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Climate-smart Cocoa in Central America and the Caribbean

Towards resilient production at a scale

Key Messages

- Projections for climate change impacts on cocoa production in Central America and the Caribbean indicate that there will be important changes in the future distribution of suitable zones for this crop.
- The objectives of Climate-smart Cocoa (CSC) are: increasing productivity, adapting to climate change, and mitigating greenhouse gas emissions, with the purpose of building resilient livelihoods.
- To boost cocoa production in the region in the short and long term, we recommend the implementation of CSC practices.
- The CSC practices outlined in this document may be implemented immediately. The list was identified and prioritized with experts from Honduras, Nicaragua, Guatemala, the Dominican Republic, and El Salvador, and many practices are already known to farmers.
- Designing efficient adaptation processes within the framework of CSC represents a multidimensional challenge. This document organizes practices according to the following axes: 1) degree of climate change impact: incremental, systemic, or transformational adaptation; 2) type of extreme climate event, as a result of climate variability: intense rains, strong winds and storms, or drought; and 3) stage of crop development: nursery, establishment, or production.
- Implementing CSC practices at a scale requires appropriate strategies and an enabling environment to support farmers.

Climate-smart Cocoa (CSC) is a concept that brings together the goals of what is known as Climate-smart Agriculture (CSA) and adjusts them to the characteristics and needs of cocoa production. The concept of CSA was originally developed by FAO. Just like in the case of CSA, the main objectives of CSC are sustainably increasing productivity, enhancing climate change resilience, and reducing or mitigating greenhouse gas emissions, and its ultimate purpose is building resilient livelihoods for farmers.

At the individual plot level, resilient CSC production withstands gradual climate changes in the long-term (>10 years), and production recovers rapidly after an extreme climate event. Scaling up, the impact of farms on local climate should be taken into account, because cocoa farms constitute a significant portion of the Central American landscape. While the vast majority of farms have been established under agroforestry systems, the abandonment of farms and deforestation are sources of greenhouse gas emissions.

Thus, implementing climate change adaptation practices becomes necessary both to sustain productivity and to reduce emissions. On the other hand, the term adaptation refers to the ability to cope with potential negative effects of gradual changes in climate and extreme climate events on production.

This brief summarizes the results of participatory workshops and research on the implementation of CSC in Central America. Many of the practices proposed are already known to and used by Central American farmers seeking to reduce the risks for both the quality and quantity of their production. The interventions summarized in this document can be promoted at different technological, organizational, institutional, and policy levels, as they were developed in a participatory manner with regional experts to leverage the prioritization of known practices. These interventions may be implemented immediately to achieve the expected results in the future.

This study is the result of a joint initiative between the International Center for Tropical Agriculture (CIAT), the World Cocoa Foundation (WCF), and Rikolto-Latin America, with support from the United States Agency for International Development - USAID's Feed the Future initiative, and funds from the Swiss Agency for Development and Cooperation (SDC).

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Snapshot of Current Cocoa Production

Over 167,000 hectares are planted with cocoa in Central America and the Caribbean, mostly in the Dominican Republic (150,000 ha) and the rest in Nicaragua (9,907 ha), Guatemala (4,354 ha), Honduras (1,933 ha), and El Salvador (800 ha). Productivity (kg/ha) varies across these countries, ranging from 388 kg/ha in Honduras to 666 kg/ha in Nicaragua. The accreditation of production and crops with multiple certifications is common, especially in the Dominican Republic, Nicaragua, and Honduras. With the exception of El Salvador, the rest of the aforementioned countries are annually recognized as exporting fine and flavor cocoa by the International Cocoa Organization (ICCO).

Notwithstanding the extension of the crop, currently, this region contributes less than 1% of the world's traded cocoa. That has not always been the case: diseases, low prices, and loss of harvests, as well as lack of credit, investment, and support from government, led to the downturn of the cocoa sector in the early eighties, especially in countries like Costa Rica.

