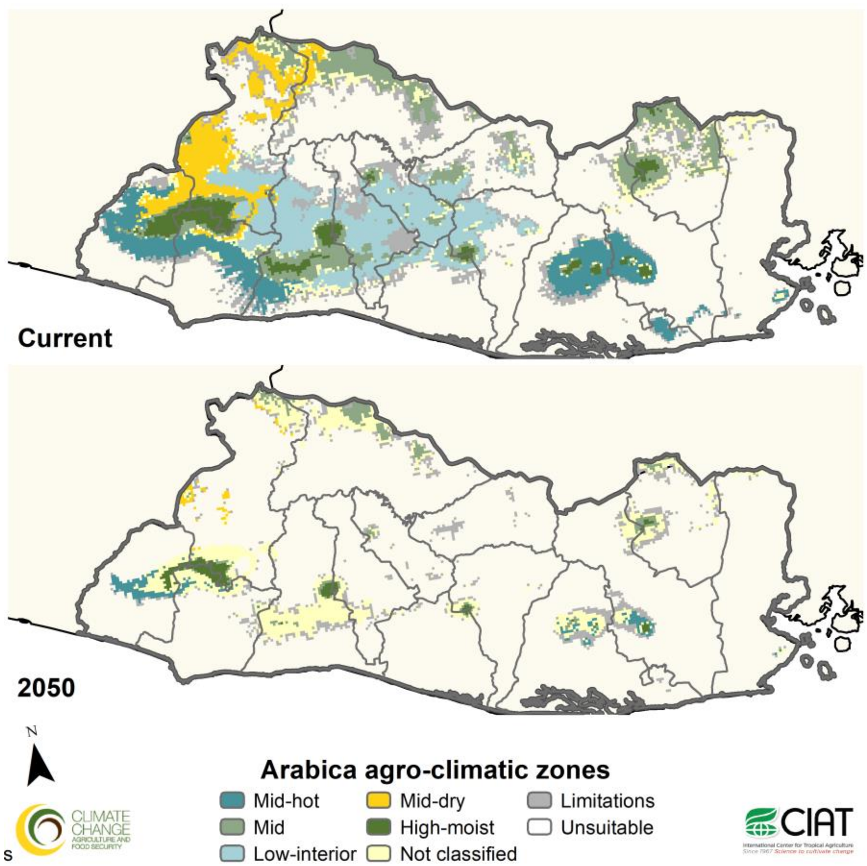
How are future climate projections generated?

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 socioeconomic and technological developments.

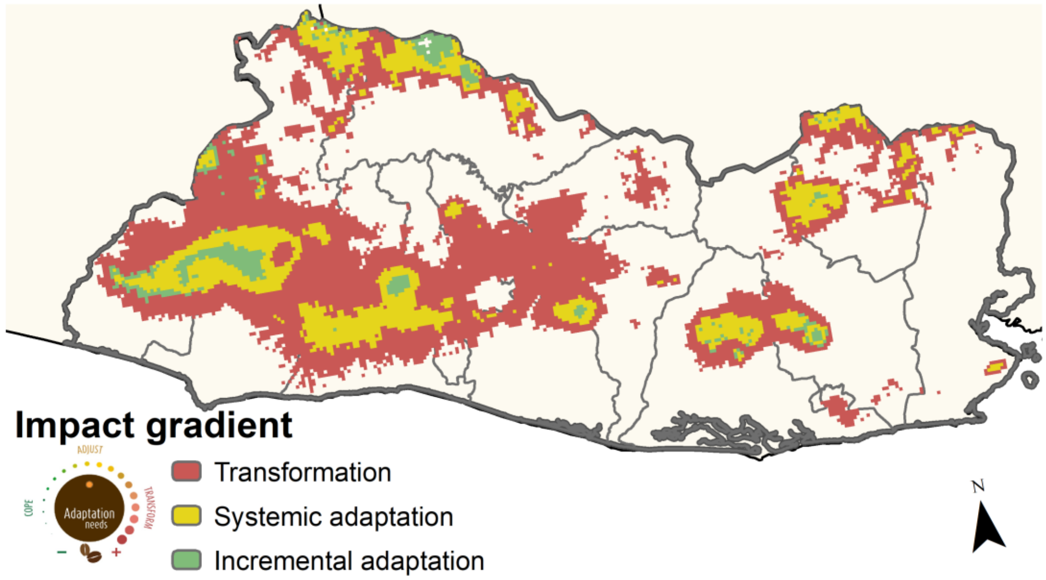
GCM outputs have a coarse resolution of 100 or 200km, which is not practical for assessing agricultural landscapes. We therefore use downscaled climate projections. For each GCM anomalies are calculated as the delta between modeled baseline climate and future prediction. These anomalies are interpolated 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.

