Climate-smart coffee in Honduras

Summary

Honduras is now the largest coffee producer in Central America. Low cost of production, generational change and institutional support resulted in an average annual production growth of 5%. About 110,000 families have coffee as a primary income. 95% of these are smallholders with less than 7ha. Coffee provides employment to an estimated 1 million people.

The bulk of production is higher quality Arabica coffee which is highly vulnerable to climate change. Most production is shaded at altitudes above 900masl. Many plantations were recently renovated but remain susceptible to major climate driven diseases. Most coffee producers diversify their income sources and crops because a failed coffee harvest may result in enduring malnutrition.

Coffee production areas in Honduras 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. These trends likely increased the water needs of the coffee crop.

Climate model projections show an unambiguous trend to higher temperatures at coffee locations. The seasonal distribution of rainfall will likely remain similar. Precipitation amounts during the dry season should remain similar to current conditions. May precipitation may increase compared to current conditions with possible reductions in the following months. However, a wide range of projections reflects the difficulty to predict future precipitation. Projected temperature increase and mean reduction in precipitation make droughts more likely and potentially more severe for coffee production. Stakeholders should prepare for more efficient water management.

To support efficient adaptation, we developed a coffee specific evaluation of the projected climatic changes described above. Previously sub-optimal sites will likely become uneconomical for coffee. This trend is evident in the gradual disappearance of Honduran Standard grade coffee in the last decade.

High grown grade coffee will struggle to remain productive unless comprehensive adaptation measures are implemented. Strictly high grown grade will require incremental management changes to remain productive. Areas above 1800masl may become attractive for coffee production in the future but measures should be taken to exclude protected areas from value chains and ensure sustained provision of key ecosystems services that underpin productivity.

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.

Adaptive action at scale needs to be taken immediately, and with a forward-looking approach. Coffee production is an investment of several decades and many CSC practices have a long lead-time. About 85% of Honduran farmers are associated with institutions but the training benefits received are often inadequate. Local institutions are understaffed or struggle to act as agents of innovation. 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. We suggest four alternative scaling pathways for climate smart coffee: Voluntary certification, carbon insetting, impact investing, and private sector training.

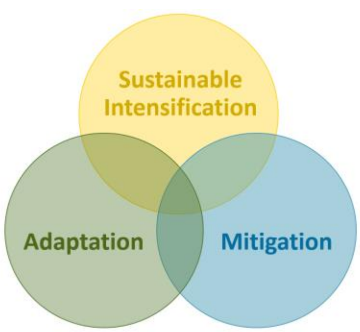
The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, 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.

Climate smart coffee

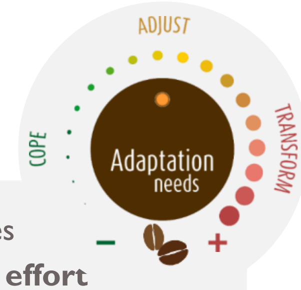
Climate smart coffee production sustainably increases productivity, enhances resilience to climate risk, and reduces or removes greenhouse gases (GHGs). While the concept is new, and still evolving, many of the interventions that make up CSC already exist worldwide and are used by farmers to cope with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

We focus on farm level adaptation for sites where adaptation is feasible. 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.

However, with increasing degree of climate impacts the importance of systems approaches and the enabling environment increases. Practice focused adaptation seeks to mitigate impact through intensified production effort. Intensification reaches a limit when alternative systems become relatively more attractive. In this case, a change of the livelihood strategy may gain importance. Value chain inclusive systems approaches to adaptation seek to include a wider range of products into the chain to manage risk from coffee. The chain itself may be made risk proof or more efficient, for example at processing and transport stages. Finally, the enabling environment for CSC is the framework condition that facilitates and supports these intensification and systems approaches. The enabling environment includes policies, institutional arrangements, stakeholder involvement and gender considerations, infrastructure, insurance schemes, as well as access to weather information and advisory services.

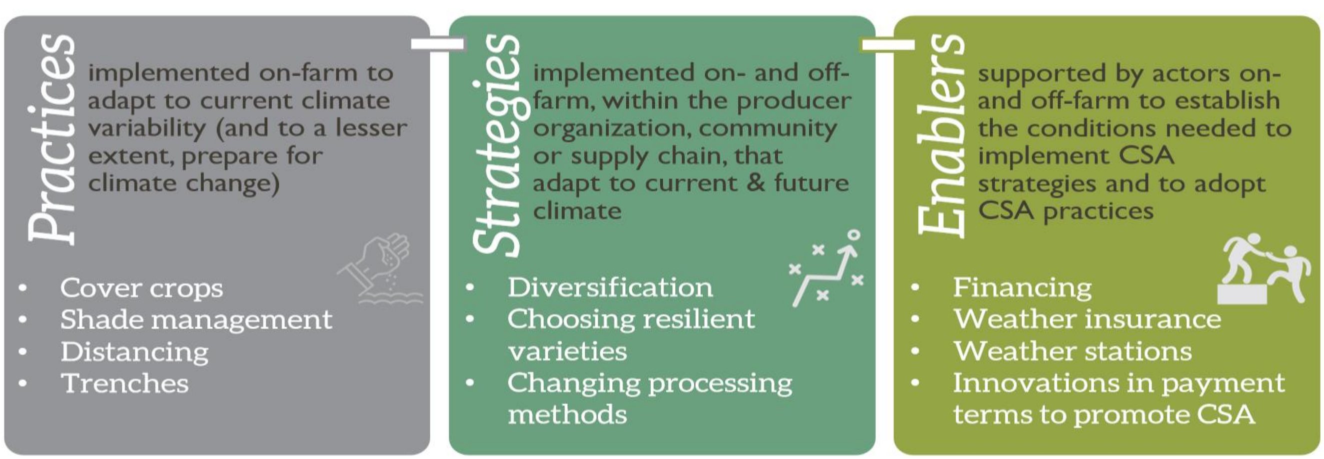


In the following, we give an overview of suggested practices. Additional information about the practices can be found in the annex or at Coffee & Climate [10]. We provide some information about diversification strategies, landscape approaches and insurance as an alternative to off-farm labor. Finally, adapted varieties are given some more attention because of the importance of renovation for CSC.

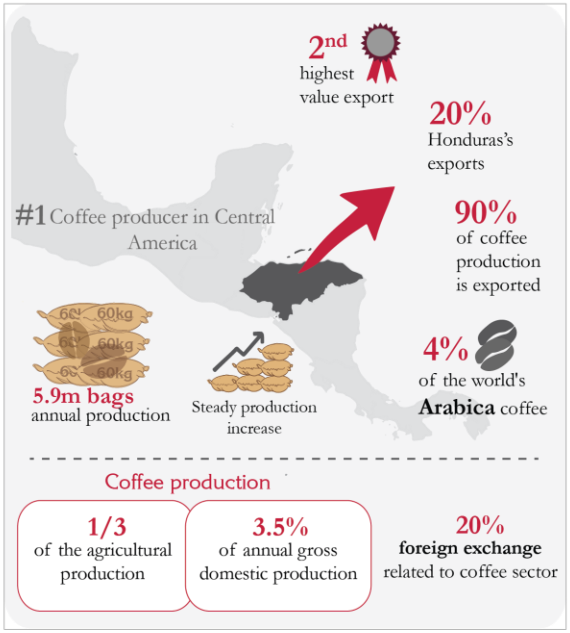


Three degrees of adaptation **effort**

- **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 remain suitable but with substantial stress 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, will require a focus on a change of strategy and adequate enablers as practices alone may be uneconomical

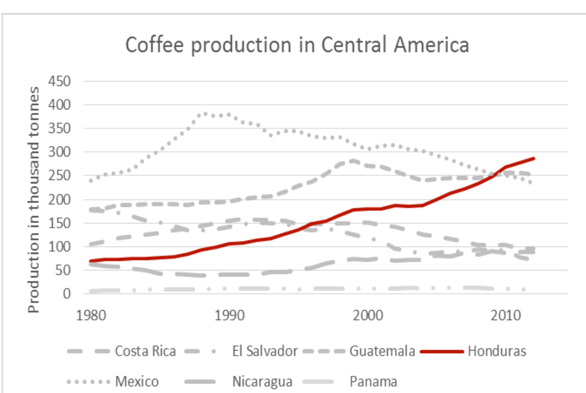


National context



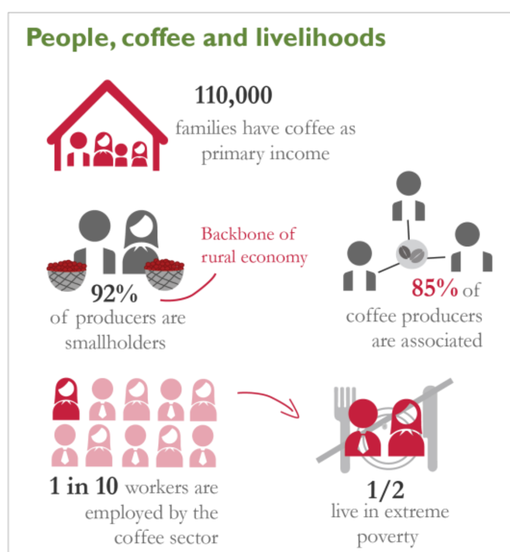
Economic relevance of coffee

At 5.9 million 60kg bags Honduras is now the largest coffee producer in Central America [1]. Where other major producer countries in the region have experienced phases of expansion and contraction of production, in Honduras production has increased steadily over the past decades. Low cost of production, generational change and institutional support resulted in an average growth of production of 5% annually so that total production is now double what it was just 20 years ago. Unlike other countries in the region, Honduran producers have been able to increase yields by about 25% and Honduras is now among the most productive countries globally.