It is expected that current efforts to revitalize the sector will increase the share of international trade of Central American cocoa, where high-quality production also receives higher prices. Promoting fine or flavor cocoa production to differentiate the crop can lead to an increase in production in the short term. However, long-term plans are needed to enhance resilience, maintain the quality that characterizes cocoa from this region, and increase productivity (CSC objectives).

To maintain quality and increase productivity in the face of climate change, it is necessary to develop long-term plans designed to enhance resilience.

A geographical shift in the suitability of cocoa-growing areas will be unavoidable if adaptation measures are not taken. Therefore, different stakeholders from the cocoa value chain are increasingly requesting support in decision-making to orient adaptation, which is also crucial to sustain cocoa quality and commercial classifications, which provide access to high-value markets.

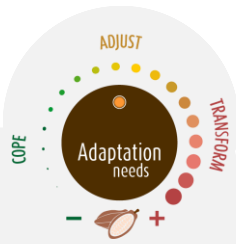
Projections of Climate Change Impacts on Cocoa

Although countries in Central America are relatively small emitters of greenhouse gases, this region is projected to be among the most affected by climate change. Cocoa farms in this region are vulnerable to a series of climate risks. The progressive increase in average temperature and the uncertainty regarding the distribution of rainfall during the rainy season will change the location of suitable areas for cocoa production observed in the map. The increase of climate variability and the occurrence of extreme climate events, such as El Niño, droughts, storms, strong winds, intense rains, and floods, will also represent a challenge for cocoa plantations in the future.

A geographical shift of the cocoa-growing areas will likely be unavoidable if adaptation measures are not taken.

The degree of climate change impact on cocoa in Central America and the Caribbean was assessed comparing future bioclimatic suitability (2040–2069, or “2050 period”) with current suitability (1950-2000). These degrees show the level of adaptation needed in different zones in the region for several future potential climate scenarios.

This study identified four categories of zones, according to the degree of climate change impact expected: those requiring **incremental adaptation**, those requiring **systemic adaptation**, those requiring **transformational adaptation**, and **opportunity zones**. Some cocoa plantations may be maintained with minimal or great adaptation efforts (incremental or systemic adaptation), while others are expected to become unprofitable, in which case it is recommended to transition to other crops or to make a radical