We used a Random Forests model and machine learning to create the projections of changes in climatic suitability for arabica coffee. We also used data from 10.584 plots collected by CENTA-Café. Based on the climatic variables projected by these models, we delineated the impact gradient for the coffee-producing areas in El Salvador. Degree of impact maps represent the superimposed agroclimatic zones maps for different periods. Most transformation impacts are expected around 2050. Transformation zones will expand in the center of the country, mainly in the states of Cuscatlán, Cabañas, and San Vicente. Incremental adaptation zones are projected principally between the states of Usulután and San Miguel, and in the Apaneca- Ilamatepec mountain range, located between Ahuachapán, Santa Ana, and Sonsonate.

A considerable decrease in suitable areas for coffee is projected, especially at the extremes, in regions which are either very suitable and less suitable for coffee currently. Incremental adaptation areas tend to correspond with areas located at higher altitudes. Coupled with the diversification of production systems, relatively small changes in management practices would be required to improve productivity, quality, and mitigation of GHG emissions in incremental adaptation areas.



Degrees of impact maps show that by 2050 30% of current coffee production areas will require transformative adaptation and farmers are advised to redesign their production systems or dedicate their fields to different crops. Just 8% of farms in 2050 are located in areas that are projected to require incremental adaptation. As a rough estimate, all else being constant, only US$ 42 million worth of production are located in incremental adaptation zones. At current prices, production in systemic adaptation and transformation zones, which is at risk of negative impacts from climate change is worth roughly US$ 117 million annually.



Impact gradient map for 2050

Incremental adaptation

These areas are most likely to remain suitable. The 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

Incremental adaptation areas are likely to be constrained to high altitudes. 23732 ha of coffee are **above 1200 masl**

Systemic adaptation

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
Grafting Arabica onto Robusta rootstock
Organic barriers

Additional coffee practices:
Grafting arabica onto Robusta rootstock
Deeper bags and deeper holes for planting
Canals (acequias) for drainage
Deeper holes and bags for planting
Water harvesting
Drip irrigation
Biochar
Gypsum
Leguminous cover crops
Windbreaker curtains

Systems strategy:
Crop diversification (on-farm)
Income diversification (off-farm)
Insurance

Systemic adaptation areas will be found at mid-level altitudes, corresponding to High Grown coffee and 51120 ha **between 1200 and 900 masl**

Transformation

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

Transformation areas will mostly be located in the "bajío" at **less than 900 masl**. Areas at this altitude make up 77488 ha

Altitude	Commercial sublevel	Agroclimate	Likely degree of impact
>1200	Strictly High Grown	Cold and wet	Incremental
1200-900	High Grown	Hot and dry	Systemic
<900	Central Standard	Hot	Transformation

How certain is the projection?

As any with any future outlook our model has a considerable degree of uncertainty and should be considered a projection, not a prediction. 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 El Salvador

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 climate smart coffee development is to promote the scaling of no-regret farmer coping strategies within suitable decision domains. No-regret strategies are those which are intended to yield benefits for the farmer under a wide range of possible future climate scenarios. The following list consists of expert validated practices which can serve as a starting point to develop portfolios for each of the risk zones. Additionally, we consider the possible adaptation benefits for each practice to prevent and/or recover from extreme climate events. More information about the practices can be found at ***Coffee & Climate*** [15].

CSC practices	Adaptation level	Adaptation benefit	Total Climate Smartness
Increase shade cover	🟥🟨🟩	FHDR	4.66
Diversification	🟥	FHR	4
Coffee rust resistant varieties	🟥🟨🟩	R	4.33
Soil conservation	🟥🟨🟩	DF	4.66
Plant nutrition	🟥🟨🟩	HR	2.33
Water harvesting	🟥🟨🟩	FDHR	1.66
Coffee renovation	🟥	R	3
Organic fertilizer	🟥🟨	FDR	1
Drainage	🟥	FR	1
Fungicides	🟥	FR	1
Shade tree renovation	🟥🟩	FDHR	1
Irrigation	🟥	DHR	1
Increase planting density	🟨	FR	2
Windbreaks	🟨🟩	FHR	2
Stratified shading	🟨	FDHR	1
IPM	🟨🟩	FHR	1.5
Soil cover	🟨🟩	FDHR	1
Incorporate organic matter	🟩		1
F- Flood/torrential rain/erosion; D- drought; H- Heat; R-Resilience	🟩 Incremental 🟨 Systemic 🟥 Transformation		