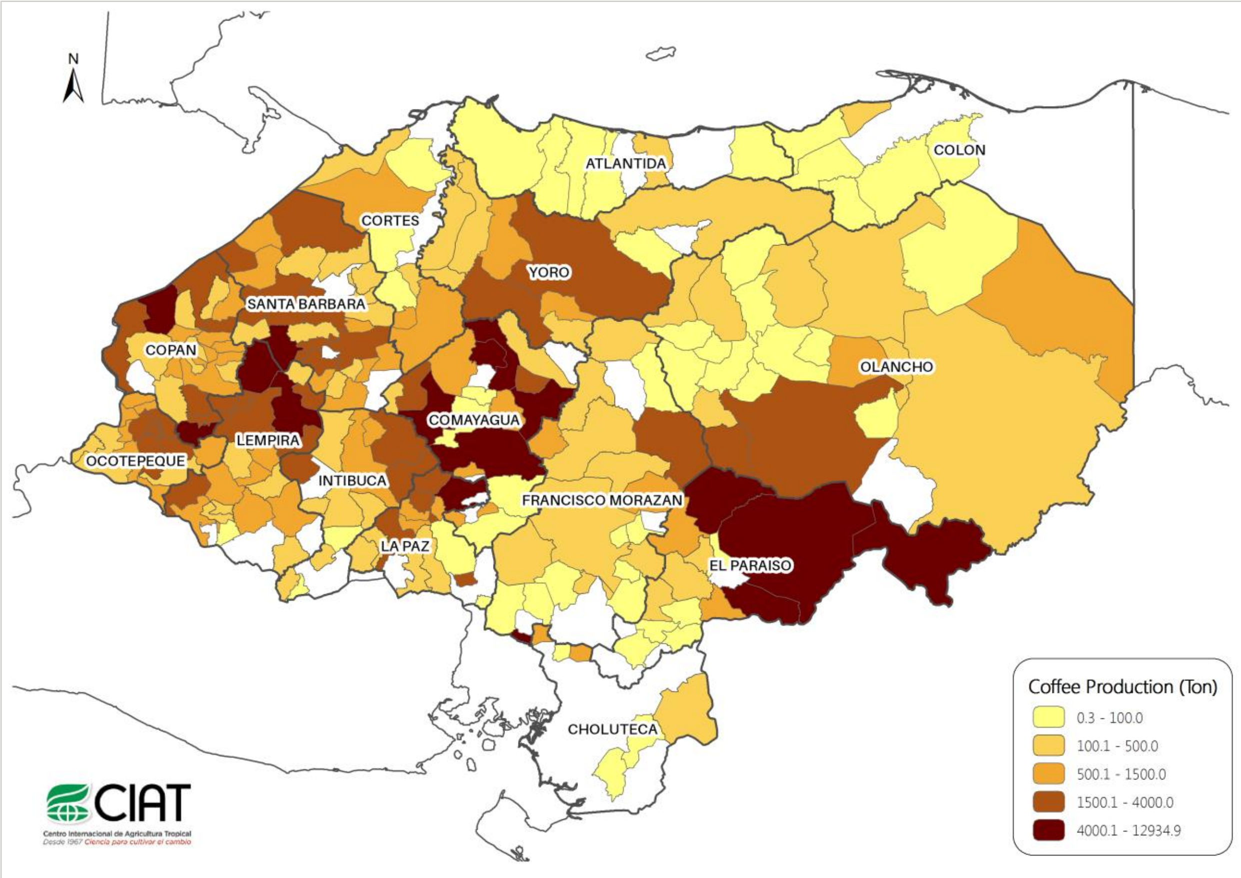


The production of coffee constitutes about a third of agricultural gross domestic production (GDP) and is Honduras's second highest value export behind the manufacturing sector. It accounts for approximately 20% of exports and 3.5% of the GDP [2]. This importance of coffee to the Honduran economy has increased in recent years: accounting from an average of 2.4 percent of annual GDP from 2003–2007 to 3.7% of GDP between 2008 and 2012. In addition, there are strong linkages between the coffee sector and the external accounts. Around 90% of coffee production is exported. The importance of coffee for the economy is also reflected in the foreign exchange purchases of which about 20% were related to the coffee sector. Annually, Honduras exports coffee worth between 0.9–1.5 billion USD [3]. Traditionally, Germany has been the largest buyer of Honduran coffee but recently the USA has closed the gap. In 2016 about 60% was exported to Europe, 30% to North America, and the remaining 10% to other parts of the world.

The coffee sector is a key driver of rural economic activity and an important source of income. It is estimated that about 110,000 families have coffee as a primary income. 92% of these producers are smallholders that form the backbone of the rural economy. In addition to the farmers, coffee provides employment to an estimated 1 million people. One in 10 workers, and one in five rural workers, are employed in the sector. Around half of these workers live in extreme poverty.



Coffee and land use



In the major coffee regions coffee covers up to 50% of agricultural land. Honduras has one of the highest deforestation rates worldwide and the establishment of coffee has been a major driver of this development. Since 1990 about 45% of natural forests have vanished and were converted to other land uses. In 2015 forests covered about 40% of Honduran territory, down from over 70% in 1990. Of the area with forest cover about 20% (or 1.1million ha) were affected by reduced canopy cover, symptomatic of coffee expansion. In some regions, 50% of post-deforestation land use is for coffee. Some efforts to replant forests exist, which means that about 40% of remaining forest is protected area. All land above 1800masl is protected and should not be used for agriculture[4].

Predominant production systems

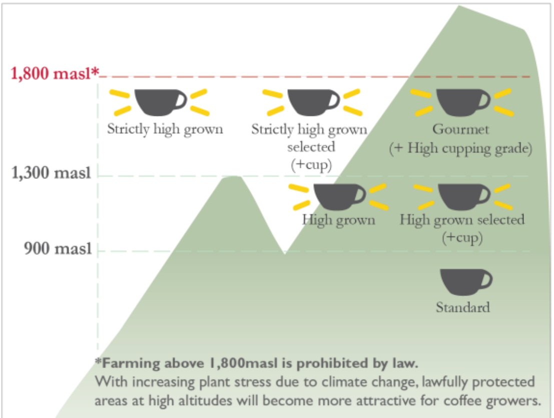
The bulk of Honduran coffee is higher-value washed Arabica, with Honduras's share of world Arabica coffee exports rising from 2.3% in the 1990s to 4% over the last decade. Robusta is not produced.

Most smallholder producers diversify their system planting primarily maize, beans and sorghum for self-consumption, little of this is commercialized. Depending on the ecological zone and market access fruits and vegetables are also produced.

Most coffee is produced under shade. Some sources claim 98%[5], others differentiate traditional diverse shade systems (35%), low diversity shade systems (45%) and full – sun production (20%) [6].

From 2007/08 until 2015/16 the share of differentiated or specialty coffee grew from 7% to 19%. Fair Trade/Organic coffee made up 32% of the differentiated coffee, followed by UTZ Certified with 24%, Certified Organic with 17%, Fair Trade 8%, Rainforest Alliance 8%, Café Practices 6% and 5% others or combinations. **Honduras differentiates 6 quality grades:**

In 2016 only high grown and above was exported; standard coffee was no longer included in the statistics.



Productivity Indicators

Smallholders produce 95% of total production on farms with less than 7ha relying mostly on family labor. Three segments of producers are differentiated: a third of coffee is produced by 70% of smallholders with farms of less than 2ha. On 2–7ha 25% of producers harvest another third of the total, and the 5% of producers with plantations of more than 7ha harvest the remaining third.

Despite the growing productivity in 2012 the average monthly income among coffee workers was about HNL2700 per month (~USD140). Around half of the workers in the sector live in extreme poverty, and over two-thirds are poor.

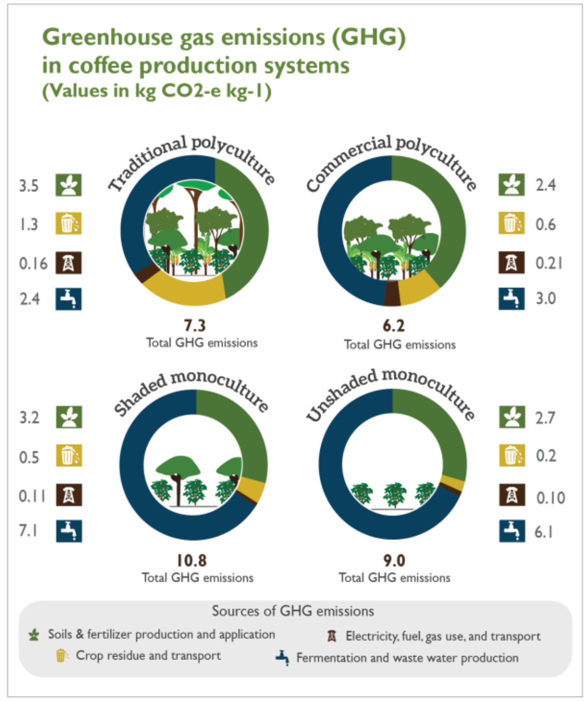
Following the coffee price crisis (1998/99 to 2002/03) and the rust epidemic (2012–2014) extensive replanting efforts took place. It is estimated that now 65% of plantations are less than 9 years old. Thus, declining productivity caused by aging plants will not represent a problem for the next 10 years.