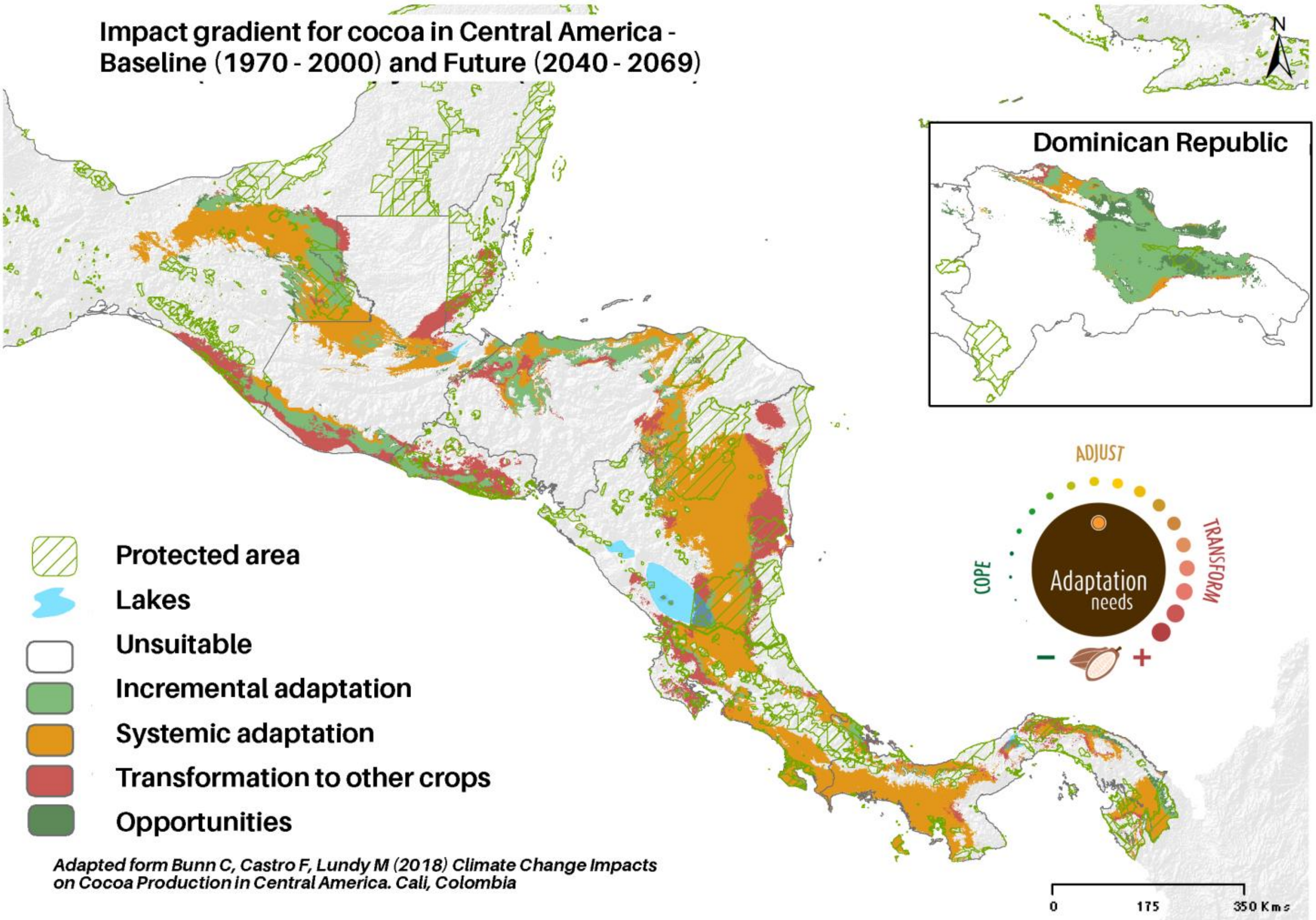


Three Degrees of Adaptation Effort

1 **Incremental Adaptation**: climate is most likely to remain suitable and adaption will be achieved through a change of improved practices, strategies and enablers (see Table 2). The altered patterns of pests and diseases, uncertain rainfall, as well as drought and heat, can affect the crop, but cocoa production will remain feasible.

2 **Systemic Adaptation**: climate is most likely to remain suitable, but with substantial stress in traditional production systems; adaptation will require a comprehensive change of practices and redesigning the system, in addition to external support to implement changes. Without changes, the risk for production will be unsustainable. Better adapted varieties, diversification, and financial mechanisms will be necessary to reduce risks.

3 **Transformational Adaptation**: climate is more likely to make cocoa production unfeasible. Adaptation will require redesigning the production system or switching to new crops. External enablers will be crucial to support change, because it will likely be more feasible and cost-effective to switch to other crops than to sustain cocoa production in these conditions in the future.



change in the management of the plantation to sustain it (transformational adaptation). On the other hand, some regions that were not suitable will gain suitability, according to future projections; these are referred to as opportunity zones.

For more details and to obtain information on climate change impacts on cocoa in the region, please see the Climate Change Impacts on Cocoa Production in Central America and the Caribbean Atlas: https://hdl.handle.net/10568/105604

The gradient indicates that most cocoa areas in the Dominican Republic will require incremental adaptation, while most of the cocoa zones in Central America will require systemic adaptation. Some zones, such as the eastern part of Nicaragua, will need transformational adaptation. A very limited number of zones studied will become suitable as a result of climate change.

The efforts for implementation at a scale should take into consideration long-term climate change projections, as these may help understanding if the zones where cocoa is currently produced will continue to have favorable climate conditions in the coming years. They are also useful to envision the necessary actions or investments to ensure cocoa production in the long-term.