Renovation with adapted varieties

Coffee farms in El Salvador are relatively old. The average age of coffee plants according to data from Centa is 30 years, and the varieties planted are very vulnerable to coffee rust. The direct distribution of or improvement of access to resistant varieties for replanting should be at the foreground of sustainable coffee farming practices. The main threat at the moment is coffee rust, but varieties that are resistant to extended dry periods, droughts, and strong winds will become increasingly important in the future.

Through Centa-café, the government of El Salvador distributed millions of coffee rust-resistant plants, targeting smallholder farmers (less than 3 ha). The area farmed by the target group is just 10% of the area cultivated with coffee, and unfortunately, farmers often chose to sell their seeds instead of planting them. Those who opted for planting the resistant seeds ran the risk of the plants dying because they lack the necessary inputs to ensure adequate plant health and future survival. More resistant and higher-yielding plants also require more fertilizer, an expense farmers either did not know they had to make or couldn't afford. Criticism of the quality of the plants and means of transport used for their distribution is widespread. As such it is difficult to evaluate which varieties were planted successfully and which were abandoned or died off. Furthermore, the Salvadorian Coffee Association estimates that 300 million rust-resistant coffee plants would be required to fully renovate Salvadorian coffee production[16].

Climate change and disease exposure enhanced by the old age of farms make the need for replanting and renovation evident USAID estimates that renovation and replanting could produce a 16% increase in total national yields. Smallholder yields would potentially increase 100%, from 220Kg/ha to 440Kg/ha.[5]. Nicaragua has a private lab for coffee seedlings and provides seeds to Honduras, Guatemala, and El Salvador through CIRAD and ECOM [5]. Stakeholders in El Salvador were aided by ISIC and then Procafé in the adoption of improved varieties, but the coffee fields of Procafé currently lay abandoned.

From the classification of coffee varieties by the Salvadorian Coffee Council, aside from the Hybrid F1, a trade-off between quality and to pests and diseases seems apparent. The two most widely planted varieties, Tekisic and Pacas, are not very high yielding and they are very susceptible to pests and diseases, including coffee leaf rust [18]. Although climate change may not have been at the heart of developing new varieties, resistance to droughts, winds, and intensive rainfall will become increasingly important in the coming decades. Resistance to pests and diseases should also be considered when replanting, as increasing plant stress will also make coffee more vulnerable to damage from these sources. Nonetheless, replanting with tolerant or resistant varieties should be combined with adequate agronomic farm management practices to reach the desired production potential and adaptation to climate change.

Variety	Main characteristics [16]	Share of planted varieties[17]
Tekisic (Improved bourbon)	-High cup quality	68%
Pacas	-Tolerant to winds and droughts -High cup quality	28%
Pacamara	-Wind resistant -High cup quality	3%
Catuai Rojo	-Highly productive at high altitudes -High cup quality	
Catisic	-Resistant to coffee rust (Hemileia vastatrix Berk and Br) -Resistant to intensive rainfall -Acceptable cup quality	
Cuzcatleco	-Resistant to nematodes -Early yields -Resistant to coffee rust -Acceptable cup quality	
Hybrid F1	-Early yields -Resistant/tolerant to coffee rust -High cup quality	
Icatú	-Under evaluation	

According to WCR, before recommending one variety or another the individual characteristics of the farm would have to be analyzed and considered. Crucially, the genetic and physical quality of the plant has to be considered, the agroecological zone, the altitude, and the capacity of producers to invest in their farm as some varieties will require more nutrition and management than others. For incremental and systemic adaptation areas the following varieties could be recommended:

- At an altitude above 1200 masl: Caturra, Central American H1, H3, and Pacamara
- At an altitude below 1200 masl: Cuscatleco, Parainema, CR95, Marseille, and Obata
- Between 800 and 1500 masl Mundo Maya