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 [7].

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[8].

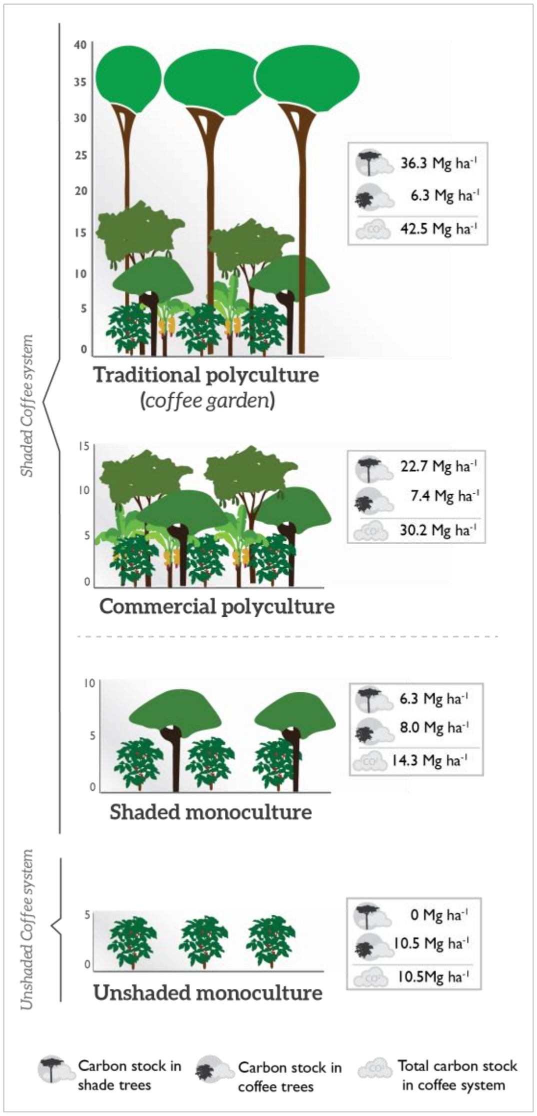
Polyculture systems have a lower mean carbon



footprint, of 6.2–7.3 kg CO_2-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 foot print reveals that 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 trees, the use of their wood to substitute for fossil fuel 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 and marketing in the country

About 87% of farms are male- and only 13% are female-led. The average age of farmers is 46 years and education is usually limited to 6 years of elementary school. Rural communities have very limited access to health care.



Most producers diversify their systems because in years with low yields or prices household food security is threatened. The coffee crisis around the turn of the millennium resulted in a substantial share of coffee farms abandoned and producers migrating to urban areas. Many coffee farmers were able to eat little more than maize and beans; meat and milk products were unaffordable.

Honduran coffee production is located in the Central American Dry Corridor. The region faces recurrent droughts, excessive rains and severe flooding, affecting agricultural production.

Three main pests and diseases affect coffee production in Honduras: Coffee leaf rust ("roya de café" [*Hemileia vastatrix]*), American leaf spot disease ("Ojo de Gallo*" [Mycena citricolor]*) and the coffee berry borer ("broca del café" [*Hypothenemus hamperi])*.

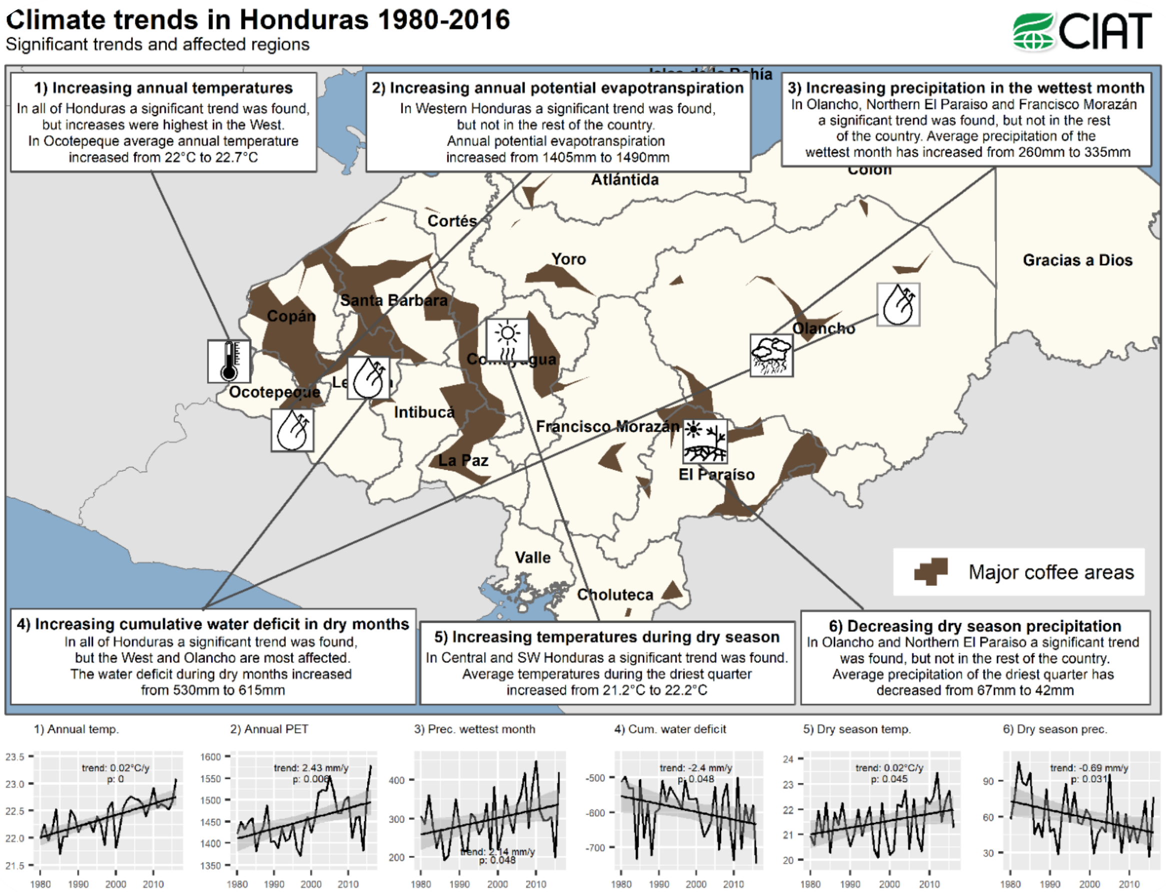
The coffee leaf rust crisis (2012/13) in Central America reduced yields in the region by about 15%. Favorable conditions and increasing minimum temperature are a plausible driver of this outbreak. Honduran producers were not as hard hit as other countries but the disease affected about 25% of areas, mostly towards the West. The recovery was estimated to cost about 100 million USD including extensive replanting with resistant varieties.

Leaf spot disease is also a fungal disease that strives under moist conditions on farms caused by high rains or high shade cover. Some of the most widely used rust-resistant varieties are suspected to be susceptible to leaf spot disease.

The most important pest is the coffee berry borer which plants its eggs into the fruits. The highest incidence occurs at the onset of the wet season and management is mostly manual. The coffee berry borer has been shown to benefit from higher temperatures through higher reproduction rates and is increasingly a problem at higher altitude

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. 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 and to cause 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 2016. Next, we will report changes that were projected by global climate models in a climate change scenario of intermediate severity.



Observed risk and trends

Coffee production areas in Honduras 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 Honduras. 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. To make things complicated, start and endpoint of trend analysis may affect the detection of trends, or they may sometimes be a function of natural variability over multiple years. 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.

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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 CRU TS v. 4.01 interpolated monthly climate data (Harris et al. 2014) 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 0.5° grid cell of Honduras 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.

When is the dry season in Honduras?

Months with less than 50mm precipitation are generally considered a dry month for coffee. In Honduras this threshold coincides with the driest quarter of the year. The driest quarter begins in January for most coffee regions in Honduras, although in the extreme South the onset may be in December and towards the center a little later in February. Coffee harvest can be expected towards the end of wet months and the highest green coffee availability may be expected during the driest quarter.

What is potential evapotranspiration?