CSC Practices to Address Long-term Climate Change

In light of the uncertainty inherent to future projections and the increased climatic variability across the region, this document recommends practices known and validated by local experts, such as shade management or improved planting with deeper holes and larger bags. These practices can increase the economic and social benefits for farmers, under a wide range of possible changes in future climate conditions. These are “no-regret” practices, i.e., they enhance resilience in the face of several future scenarios, and, in addition, they generate benefits in the short term, because the adaptation cost is relatively low compared to the benefits that may be obtained, which incentivizes their implementation at scale.

Practices originate from workshops held in Honduras, Nicaragua, Guatemala, the Dominican Republic, and El Salvador. Not all the practices were mentioned in all workshops; however, they are considered beneficial, regardless of the country in which they are implemented. The feasibility of these practices was further validated by a review of the scientific literature.

In this section and the Annex, we outline the recommended CSC practices in four different tables with supplementary information: Table 1 contains practices that enhance resilience in the face of climate change by climate impact gradient and the phenological stage of the crop; Table 2 outlines practices to enhance resilience in the face of extreme climate events resulting from climate variability, and they are organized by phenological stages; Table 3 presents cost-benefit analyses of some sets of CSC practices; and finally, Table 4 in the Annex provides summary information on the contribution of practices to adaptation, mitigation, and productivity, as well as information on the feasibility of their adoption.

Given the urgency to adopt these practices at scale, an obvious approach to the development of CSC is promoting risk-adequate resilience strategies, according to the social and economic context. Some of these practices may be currently in use in the region, and they enhance the resilience of farmers. They may also serve as a starting point to develop portfolios for each risk zone.

Degree of impact maps help in proposing adaptation practices more efficiently.

Table 1 contains a series of practices recommended for the region, according to the degree of climate impact, organized by phenological stages of the crop. In some cases, the same practice is recommended for the three degrees, but with a different intensity. For instance, regarding pest management, it should be carried out more frequently and preventatively in systemic adaptation zones than in incremental adaptation zones which require some monitoring and less frequent management. This way, impact degree maps help to propose adaptation practices more efficiently.

The transition to growing timber and fruit tree species, for example, is more important in transformational adaptation zones, than in incremental or systemic adaptation zones. The fact that some climate impact zones might benefit from certain practices more than others, however, does not mean the implementation of recommended practices for systemic adaptation cannot have a positive effect on incremental adaptation zones; as a matter of fact, these practices should also be promoted in these zones.

The decisions made at any time in different phenological stages of the crop have long-term consequences and might be difficult to change in the future.

The decisions made at different phenological stages of the crop have long-term consequences and might be difficult to change in the future. In the nursery, for instance, the genetic material used at planting is determined. To address issues related to heat or water scarcity, roofs can be placed in the nursery to provide shadow, as well as mechanisms to access water sources. In contrast, if these same issues arise in an already established farm, actions must be taken in terms of managing soil cover and shadow from trees, to maximize the amount of water available to cocoa plants. For this reason, we organized the recommended practices by stages of the crop.

Participants in workshops rated the contributions of each practice to CSC objectives from zero to three. From the mean of scores given at each workshop, a climate-smartness score was calculated (see Table 4). The table in the annex also includes considerations of the size of investment and level of returns.

In the nursery, the selection of an adequate site – slightly sloped, at a moderate distance from water sources, and in non-deforested areas – received a high score, and this is especially important in transformational adaptation zones to prevent damage by intense rains and floods. The use of resistant or pest-, disease-, and drought-tolerant varieties was also highlighted, even from the incremental adaptation level, giving more importance to resilience against quality in systemic and transformational adaptation zones. Windbreaker curtains, either organic or artificial, are one of the major practices in the face of strong winds and storms in all production stages, as such, they also scored very highly.

In the plantation establishment stage, agroforestry systems, along with shade management stand out for their contributions to all pillars, and they are indeed the practices with the best total average score (2.8 and 2.9 over 3). The number of species and the percentage of shadow will vary according to the degree of impact. For the transformational adaptation areas, it is important to diversify the farm with productive trees (timber and/or fruit trees). Planting cocoa in deeper holes filled with organic matter or fertilizer contributes to adaptation and productivity, and it also reduces the damage caused by drought and intense rains. Finally, soil management with organic fertilizer, canals for drainage, and leguminous plants, in addition to obtaining a high average score, stands out for the high return to investments and high availability of knowledge among farmers.