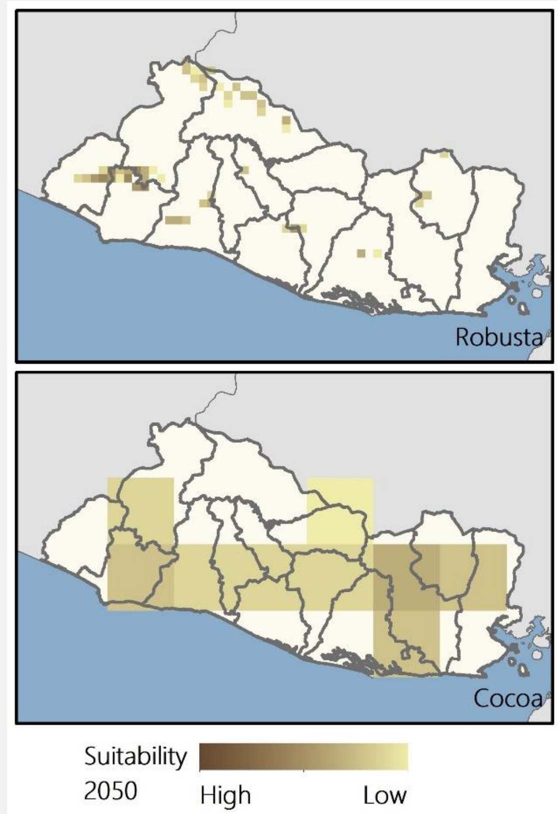
The Robusta trap

It's paradoxical that a country which proudly produces and exports high quality coffee, should be an importer of soluble coffee from its neighbors. For many public and private stakeholders, reshoring the production of soluble coffee and replacing unsuitable areas for Arabica production with Robusta seems to be a potential solution to climate change impacts and the aforementioned paradox.

However, as the map to the right developed by CIAT indicates, by 2050 the areas suitable for Robusta will be quite small, moreover they will coincide with the areas that are projected to remain suitable for Arabica production.

Ultimately, initiatives to promote Robusta could backfire on two fronts: first, production in areas unsuitable for arabica would be very vulnerable to climate change under current projections, and second, reputation of high-quality and designation of origin could be lost due to Arabica and Robusta being grown in the same areas.

In areas with sufficient precipitation, an alternative for farmers looking to keep producing under agroforestry would be cocoa. This crop, which is also commonly grown under shade, may be suitable, though challenged, for production in a much wider area than coffee in the future providing a way out for farmers seeking profits and society looking to maintain the ecosystems services of agroforests. Where cocoa may not survive due to the increasingly dry conditions in El Salvador it may be necessary to introduce previously unused crops.



Cost-Benefit Analysis of climate smart coffee

The capacity of smallholder farmers to invest in their farms is often limited by their incomes. Years of low yields or low coffee prices are commonly followed by a decrease in the use of inputs, hindering a quick recovery of production. In this sense, economic arguments can leverage the decisions of farmers and their lenders in favor of the continued adoption of Climate Smart Coffee practices. Cost-Benefit Analyses (CBAs) are a powerful tool to invoke such an economic argument. These analyses are ex-ante evaluations of incremental cost and benefit flows, as such, they involve a certain degree of uncertainty due to the stochastic nature of yields and weather. CBAs not only serve as a pro et contra economic argument of CSC, but they also aid in prioritizing different practices.

Methodology

At their core, the CBAs presented here are a comparison of the expected stream of costs and benefits accrued over twenty years in one scenario of improved practice adoption versus the baseline scenario with unchanged farming practices. The selection of practices is based on workshops with coffee technicians and modeling of coffee suitability in different degree of impact zones. A consensus was reached on the prioritization of two practices, namely, renovation with improved varieties adequate for each altitude, and agroforestry systems. Data was sourced from CENTA-café technicians and specialists, and the available literature. The Net Present Value (NPV) and Internal Rate of Return (IRR) can be derived from the CBA to obtain a single numerical value to help in prioritizing practices. The discount rates (DR) chosen to apply these methods are 5% and 10%, depending on the expectations of interest rates in the future one would be preferable to the other. A higher DR will lower the NPV, making investment decisions more cautious. "Indirect" costs of the improved farming practice were not considered, these include the cost of tools, technical assistance, leasing, and loan interest payments. The time horizon for the analysis is 20 years.

Results

Both renovation with improved varieties and the establishment of diversified agroforestry systems in the three degrees of impact zones appear to be highly profitable investments for farmers regardless of the discount rate used.