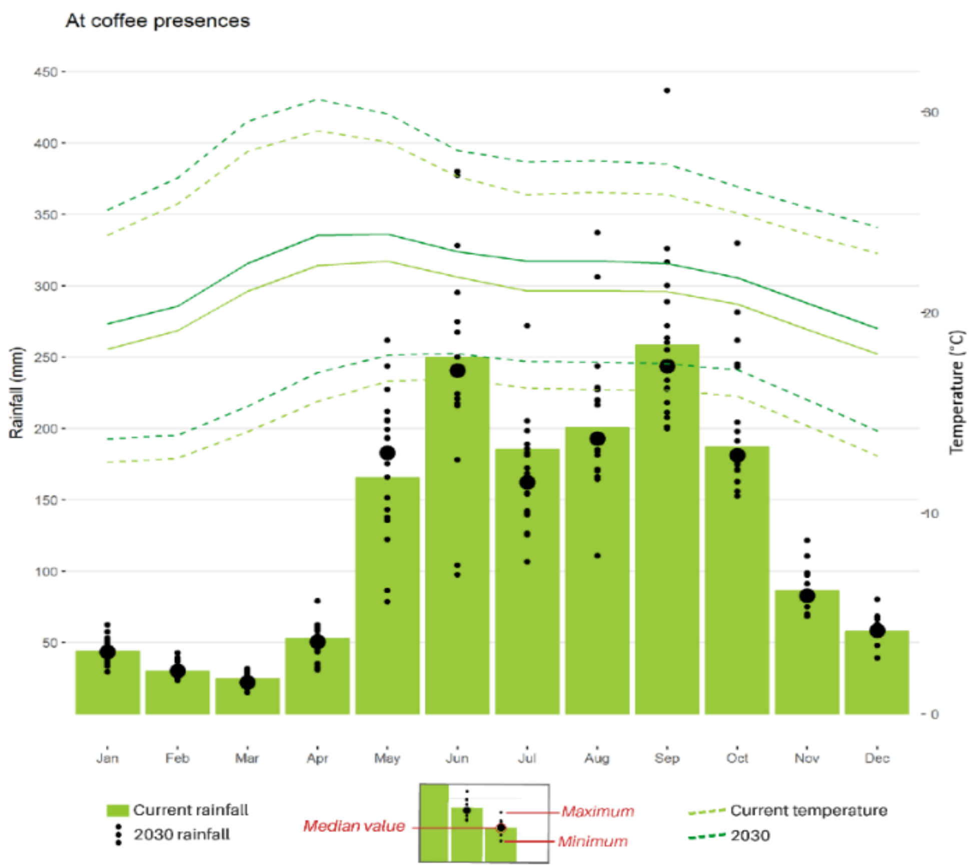
Evapotranspiration is the combined process of evaporation from the Earth's surface and transpiration from vegetation. Potential evapotranspiration (PET) is the amount that would occur if sufficient water were available. It is estimated using temperature, vapor pressure, cloud cover and wind speed in the Penman Monteith method (Harris et al. 2014). The cumulative water deficit at the end of the dry season is the cumulative excess PET over precipitation.

Projected climatic changes

The annual mean temperature was projected to increase by 1.6°C-1.9°C until mid-century. In line with the current trend the increase was projected to be higher in the West, than in the East of Honduras. Changes in total annual precipitation were limited to -0.4 % (Caribbean Coast) to -3.8% (West) averaged over all projections. This spatial pattern is similar to already observed insignificant changes over the past decades but masks potential changes in seasonal peaks.

The climate diagram that combines the current distribution of precipitation and temperature shows that there is an unambiguous trend to higher temperatures at coffee locations. The seasonal distribution of rainfall will likely remain similar. The most likely precipitation during the dry season is of similar amounts as currently. May precipitation may increase compared to current conditions with possible reductions in the following months. However, the wide range of projections reflects the difficulty to predict future precipitation.

The projected temperature increase and mean reduction in precipitation make droughts more likely and potentially more severe for coffee production. Studies that examined the potential severity of drought in the Central America region consistently projected a tendency to higher water stress[9]. Despite the uncertainty of projections, stakeholders should therefore prepare for more efficient water management.

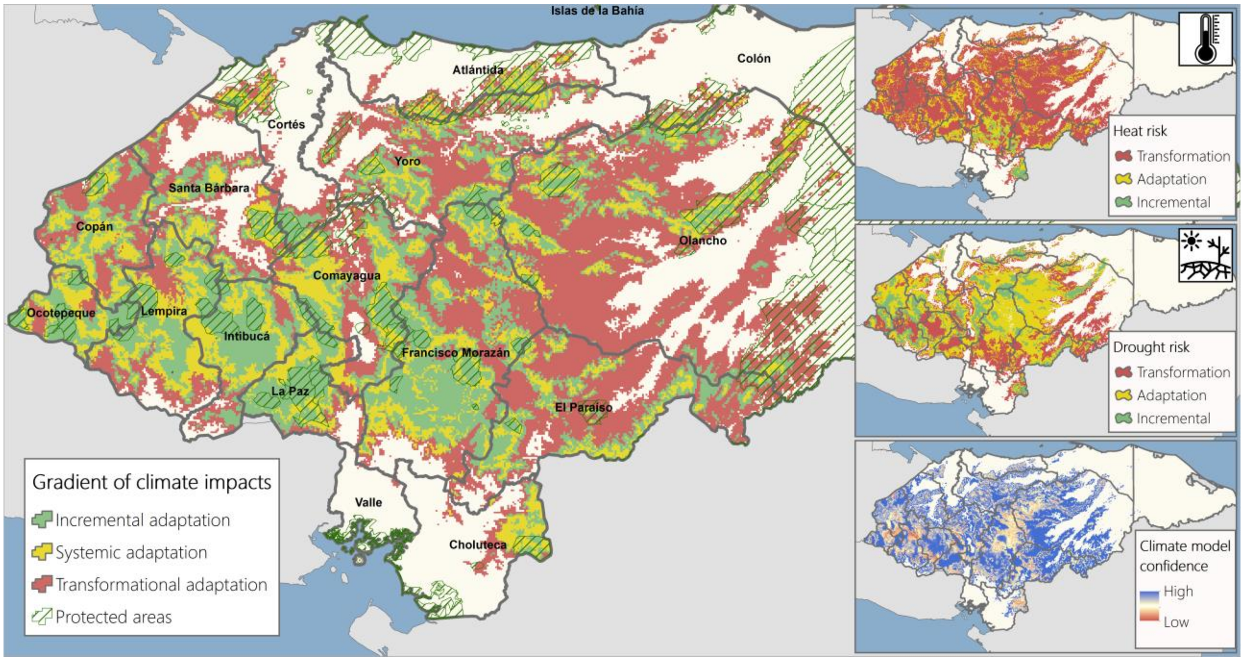


How are future climate projections generated?

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 efficient 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 the historic 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. The gradient shows the most likely degree of necessary adaptation effort across several potential future climate developments.

Incremental adaptation

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:
- Cover crops for soils management
- Use of permanent shade
- Selection of P&D resistant varieties

Additional coffee practices:
- Soil moisture retention (mulch coverage)
- Low cover crops
- Use of temporary shade
- Live fences
- Windbreaker curtains

Optional:
- Drip irrigation
- Water harvesting
- Water retention polymers
- Biochar
- Grafting Arabica onto Robusta rootstock

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:
- Cover crops for soils management
- Use of permanent shade
- Selection of P&D resistant varieties (once available, abiotic stress tolerant varieties)
- Soil moisture retention (mulch coverage)
- Low cover crops
- Use of temporary shade
- Live fences
- Windbreaker curtains

Additional coffee practices:
- Drip irrigation
- Water harvesting
- Water retention polymers
- Biochar
- Grafting Arabica onto Robusta rootstock

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

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:
- Cover crops for soils management
- Use of permanent shade
- Abiotic stress tolerant varieties
- Soil moisture retention (mulch coverage)
- Low cover crops
- Use of temporary shade
- Live fences
- Windbreaker curtains
- Crop diversification (on-farm)
- Drip irrigation
- Water harvesting
- Water retention polymers
- Biochar
- Grafting Arabica onto Robusta rootstock

About 45% of the area that is potentially suitable under current conditions will become unsuitable for coffee production without adaptation. A fifth will require substantial adaptation efforts to production systems. The remaining third will be less affected and will only require incremental adaptation to improve the resilience of the system. We found a clear relationship of these impacts with altitude. The lowest suitable regions will be 200m higher in altitude than under current conditions. We could not find a clear relationship between impacts and dry season characteristics, probably caused by the high precipitation uncertainty of global climate model projections.

Altitude	Adaptation strategy	Honduran grade approximation
<1000	Transformation	Standard
1000–1200	Systemic adaptation	High grown
1200–1500	Incremental adaptation	Strictly high grown
>1500	Sustainable expansion	
>1800	Exclusion	Protected areas

Previously sub-optimal sites will likely become uneconomical for coffee. This trend is already evident in the gradual disappearance of Honduran Standard grade coffee in the last decade. High grown grade coffee will in part struggle to remain productive unless comprehensive adaptation measures are implemented. Strictly high grown grade will require incremental management changes to remain productive. As higher altitudes become more suited for coffee production expansion must be implemented with care to protect ecosystem services that sustain regional productivity. Areas above 1800masl may become attractive for coffee production in the future but measures should be taken to exclude protected areas from value chains.