CBAs indicate that renovation will have a positive impact on farmer incomes, increasing their benefits by over US$ 1430 per hectare. The NPV is at least 96% higher for all practices analyzed. These increases are a consequence of higher yields and benefits from diversified agroforestry species. For the agroforestry practice, different systems were evaluated depending on the degree of impact zone. For systemic adaptation zones, for example, agroforestry wit timber species is recommended to generate a better microclimate for coffee and to compensate farmer incomes in the face of lower coffee suitability.

In terms of costs, labor constitutes the highest share and the highest increasing cost in the improved systems relative to baseline costs. Establishment costs are substantially higher in the improved systems (e.g. establishment with timber species costs US$ 130 more than with *Inga* species). Annual harvesting costs also increase due to higher yields.

Adaptation level	Recommended species
Incremental	***Leguminous species:*** *Inga vera, Gliricidia sepium, Inga juinicuil*
Systemic	***Timber species:*** *Cedrela odorata, Cordia alliodora, Swietenia humilis*
Transformation	***Timber species*** ***Fruit species*** *(Musaceae): banana, jocote*

Current farming	Climate smart practice	Cost	Benefits	IRR/NPV compared to BAU
More than 50% of farms are older than 20 years and are planted with non-resistant varieties, one-time application of fertilizer	Farm renovation and replanting with improved varieties with resistance to coffee rust and water stress. Fertilizer applied twice a year	Higher labor costs Higher harvesting costs Cost of additional fertilizer application	Higher yields (300% higher in the 4th and 5th year, 100% higher afterwards) Lower plant stress Less susceptibility to pests and diseases	DR=5% IRR +280% NPV +191% DR=10% IRR +90% NPV +96%
Lack of diversification in incremental adaptation zones. 40 to 70% shade cover.	50% shade cover Diversification with trees that provide ecosystem services in renovated incremental adaptation zones	Higher labor costs Higher harvesting costs Planting and seedling costs Higher establishment costs	Lower temperatures (up to 3°C lower) Benefits from productive shade trees (e.g. banana) Higher yields (starting from the third year)	Incremental DR=5% IRR +160% NPV 472% DR=10% NPV +350%
Lack of diversification in systemic adaptation zones	50% shade cover Diversified production systems with timber in systemic renovated adaptation zones	Higher labor costs Higher harvesting costs Planting and seedling costs Higher establishment costs	Lower temperatures (up to 3°C lower) Benefits from productive shade trees (e.g. banana) Higher yields (starting from the third year)	Systemic DR=5% IRR +260% NPV +406% DR=10% NPV +194%
Lack of diversification in transformation and resilience adaptation zones	50% shade cover Diversified production systems with timber and high-value fruit species in a renovated plot	Higher labor costs Higher harvesting costs Planting and seedling costs Higher establishment costs	Lower temperatures (up to 3°C lower) Benefits from timber species Higher yields (starting from the third year)	Transformation/Resilience DR=5% IRR +460% NPV +534% DR=10% NPV +368%

Systemic and enabling interventions

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

CSC strategies run the risk of failing if they do not consider the systems or environments in which coffee farmers make their investment and management decisions. It is counterintuitive why many farmers continue to grow coffee after facing losses, therefore, the culture and tradition aspects of production should be acknowledged and leveraged to increase the rates of adoption of improved practices. 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.

The general public sometimes views coffee farmers with disdain, seeing them as oligarchs taking advantage of the government for higher selling prices and inexpensive or free inputs. Although the majority of the coffee area is held by a relatively small minority, this notion is also detrimental to smallholder farmers, while large landowners may be able to substitute government aid and extension through private means, smallholders suffer the consequences. Programs destined to support smallholders should be promoted and popularized.

Greater transparency in the markets both for inputs and for selling production are required to make sure that farmers are receiving their fair share of profits and can invest in their farms adequately to obtain reasonable returns. Farmers are tied to their respective value chains through so-called beneficiaries ("Beneficiarios") which weigh, store, and partially process coffee. Beneficiaries may be cooperatives (e.g. Cooperativa Cuzcachapa), exporters (e.g. UNEX), or farmer groups. Some beneficiaries also act as intermediaries between the financial sector and sell plants to farmers or the government for distribution to farmers. Beneficiaries are also a link between government organizations like the Salvadorian Coffee Council and smallholder farmers.

The Trifinio Plan, which is also sponsored by the HRNS is centered around **Ecosystem-based adaptation** (EbA). This 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 in agroforestry. 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 share of areas gradually to become unsuitable for coffee production is projected to increase dramatically in the coming decades. This is because growing coffee may become uneconomical in the medium- to long-term in these areas due to an unsuitable climate. Coffee farming households in these transformation areas are recommended to transition to a different crop, preferably one grown under agroforestry to ensure ecosystem services are sustained.

Intercropping timber and fruit species, for example with avocado (*Persea Americana*), is recommended, but the practice has not yet been widely adopted [2]. For many stakeholders, Robusta coffee (*Coffea canephora*) and cocoa (*Theobroma cacao*) considered as alternatives for areas where arabica coffee will no longer be suitable. However, where drought threatens Arabica, these crops are unlikely to be a good choice because of their high precipitation requirements.

Diversifying production 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 overall production risk. For farmers to achieve these changes and follow recommendations they require adequate access to financial markets and credit. Any transformation to a different crop would require access to financial markets and support from the government and NGOs.

An innovative approach to reducing the negative impact of climate change on smallholder farmer incomes are **index-based weather insurance** schemes. In essence, these systems pay out an amount to farmers whenever a pre-determined weather event is registered. Farmers would pay into the system during high yielding seasons. This type of insurance has the advantage over individual index-based insurance of not requiring any verification of production losses. Low uptake could be remedied through the targeting of farmer groups, for example, farmer cooperatives. The Microinsurance Catastrophe Risk Organization (MiCRO) based in Barbados is an example of this type of approach which will be implemented in El Salvador[19].

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.

Adoption and scaling business cases

Active efforts to scale out climate smart practices are a priority to secure the long-term sustainability of the coffee sector. Because coffee production is an investment of several decades and many CSC 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 CSC that respond to business incentives: Voluntary certification, carbon in-setting, impact investing, greater ease for selling outside the international market price ("*Fuera de bolsa*") and sustainability branding.

Certifiers act both as a verification body of sustainable practices and providers of training. Certifiers' interest in climate adaptation is grounded on the premise that the final consumer is willing to pay a premium for certified products. Currently, less than 4% of coffee exports in El Salvador are certified Fair Trade or Organic. By facilitating access to certification to those smallholders that are organic by default, certifiers would be able to provide economic incentives and innovative training to a large segment of farmers. One important issue farmers have with certification is that the price premium varies while certification and management costs remain fixed, according to stakeholder premiums are lower when the international price is low disincentivizing farmers from certification under these circumstances.

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, international roasting and trading companies can offset their GHG footprint by investing in carbon-sequestering activities at farmer level that at the same time support the adaptation of farmers to progressive climate change serving the double purpose of also securing their supply chains. 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 [20]. 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-averse large brands with their large constituencies to achieve CSC adoption at scale.

Policy Environment

Institutions

The **Coffee Association of El Salvador (ACAFESAL)** is a non-profit group which claims to represent over 22 thousand coffee producers in El Salvador with offices in 13 of the 14 departments. It aims to defend the interest of farmers, research, and increase the sustainable use of natural resources.

As a government body, the **Salvadorian Coffee Council (CSC)** was created to promote Coffee from El Salvador on national and international markets, help in the implementation of government programs, produce strategic information, and strengthen national and international cooperation for sustainability. The minister of agriculture is also the president of the council. Export associations, like ABECAFE, Coexport, and PROESA are also part of the CSC committee. Since

2015 the ministry of the environment and the ministry of tourism are also part of the committee.

The **Central Bank Reserve of El Salvador (BCR)** provides credits to producers either directly or through intermediaries such as cooperatives and coffee processors [3].

Now inoperative, the **Salvadorian Foundation for Coffee Research (Procafe)** substituted the Salvadorian Institute for Coffee Research (ISIC) as a private entity managed by farmers through the four main coffee associations of the country: Cooperative Union of El Salvador (UCAFES), Coffee Association of El Salvador; Union of Agrarian Reform, Beneficiaries, and Exporter Cooperatives (UCRAPROBEX); and the Association of Producers, Beneficiaries, and Exporters of El Salvador (ABECAFE). There is talk among stakeholders and interest among members o the new government to relaunch a similar organization in the future.

The **International Regional Organism for Plant and Animal Health (OIRSA)** is headquartered in the capital of El Salvador. Its aim is the improvement of phytosanitary problems and food safety. This organization carries out research to reduce the impact of coffee rust and other plagues.