In general, Eastern Honduras (Olancho, El Paraiso, Francisco Morazán) will be more affected by climate change than the West. Its lower slopes will require transformative adaptation. For higher altitudes the model projected high adaptation needs, either because of significant changes, or because there was high disagreement of global climate models. Only the highest locations were projected to remain suitable, but these are often in protected areas and cannot be used for coffee production.

Impacts will be relatively lower in Central Honduras (La Paz, Comayagua, Yoro). In these departments, only the lowest areas will become unsuitable and there was better agreement of global climate models. High (systemic) adaptation efforts are required to keep coffee productive as few areas with low adaptation needs can be found outside of protected areas.

The West (Lempira, Ocotepeque, Copan, Santa Barbara) will retain area suitable for coffee production even outside of protected areas. Intermediate altitudes will require systemic changes to remain viable and low areas will likely transform.

Which emissions scenario was used?

We used projection data from 19 different GCMs in an intermediate emissions scenario (RCP 6.0). More optimistic scenarios assume that net carbon emissions become zero in the near future (RCP 2.6), an assumption that appears unfeasible from our perspective. The commonly used RCP4.5 emissions scenario projects warming of comparable degree by mid-century but is more optimistic towards the end of the century. Finally, in the pessimistic RCP8.5 scenario GHG emissions keep growing resulting in extreme warming. Several publications show that in this scenario coffee would struggle to survive. We therefore decided that RCP6.0 is an adequate choice to guide adaptation.

How was the impact gradient determined?

To determine zones of different degree of climate impact we modeled changes in bioclimatic suitability for coffee under present and 2050s climate conditions using a machine learning classification model. First, a database of locations where coffee is currently cultivated was assembled. Second, monthly climatological means of the 1950-2000 period, interpolated onto a 0.5 arcminute grid, were downloaded from the WordClim database (Hijmans et al., 2005), representing our current baseline climate. They were used to calculate 19 bioclimatic variables commonly used in modeling of crop suitability (Nix, 1986). Third, applying Random Forests in unsupervised variation to biologically meaningful bioclimatic variables, different clusters of coffee suitability were detected within the occurrence data. These clusters can be interpreted as different climate zones all of which allow for coffee cultivation, yet under different climate conditions. Fourth, using all bioclimatic variables Random Forest classifiers were trained to distinguish between suitable areas (falling into one of the suitable climatic zones) and unsuitable areas for coffee. The classifiers were applied to climate data from for 19 climate scenarios of the 2050s from different climate models. This resulted in 19 distinct suitability maps for the 2050s.

Our modeling approach is a comparison of the distribution of climate zones in which coffee is currently produced and their distribution under future climate scenarios. This means that we considered the adaptive range currently available in Central America, but not a possible expansion of this range by novel technologies or technology transfer from other countries. Adoption of adaptive agricultural practices (e.g. novel varieties, irrigation, or shading) that expand the climatic range under which coffee may be produced profitably may result in alternative developments of the distribution of coffee in the future.

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 Honduras

Farm level adaptation

CSC practices	Adaptation level	Adaptation benefit	Total Climate Smartness
Cover crops soil management	1	FDHR	5
Use of permanent shade	1	FDHR	5
Selection of rust-resistant varieties	1	R	2
Low cover crops	2	FDHR	4
Soil moisture retention (mulch coverage)	2	FDHR	4
Use of temporary shade	2	FHR	3
Live fences	2	HR	3
Windbreaker curtains	2	HR	3
Rainwater harvesting	3	FDHR	3
Water retention polymers	3	DR	3
Drip irrigation	3	FDR	3
Biochar	3	DHR	3
Application of lime sulfur to control coffee rust	3	R	2
Gypsum application to soil	3	FDR	2
Swales	3	HR	2
Grafting Arabica Scion onto Robusta rootstock	3	DR	1
Use of deeper bags	3	DR	1
Use of mycorrhiza in seedlings and nurseries	3	DR	1
Use of trichoderma	3	DR	1

F – Flood/torrential rain/erosion; D – drought; H – Heat; R – Resilience

Additional information about the practices can be found in the annex or at Coffee & Climate [10].

Renovation with adapted varieties

Renovation and rehabilitation (R&R) of poor yielding coffee trees with improved varieties that are tolerant of abiotic stress or resistant to important disease threats is a key tool to maintain a high coffee productivity in a changing climate. Despite the young age of plantations, about 70% of Honduran farms remain susceptible to rust outbreaks.

The Honduran Institute of Coffee (IHCAFE) [15] has the infrastructure and qualified technical-scientific personnel to provide planting material. The program to verify nurseries and seed production by World Coffee Research [16] may provide additional support to access quality planting material. In the Central American region IHCAFE is one of the few institutes that maintained its research and development program and as a result was able to release three rust resistant varieties: the Catimores IHCAFE 90 and Lempira, and the Sarchimor Parainema.

Lately, the resistance of the variety Lempira was overcome by a novel rust strain and is therefore no longer recommended for R&R. Rust resistance that was derived from the Timor hybrid may be relatively short lived, and the resistance of varieties in this class may be overcome slowly by novel rust races. In addition, IHCAFE 90 is said to have an inferior cupping profile. **Parainema is therefore the recommended choice**.

In addition, the following varieties could be used:

Varieties from seeds	F1 hybrids from cloning
Sarchimors: Marsellesa, Obatá and Tupí	Hybrids Promecafe-CIRAD-CATIE
Cavimor group: Catiguá MG2	Hybrids ECOM-CIRAD

In general, rust resistant varieties have also shown an improved tolerance of drought stress, and a better convalescence after other types of physiological stress. This may be explained by heterosis effects, or hybrid vigor.

Even though climate change adaptation has not been an objective during the development of these varieties, these characteristics can be considered a key advantage that justifies their adoption. However, the full potential may only be achieved in combination with adequate agronomic management and novel varieties should be developed that aim to reduce the impact of drought and heat on productivity.

Systemic and enabling interventions

Coffee producers at locations that are severely affected by climate change will need income alternatives. **Diversifying production** can be a measure to reduce climate shock risk to household income. However, oftentimes field crops don't offer the same income and ecosystem services benefits as coffee. Other tree crops are therefore preferential. 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 Robusta in most Honduran coffee regions [12].

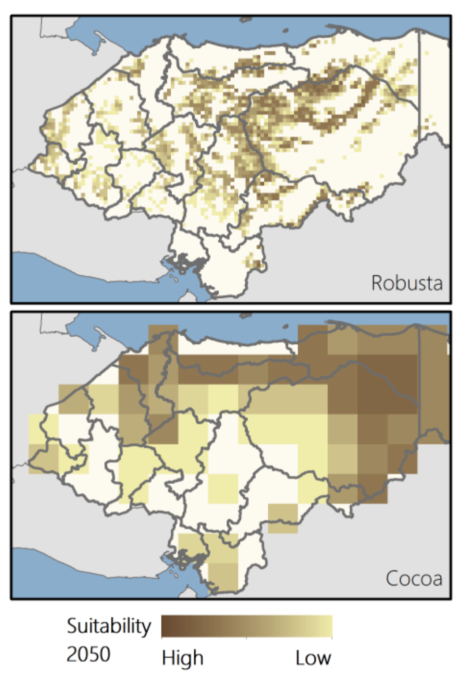
Index-based weather insurance offers a new promise for reducing climate risks. Pay outs are triggered by pre-determined weather events and thus does not require verification of losses. Such index insurance may avoid problems of adverse selection and moral hazard. It also has minimal transaction costs, 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.

Ecosystem-based Adaptation (EbA) is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change. Many farm-level practices have external benefits when implemented at landscape scale. In addition, the restoration of degraded areas or forest patches, or protection of riparian vegetation can improve the resilience of a landscape. Such measures aid to keep moisture in the landscape and can effectively reduce temperature [13].

A major reduction in deforestation is needed to mitigate climate change and biodiversity loss in Honduras. Climate Smart Coffee has to eliminate deforestation from the supply chain. To achieve broader impact **zero-deforestation policies** by companies need to avoid leakage, lack of transparency and traceability, selective adoption and smallholder marginalization. For Honduras Terra-I offers real time deforestation monitoring and early detection warnings that can be used by public and private stakeholders. There are ambitions to improve the detection of coffee driven deforestation [14].

Adoption and scaling mechanisms

Understanding impacts on production and identification of more resilient practices on its own does not lead to widespread adoption. Farmers will need information, training and incentives to change practices. Active efforts to scale out climate smart practices are a priority to secure long-term sustainability of the 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, and with a forward-looking approach.

About 85% of Honduran farmers are associated with institutions but the training benefits received are often inadequate. IHCAFE is understaffed to reach all 100,000 producers and cooperatives don't act as agents of innovation. 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. We suggest alternative scaling pathways for climate smart coffee: Voluntary certification, carbon insetting, impact investing, private sector training.

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. Rainforest Alliance (Utz), Organic and Fairtrade International currently certify about 20% of Honduran coffee production. Certifiers are able to provide economic incentives and innovative training to a large segment on farmers.