The National Center of Agricultural and Forestry Technology (CENTA) has a branch (CENTA-Café) dedicated to creating workshops, providing extension services and technical assistance, and input provision, among other diverse tasks related to improving coffee productivity and resilience. CENTA also manages data on soils. Currently, the number of extension agents is slightly lower than in the past.

The **Salvadorian Association of Beneficiaries and Exporters of Coffee (ABECAFE)** gives a joint voice to the many cooperatives, exporters, and coffee processors in the country. They are also part of the CSC committee.

Policies

Historically, El Salvador was sometimes referred to as "The Coffee Republic"; coffee was a central part of the Salvadorian economy and the flourishing of cities and towns [21]. During the 20th century, just 14 families owned over 81000 hectares of coffee plantations. Land reform was included in article 105 of the constitution of 1983 prohibiting any citizen from owning more than 245 hectares, cooperatives and farmer groups were exempt[22].

Land reform policies led to the creation of cooperatives and secondary cooperatives which centralize the purchasing and processing of small and medium coffee farmers, while also providing them with access to credit to prepare or renew their production systems. Larger producers are able to sell their coffee cherries directly to processors and exporters or even export them directly[23].

There is a strong need for amending the laws that direct coffee production in El Salvador. Many of these are excessively restrictive and anachronistic due to the fact that many of these laws were passed during a period of civil war. Moreover, punishments for not following the law are still recorded in Colones, a currency no longer circulated in the country. Additionally, there seem to be pervasive misunderstandings with parts of the law. For example, some believe that according to a law passed in the 1950s planting Robusta in El Salvador is forbidden, yet there is no recorded evidence of the existence of this law.

Export registration permits allow the Salvadorian Coffee Council to monitor exports. To cover maintenance and harvesting, the government-guaranteed loans to farmers of US$70 per 45.36Kg (one hundredweight) through government-owned financial institutions. Furthermore, the price producers receive is partially determined by the stock exchange, although deductions are applied depending on the bean processing costs.

In 2001 the government set up a Coffee Trust (FICAFE) to defer repayments on farmer debts. Some farmers are still repaying their debts to this trust although grace periods were adopted in 2014 to deal with the coffee leaf rust and this period has been extended until the end of 2018 [3]. Lending from private banks is very limited due to the perceived default risk, especially after recent production crises.

The CENTA Café organization oversees extension to coffee farmers. In the past, through this organization, the Ministry of Agriculture has provided smallholder farmers (less than 3 hectares) with fungicides, fertilizers, and seedlings. In the year 2018, 18 million coffee rust-resistant seedlings were distributed. Free seedling distribution programs have been criticized for the lack of support and funding given to farmers to care for the plants until they start being productive, leading many farmers to sell their seeds.

Existing initiatives

Designation of origin projects and promotion are on the rise. One of the principal initiatives in El Salvador is the **Cup of Excellence** ("*Taza de Excelencia*"). This event gathers together producers, businessmen, and cooperatives from all coffee regions in El Salvador to promote farming practices that increase coffee quality and position Salvadorian coffee among the premium/specialty coffees worldwide to achieve higher world market prices. As part of this event, global electronic auctions are carried out to bring together local producers and international buyers paying premiums above the spot market price.

Having one of the agricultural sectors most vulnerable to climate change, El Salvador draws many initiatives.

Coffee Under Pressure (CUP) is a project by the Catholic Relief Services with support from the Center for International Tropical Agriculture (CIAT) and financing from the Green Mountain Coffee Roasters. It studies the vulnerability of communities to climate change and helps farmer organization and value chain actors design adequate scenarios to optimize their production systems.

There are numerous projects currently in development, for example, the Project of Support of the Salvadorian Productive Sector for Coffee Production which seeks to connect producers and buyers and provide the former with the necessary technology to generate added value. Another example is the Project to support the coffee sector for its insertion in the internal market and the Project of support of value-added Salvadorian coffee in collaboration with the Italian government.

Project **MOCCA** (maximizing the opportunities for coffee and cocoa in the Americas is a five-year initiative supported by the Ministry of agriculture of the United States and implemented in six countries. The aim is to provide producers with the necessary assistance to renovate their farms and kickstart their productivity commercialization and income growth.

Initiatives are also underway to increase the transparency of the fixed processing costs of exporters and cooperatives. Currently, farmers receive 50% of the FOB price, the remaining share going mainly to the exporter or organization in charge of processing and storing the harvest. It is argued that with higher prices the share of the final price received by the farmer while the amount given to the processor remains constant.