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 insetting 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. 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 CSA 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 CSA approaches that can be mainstreamed by the more risk-adverse large brands with their large constituencies to achieve CSA 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. The main impact investment agencies annually loan about USD 400m to producer organizations. Impact 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 CSA. However, currently incentive investors are limited in their constituencies.

Adaptation		FARMER	PRODUCER ORGANIZATION	TRADER	ROASTER
Incremental adaptation	Practices	Cover crops, fertilizers, GAP	Good governance, transparent pricing & payment mechanisms, extension & credit	Good governance, transparent pricing & payment mechanisms	Traceability, transparent pricing & payment mechanisms
	Strategies	Organic matter management within the farm, conservation of riparian areas	CSA adapted extension services, improved processing & post harvest, access to adapted germplasm	Product differentiation, carbon insetting	Product differentiation, carbon insetting
	Enablers	CSA extension, weather stations for better forecasting, carbon insetting, incentivizing process vs quality	Quality differentials, cupping labs, CSA credit (R&R), access to adapted germplasm (WCR), weather stations information, knowledge management	Price differentials, access to adapted germplasm (WCR), information, knowledge management	Consistent price differentials, earmarks for WCR, information & knowledge management, transparent trade & payment processes
Systemic adaptation	Practices	Irrigation, novel varieties, novel soil management	Good governance, transparent pricing & payment mechanisms, extension & credit	Good governance, transparent pricing & payment mechanisms	Traceability, transparent pricing & payment mechanisms
	Strategies	On-farm diversification (e.g. new crops for subsistence or commercial use), different processing methods	CSA adapted extension services, low-water processing, access to adapted germplasm, product diversification	Process-based differentiation (i.e. voluntary certifications), carbon insetting, volume incentives	Process-based differentiation (i.e. voluntary certifications), carbon insetting
	Enablers	Crop insurance (drought, hail), access to finance to support adaptation	Adapted germplasm (WCR), weather stations information, knowledge management, crop insurance (drought, hail), access to finance to support adaptation	Access to adapted germplasm (WCR), information, knowledge management, crop insurance (drought, hail), access to finance to support adaptation	Earmarks for WCR, information & knowledge management, transparent trade & payment processes, carbon insetting
Transformation	Practices	Switch to robusta, better adapted non-coffee crops	Good governance, transparent pricing & payment mechanisms, extension & credit for non-coffee crops	Good governance, transparent pricing & payment mechanisms for non-coffee crops	Traceability, transparent pricing & payment mechanisms for declining/ disappearing coffee production
	Strategies	Diversify livelihood strategies away from farming or out of farming entirely	Identify new crop options, provide access to technologies and training, build new commercial relationships	Identify new commercially viable crops to replace coffee	Diversify coffee sourcing regions
	Enablers	Developing new value chains for new cash crop systems	Market information, commercial contacts with non-coffee buyers	Market information, commercial contacts with non-coffee buyers, access to adapted production technologies, credit and crop insurance	Information on other viable coffee regions for quantity and quality requirements

Icons created by CIAT and Symbolon, Thomas' designs and Gan Khoon Lay from the Noun Project

Policy Environment

Institutions

The **Consejo Nacional del Café (CONACAFE)** is the coordination body that formulates coffee sector policies in Honduras, as well as emitting control and emergency measures to protect the public interest in the coffee sector. It consists of representatives of all relevant ministries and coffee sector organizations. Its policy decisions are carried out by IHCAFE.

The **Honduran Coffee Institute (IHCAFE)** is the lead research and outreach institute for the coffee sector in Honduras. With a total staff of about 1000 it is the lead technical implementer of sustainable coffee policies. IHCAFE has the following strategic axis: a) production and productivity, b) quality of Honduran coffee, c) promotion, d) diversification and e) financing of the coffee sector. It provides guidelines and regulations for the entire coffee value chain, establishes commercialization procedures and controls coffee production and exports.

The board of directors includes all large coffee stakeholder organizations: **AHPROCAFE** (Asociación Hondureña de Productores de Café) and **ANACAFEH** (Asociacion Nacional de Caficultores de Honduras) consist of local and regional committees that organize the interests of the 100,000 coffee farmers of Honduras. **LA CENTRAL** (La Central de Cooperativas Cafetaleras de Honduras) and **UNIOCOOP** (Unión de Cooperativas) represent the interests of cooperative members. In addition, **ADECAFEH** (Asociación de Exportadores de Café de Honduras) represents the coffee exporters and **TOSCAFE** (Asociación de Tostadores de Café) the roasters.

The ministries responsible for the formulation, coordination, execution and evaluation of public policies for the coffee sector are the **Secretary of Agriculture and Livestock (Secretaría de Agricultura y Ganadería - SAG)** and **MiAmbiente** (Secretary of Energy, Natural Resources, Environment and Mining - Secretaria de Recursos Naturales Ambiente y Minas) for climate change mitigation and adaptation policies. In addition, the **Honduran Presidential Office for Climate Change**, constitutes the superior instance regarding the approval and articulation of the public policies and investment related to Climate Change in Honduras.

The most important public finance institute for the coffee sector is the National Coffee Fund **FCN** (Fondo Cafetero Nacional or **FONDACAFE**). The FCN funds road and supply chain infrastructure in the coffee zones in Honduras but is currently not involved in climate change adaptation.

The **Central American Bank for Economic Integration (CABEI)** is a multilateral development bank focused on Central America and implements climate finance mechanisms.

A number of public and private banks provide farmers with credits. The most relevant ones are BANADESA and BANHCAFE. Loans are tied to extensive documentation and collaterals so that only few farmers can access this finance mechanisms. Loans are not tied to technical advice.

Policies

At national level four key documents provide the basis for adaptation and mitigation policies in Honduras. The **Country Vision 2010–2038 and National Plan 2010–2022** (Visión de País 2010–2038 y Plan de Nación 2010–2022) from 2010 calls for a systematic management of disaster risk management and adaptation and mitigation. The plan makes mention of 22 national development objectives, two of which are climate change related: restore one million hectares of forest area to access carbon markets, and to substantially reduce Honduras vulnerability to climate change. Furthermore, it establishes the need for a **National Climate Change Strategy** (Estrategia Nacional de Cambio Climático-ENCC) which was first described in 2010, and further elaborated in subsequent years. The ENCC provides a detailed description of immediate and long-term mitigation and adaptation objectives, and proposed action, for the entire country. It call for a systematic institutionalization of policies to reduce the vulnerability and increase the adaptive capacity in Honduras. The objectives include measures to improve the management of water resources, adoption of suitable crops, protection of ecosystem services (soils, water and forest resources) and support for resilient food systems.

The **Climate Change working group** of the **SAG** published the mitigation and adaptation plans for the agricultural sector (**Estrategia Nacional de Adaptación al Cambio Climático para el Sector Agroalimentario de Honduras** | 2015–2025). It establishes the basic criteria for climate action in Honduras: improve food security, effectiveness on short and intermediate time scale, prioritization of the most vulnerable sectors, within the authority of the SAG. Four strategic axis will seek to (1) strengthen the institutional capacity, (2) harmonize disaster response (drought/flood), (3) strengthen the technical capacity in the sector, and (4) develop innovation networks. The document makes mention of the coffee sector as a sector of high concern [17].

The 2013 **Climate Change Bill** (Ley de Cambio Climatico Decreto297-2013) regulates the principles and regulations to plan for and respond to climate risk in Honduras. It establishes, for example, that scientific uncertainty shall not hinder mitigation and adaptation action, the polluter pays principle, and the precautionary principle to protect the environment. The law defines key terms and establishes roles for the several institutions included in climate action.

Existing initiatives

Because of the high climate vulnerability of coffee production and the association with protected forest areas most sustainability and development initiatives include adaptation and mitigation dimensions. An example are the numerous programs to fight the rust epidemic, which was generally attributed to climate change. Such projects facilitated financing for replanting with resistant varieties and provided technical assistance to farmers to promote good agricultural practices, such as the adequate use of safe and effective fungicides. Other activities aimed at the development of early warning systems for rust based on weather patterns and monitoring of various rust races. Other projects aimed at reducing the environmental footprint of coffee and development of business models based on sustainable coffee production.

MiAmbiente, together with SAG, IHCAFE and CABEI, is developing a **NAMA Café** (Nationally Appropriate Mitigation Action Coffee). The NAMA Café seeks to transform coffee production in Honduras towards sustainable low-carbon production. The NAMA Café will 1) introduce comprehensive agroforestry systems management practices in coffee farms, 2) introduce more efficient fertilizer use practices, 3) incorporate waste treatment technologies in coffee mills, 4) replace mechanical-electric coffee drying by solar technologies, 5) design an MRV (Measurable, Reportable, Verifiable) system of emissions for both the production and processing levels, 6) facilitate access to finance to farmers and mill operators, and 7) design marketing strategies to help producers access to differentiated markets. The financial support mechanism will be based on the creation of a support fund that will offer concessional loans, guarantee schemes and other tailor-made financial products for coffee farmers and mill operators who adopt low-carbon technologies and practices, leveraging multilateral and commercial banks' funds for low-carbon technologies.

Outlook

Private sector initiatives have the potential to contribute to effective adaptation and reduced emissions, ideally jointly with supportive public policies. Low adoption rates of climate smart practices may be a challenge due to the unclear business case. Producers must typically bear most of the costs of shifting towards climate smart production systems and do not always perceive the benefits. Governments can support the private sector by creating effective regulation, endorsement of private standards, facilitation of supply chain transparency, covering compliance cost for marginal producers and creation of mechanisms to avoid free-riding. To increase adoption, compliance with sustainability requirements must be economically and technically feasible for producers. Supply-chain initiatives can have unintended social consequences by entrenching positions of powerful actors and excluding smallholders and indigenous groups from market access when standards non-compliance is criminalized. Climate change may further marginalize poorer producers, as farmers with good access to capital and technology are more likely to be able to manage emerging climate risk.

Private sector initiatives should therefore encourage smallholders to participate in climate smart programs 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

Wilfredo Solorzano owns a 10 ha farm, half of which is used for coffee production while the other half is conserved. He cultivates over 24,500 Lempira coffee plants, of which 71% has been renovated. With training he received from Hanns R Neumann Stiftung through the initiative for coffee&climate, he has seen firsthand the impact that climate adaptation practices can have on farm resilience.

"I was born in Cunce, San Marcos Ocotepeque, Honduras. I have worked in coffee since I was a teenager. I had always cultivated coffee the way my parents taught me. I became deeply involved attending all the [HRNS] trainings and meetings, which led the program officers to select me as a community leader. I began implementing the practices we learned on my farm, and sharing with farmers to change their mindset and adopt better practices. From soil conservation and climate change adaptation practices to waste water treatment, the practices had a tremendous impact on my farm management. This past harvest season I received an award for the best coffee quality within the cooperative. None of that would have been possible without the support from the project."

After the heavy rust attack in Central America, Will tried to manage the rust and to recover his plantation, but his strategy was not working. The coffee trees were too old to respond, so his productivity remained low, and his investment was not producing a return. In July 2015, he decided to renovate integrating CSA practices he learned from the HRNS trainings.

He changed his planting system from 2 x 1 meters to 2.5 x 0.8 meters. In both systems he had the same number of coffee trees per hectare, but in the wider system he was able to introduce Brachiaria as a cover crop. Cover crops help during the dry season to reduce high soil temperatures and increase soil moisture. He also uses gypsum to stimulate the root system and organic fertilizers.

After one year implementing these practices, his plantation began performing a lot better than the rest of his neighbors. In early 2017, after one of the driest years recorded in Eastern Honduras, some of his neighbors' plots were completely damaged by the lack of rain, but Will´s plantation was healthy and thriving, proving how effective CSA practices are.

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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.

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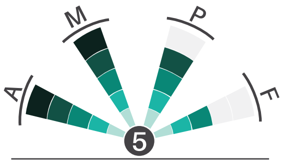
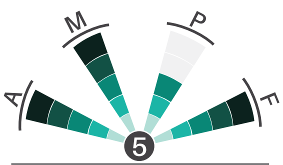
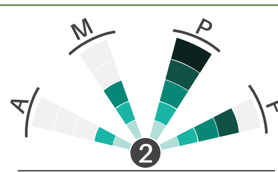
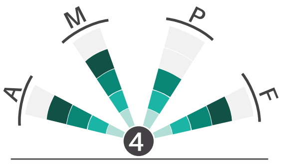
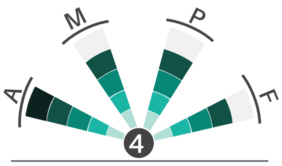
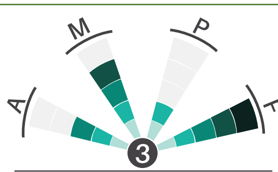
Annex

CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Cover crops soil management *Cover crops refer to a wide range of annual or perennial plants that can be sown to cover bare ground. Careful management is required to ensure that growth of the cover crop is not too vigorous to compete with the coffee trees.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of technical assistance	Buffers extreme temperatures Buffers the impacts of extreme rain Increases water infiltration or retention in the crop Improves soil structure Prevents erosion and landslides Improves soil fertility	Avoids emission of GHG through reduced use of fertilizers or pesticides Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon seque Lack of technical assistance stered in the soil Prevents GHG emissions by reducing the use of crop burning	Improves crop growth Improves fruit load Improves flowering Reduces incidences of pests and diseases.	Low cost practice, accessible to small-scale producers Easy-to-use practice Increases firewood availability
Use of permanent shade *Shade tree management helps protect the coffee plant from excessive heat and reduces its exposure to direct sunshine. Moreover, shade trees can act as wind-breaks and also contribute to soil fertility. However, there are also downsides that need to be considered in any management plan.* Read more	 Limitations for adoption • High implementation costs • Lack of technical assistance	Buffers extreme temperatures Increases water infiltration or retention in the crop Buffers the impacts of extreme rain Protects against extreme winds Prevents erosion and landslides Increases tolerance to drought Improves soil fertility	Avoids emission of GHG by reducing the use of fossil fuels (eg, transport of materials, use of machinery, etc.) Prevents GHG emissions by reducing deforestation of forests or wetlands Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon sequestered in the soil Avoids emission of GHG through reduced use of fertilizers or pesticides	Reduces incidences of pests and diseases Reduces the possible post-harvest losses Improves cup quality	Increases wood availability Diversifies income generation of small-scale producers Increases income of small-scale producers Takes advantage of local small-scale producers' knowledge Uses local and renewable inputs
Selection of rust-resistant varieties	 Limitations for adoption • Quality, concerns. • Susceptibility to Leaf Spot disease (Ojo de Gallo)	Increases or maintains crop yield in extreme events Prevents or reduces the impact of common pests and diseases due to C.C.	Captures carbon sequestered in the crop biomass (or trees in the crop) Avoids emission of GHG through reduced use of fertilizers or pesticides	Improves fruit load Reduces incidences of pests and diseases Improves crop growth Reduces the possible post-harvest losses Improves flowering	Increases income of small-scale producers Low cost practice, accessible to small-scale producerr

Total smartness points

Transformation
Systemic adaptation
Incremental adaptation

(Continue)

CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Low cover crops *Non-leguminous crops like Brachiaria grasses have vigorous root systems which help to penetrate compacted soils, increase rainwater infiltration and increase soil organic matter.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of funding	Improves soil structure Buffers extreme temperatures Improves soil fertility Buffers the impacts of extreme rain Increases or maintains crop yield in extreme events	Prevents GHG emissions by reducing deforestation of forests or wetlands Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon sequestered in the soil	Reduces the possible post-harvest losses Improves flowering	Increases wood availability Increases income of small-scale producers Easy-to-use practice Low cost practice, accessible to small-scale producers
Soil moisture retention (mulch coverage) *Fallen leaves or residues from pasture protect the soil from erosion, regulate soil temperature, retain soil moisture and suppress weed growth.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of technical assistance • Cultural constraints	Buffers extreme temperatures Increases water infiltration or retention in the crop Buffers the impacts of extreme rain Increases or maintains crop yield in extreme events Prevents erosion and landslides Improves soil fertility	Avoids emission of GHG through reduced use of fertilizers or pesticides Avoids emission of GHG by reducing the use of fossil fuels (eg, transport of materials, use of machinery, etc.) Increases the carbon sequestered in the soil	Improves crop growth Improves flowering Improves fruit load Reduces the possible post-harvest losses	Easy-to-use practice Low cost practice, accessible to small-scale producers Takes advantage of local small-scale producers' knowledge Uses local and renewable inputs
Use of temporary shade *Fast-growing plants between coffee rows that are removed as coffee trees and permanent shade trees develop.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of access to technology / practice • Lack of funding • Lack of technical assistance	Buffers extreme temperatures Prevents erosion and landslides Improves soil fertility Buffers the impacts of extreme rain	Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon sequestered in the soil Prevents GHG emissions by reducing the use of crop burning	Reduces incidences of pests and diseases Improves crop growth	Uses local and renewable inputs Easy-to-use practice Low cost practice, accessible to small-scale producers Takes advantage of local small-scale producers' knowledge Increases availability of food byproducts of producers

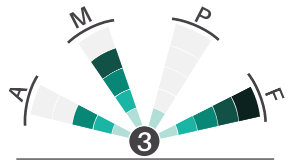
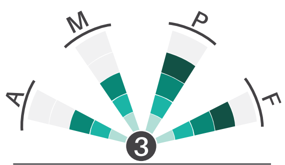
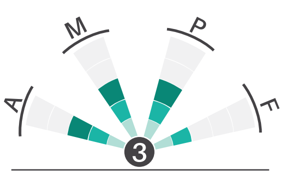
Total smartness points

Transformation

Systemic adaptation

Incremental adaptation

(Continue)

CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Live fences *Native trees predominant in the region planted to avoid the entry of external animals (livestock) and human activities.* Read more	 Limitations for adoption • Lack of technical assistance • Cultural constraints	Protects against extreme winds Improves soil fertility Prevents erosion and landslides	Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon sequestered in the soil Prevents GHG emissions by reducing deforestation of forests or wetlands	Reduces incidences of pests and diseases	Increases wood availability Easy-to-use practice Low cost practice, accessible to small-scale producers Uses local and renewable inputs
Windbreaker curtains *Fast growing biennials or perennials are planted across the slope and against the path of prevail-ing winds.* Read more	 Limitations for adoption • Lack of technical assistance • Little knowledge of the practice by producers • Lack of access to technology / practice • High implementation costs	Protects against extreme winds Prevents erosion and landslides Prevents or reduces the impact of common pests and diseases due to C.C. Increases or maintains crop yield in extreme events	Captures carbon sequestered in the crop biomass (or trees in the crop) Increases the carbon sequestered in the soil	Improves crop growth Improves flowering Improves fruit load Reduces incidences of pests and diseases	Increases wood availability Diversifies income generation of small-scale producers Increases income of small-scale producers Takes advantage of local small-scale producers' knowledge Uses local and renewable inputs Easy-to-use practice
Rainwater harvesting *Small in-field soil depressions or rainwater basins (about 0.6m x 0.6m x 0.3m deep) can reduce run-off from coffee plots and thereby give time for the water to infiltrate into the soil so that it can be used by the plant.* Read more	 Limitations for adoption • High implementation costs • Little knowledge of the practice by producers	Increases tolerance to drought Buffers extreme temperatures Increases water infiltration or retention in the crop Increases or maintains crop yield in extreme events	No impact	Improves crop growth Improves flowering Improves fruit load	Increases the availability of food by-products of producers Increases income of small-scale producers

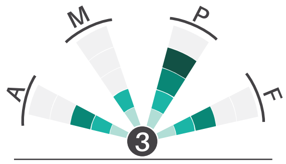
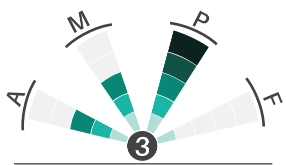
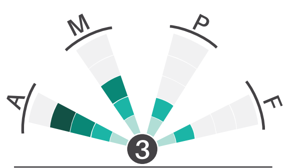
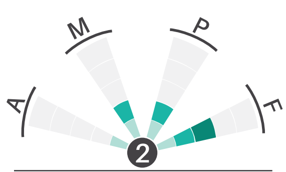
Total smartness points

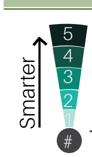
Transformation

Systemic adaptation

Incremental adaptation

(Continue)

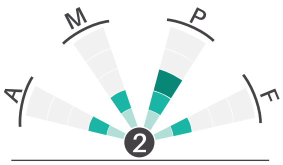
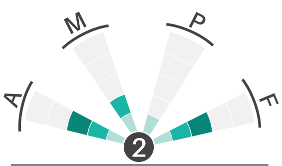
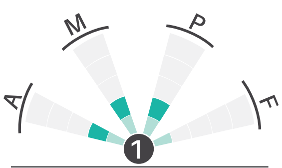
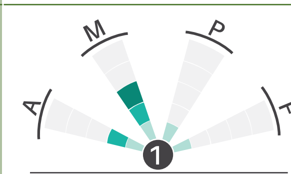
CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Water retention polymers *Mixed with the soil polymers can absorb large amounts of water and serve as a water reservoir for periods of drought*	 Limitations for adoption • Little knowledge of the practice by producers • Lack of technical assistance • Lack of access to technology / practice	Increases or maintains crop yield in extreme events Increases tolerance to drought Extends longevity of the crop Prevents or reduces the impact of common pests and diseases due to C.C.	No impact	Improves crop growth Improves flowering	Increases income of small-scale producers Easy-to-use practice Uses local and renewable inputs
Drip irrigation *With direct irrigation at ground level the water is directly targeted on to the root zone of the coffee. Evaporation losses are kept to a minimum and the limited area of wetted ground restricts weed growth.* Read more	 Limitations for adoption • High implementation costs • Lack of access to technology / practice • Lack of funding	Buffers extreme temperatures Increases or maintains crop yield in extreme events Increases tolerance to drought Extends longevity of the crop	No impact	Improves crop growth Improves flowering Improves fruit load Reduces the possible post-harvest losses Reduces incidences of pests and diseases	Increases income of small-scale producers
Biochar *Biochar is another name for charcoal, produced by heating wood or other vegetable-based materials in an oxygen-restricted chamber. When it is added to soil, especially heat- and drought-degraded soil, it can rapidly improve the soil's ability to store and then release nutrients.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of technical assistance	Increases water infiltration or retention in the crop Improves soil structure Increases tolerance to drought Improves soil fertility	Avoids emission of GHG through reduced use of fertilizers or pesticides Increases the carbon sequestered in the soil	Improves crop growth Reduces incidences of pests and diseases	Easy-to-use practice Uses local and renewable inputs
Application of lime sulfur to control coffee rust *Applying a lime sulfur mix ('caldo' in Spanish) to coffee leaves creates a physical barrier to prevent rust spore germination and/or penetration into the leaf tissue. The treatment may prevent or slow down disease development if applied at the right time.* Read more	 Limitations for adoption • Little knowledge of the practice by producers	Increases or maintains crop yield in extreme events Improves soil fertility	Avoids emission of GHG through reduced use of fertilizers or pesticides	Reduces incidences of pests and diseases Reduces the possible post-harvest losses	Uses local and renewable inputs Easy-to-use practice Low cost practice, accessible to small-scale producers

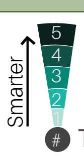


Total smartness points

Transformation
Systemic adaptation
Incremental adaptation

(Continue)

CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Gypsum application to soil *With certain types of soil, application of large quantities of gypsum (calcium sulfate) to the soil causes coffee roots to grow deeper, enabling them to access more moisture during dry seasons and prolonged periods of drought.* Read more	 Limitations for adoption • High implementation costs • Little knowledge of the practice by producers	Buffers extreme temperatures Increases tolerance to drought Buffers the impacts of extreme rain	Avoids emission of GHG through reduced use of fertilizers or pesticides	Improves fruit load Improves flowering	Easy-to-use practice Increases income of small-scale producers
Swales *Shallow, broad and vegetated channels designed to convey runoff.* Read more	 Limitations for adoption • High implementation costs	Prevents flooding Prevents erosion and landslides Increases tolerance to drought	No impact	Improves crop growth	Takes advantage of local small-scale producers' knowledge Easy-to-use practice Low cost practice, accessible to small-scale producers
Grafting Arabica Scion onto Robusta r ootstock *Some Robusta varieties may have deeper and more vigorous roots than Arabica varieties. By grafting the latter onto the former, resistance to drought may be enhanced. This is particularly appropriate in conditions where coffee trees are subject to attack from soil nematodes.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of access to technology / practice • High implementation costs • Lack of technical assistance	Increases or maintains crop yield in extreme events Prevents or reduces the impact of common pests and diseases due to C.C. Increases tolerance to drought	No impact	Reduces incidences of pests and diseases Improves crop growth	Increases income of small-scale producers
Use of deeper bags *Polybags, used to grow seedlings for 6+ months prior to planting out, vary in size but are rarely more than 20 cm deep. In conditions where rain is scarce or unreliable, using polybags that are 25 cm deep has resulted in seed-lings with more developed root systems that are better able to survive an extreme drought event once planted in the field.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of access to technology / practice • High implementation costs	Increases tolerance to drought Extends longevity of the crop	No impact	Improves crop growth	Easy-to-use practice



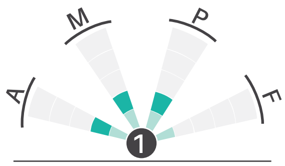
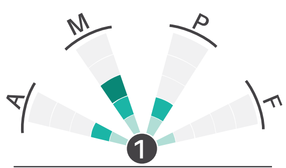
Total smartness points

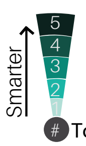
Transformation

Systemic adaptation

Incremental adaptation

(Continue)

CSA Practice	Climate Smartness	Adaptation (A)	Mitigation (M)	Productivity (P)	Family livelihoods(F)
Use of mycorrhiza in seedings and nurs-eries *Adding mycorrhizae to the soil of seedlings in polybags for both coffee and shade trees can improve root nutrition, because mycorrhizal fungi feeds on the substances that the roots exude, and in return produces nutrients that help the plant grow. This is especially relevant for degraded soils.* Read more	 Limitations for adoption • Lack of access to technology / practice • Little knowledge of the practice by producers • Lack of technical assistance	Prevents or reduces the impact of common pests and diseases due to C.C. Increases tolerance to drought Extends longevity of the crop	No impact	Improves crop growth Reduces incidences of pests and diseases	Easy-to-use practice
Use of trichoderma *Adding Trichoderma fungi to the soil of seedlings in polybags can have a num-ber of beneficial effects on the growing roots of coffee plants, building resilience of the plant to drought and other climatic stresses.* Read more	 Limitations for adoption • Little knowledge of the practice by producers • Lack of access to technology / practice • Lack of technical assistance	Prevents or reduces the impact of common pests and diseases due to C.C. Increases tolerance to drought	No impact	Improves crop growth Reduces incidences of pests and diseases	Easy-to-use practice



Total smartness points

Transformation

Systemic adaptation

Incremental adaptation