Blue harvest is a joint initiative by the Catholic Relief Services in El Salvador and Keurig Green Mountain and FOMIN in Nicaragua, and Honduras. The aim is to help farmers restore and protect water resources in coffee farming areas to ensure water supplies for downstream communities and resilient coffee production.

Outlook

Climate projections indicate that climate change will have a severe and negative impact on coffee areas in El Salvador. Climate-Smart Coffee underscores the importance of reducing on-farm temperatures, increase water use efficiency and reduce the incidence of pests and diseases. Private and public sector initiatives are required to increase farm productivity and adaptation by building resilience to climate change and to pests and diseases. Ensuring the sustainability of shaded coffee production systems in El Salvador also has the potential to mitigate GHG emissions from potential land-use conversions. Two types of practices should be prioritized, namely, the renovation of old farms with improved coffee varieties and the establishment of diverse agroforestry systems. Producers should be supported through the establishment phase and access to fertilizers and other inputs should be improved through a tighter link between smallholder producers and markets. To promote adoption, smallholders must participate in the benefits of price premiums for high-quality coffee. The effect of climate change will be more burdensome for smallholder farmers due to their limited incomes and accumulated debts. However, the coffee sector is a stronghold of protection of ecosystem services which should be maintained as well as of the livelihoods of tens of thousands of rural workers.

The private sector should collaborate on initiatives to promote the adoption of climate smart programs by smallholder farmers. Stakeholders at all links of the value chain must facilitate adoption through risk and cost-sharing initiatives.

CASE STUDY:
INTEGRATING CSA PRACTICES

Mr. Dimas (left) and Mr. Aviles (right), standing next to a coffee plant in the finca San Antonio

It is not uncommon for residents of San Salvador, the capital of El Salvador, to recall a time in which the climate was mild and the outskirts of the city center, now urbanized, were lush coffee farms. Having not yet succumbed to these changes in the landscape, the finca San Antonio managed by Mr. Dimas -who has been working on the farm since 1989- and supervised by Mr. Aviles stands a testament to time and the efforts to preserve coffee under progressive climate change.

The 73.5-hectare plot is located at 1000 masl, and is owned by the in-laws of Rene Aviles, the Daglio family, who own a total of 308 ha in El Salvador. The number of laborers is on the decline, from 150 in the harvest season to just about 80. However, finca San Antonio is not a regular coffee farm, it is also used as a testing ground for improved varieties and farm management methods. Among the varieties that can be found in the plot are the traditional Bourbon and Pacas, Costa Rica-95, Catimor 51/75, Catuai, Hybrids F1, Marseille, Catuai ch3, among others. A part of the plot is dedicated to simulating "harsh" conditions without shade or fertilizer to identify the most resistant varieties in this endeavor they collaborate with technicians from World Coffee Research (WCR).

After the outbreak of coffee leaf rust in 2012, they hired a private consultant to create a plan for renovating the farm and create seed banks of the best varieties with the intention of selling them. They found that Catimor 51/75 and Catuai were less affected by rust even under harsh conditions. Unfortunately, the business selling seeds did not take off, as other farmers were not looking to renovate due to low coffee prices and high costs.

They know climate change is happening and taking a toll on their coffee production: "This has been the hottest month; never before did we reach 35°C on the farm. Month to month the changes may be small, but over decades they are huge". Precipitation is also affected, the 1500 to 2000mm over 6 months they could previously rely on are no more and some of the water springs have dried up.

Mr. Aviles and Mr. Dimas also know what practices they would ideally implement -most of them can classified as CSC. They mention using "cajuelos" (planting in boxes with fertilizer) but costs are too high, planting tall shade trees but there is a lack of workers able to prune them properly, they have irrigation o another plot but there are no plans yet to implement it everywhere, though they do have wells for water infiltration. There are security problems in the farm in the East of the country

"Now producing more coffee means losing more money, we get paid 40 though our costs are 60, and the more we produce the more smaller producers lose" says Mr. Dimas. The owners are aware of this problem and they are considering leaving the at least 100-year-old tradition of coffee farming at finca San Antonio in their past. Mr. Aviles says they are already considering alternatives with other crops or even biomass. He believes more could have been done at the government level: "There was no vision for development as a country", Procafe helped them but was abruptly abandoned and no other organization stepped in. They need more support and better prices or subsidies for the ecological services they provide. Climate change is happening, but, as Mr. Dimas notes, for now "we are holding on tightly to the lush trees we knew when we were kids".

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