Once cocoa production in the farm is underway, the attention is focused on cocoa's adequate nutrition, due to its effects on productivity, an enhanced resilience of plants, and a faster recovery from extreme climate events; in addition, it reduces greenhouse gas emissions if organic fertilizers are used instead of chemical fertilizers. Integrated pest management is a practice, the importance of which was emphasized both in the production and post-harvest stage, receiving high scores in adaptation and productivity, since it brings along fewer emissions if fewer herbicides and pesticides are used.

In the annex of this document, there is a table detailing each practice and its contributions to each climate-smart agriculture pillar.

Table 1 Practices according to climate change impact gradient

	Incremental Adaptation	Systemic Adaptation	Transformation
Nursery	- Selection of a protected site with water availability - Water harvesting (medium-sized water reservoirs) - Natural windbreaks (e.g. eucalyptus or bamboo) - Elevate the terrain with tuff - Investing in varieties with tolerance to high temperatures and droughts - Protection of plants using a plastic mesh screen to provide shade - Larger cocoa planting bags - Drainage works to prevent flooding - Efficient irrigation for an adequate supply of water for plant development	- Selection of a protected site with water availability - Water harvesting (large reservoirs) - Windbreaks (natural or artificial) - More extensive drainage works - Use of tuff to build the nursery - Investing in varieties with resistance to diseases and extreme climate events - Larger cocoa planting bags - Protection of plants using a plastic mesh screen to provide shade - Fertigation (irrigation with water mixed with soluble fertilizer) - Use of absorbent materials (e.g., sand or gravel)	- Selection of a strongly protected site with water availability - Water harvesting (large reservoirs) - Natural and/or artificial windbreaks - Use of tuff to build the nursery - More extensive and deeper drainage works - Investing in varieties with resistance to diseases and extreme climate events - Larger bags to plant cocoa and companion plants - Protection and shade with 80% of coverage using a plastic mesh screen - Irrigation and fertilization with a 25%-increased frequency - Rigorous monitoring of pests and diseases In these areas, transitioning to other crops should be considered, preferably under an agroforestry system.
Establishment	- Planting in sloping terrain with terraces is recommended - Establishment of an agroforestry system with at least 40% shade - Using a staggered spacing system of planting at a shorter distance - Micro-sprinkler and drip irrigation - Use of organic fertilizer	- Planting in sloping terrain with individual terraces - Establishment of an improved agroforestry system with a diversity of species and at least 50% shade - Using a staggered spacing system of planting - Preparation of deeper holes to plant cocoa - Increased frequency of irrigation - Use of organic fertilizer and soil coverage - Increased shade during the dry season (planting shade trees and/or reducing pruning) - Anticipate replacement nurseries	- Planting in sloping terrain with individual terraces - Establishment of an agroforestry system with a diversity of species and at least 70% shade - Using a staggered spacing system of planting at a longer distance - Preparation of deeper holes to plant cocoa, filled with organic matter - Frequent irrigation (drip irrigation or another system) - Use of fertilizers with high organic matter content - Preventive application of fungicide - Anticipate replacement nurseries
Production	- Soil coverage - Phytosanitary management as required - Solar driers	- Soil coverage - Phytosanitary management as required and frequent monitoring - Climate-smart harvesting management schedules - Reduced pruning during drought periods - Ovens or other alternative drying systems	- Soil coverage - Preventive phytosanitary management and frequent monitoring - Climate-smart harvesting management schedules - Frequent use of mycorrhizae and (organic) fertilizers - Organic soil coverage to increase soil moisture - Adjustment of fermentation protocols - Ovens or other alternative drying systems

CSC Practices to Cope with Climate Variability

In addition to the first rating, we also include a second rating of CSC practices by phenological stage (Table 2) and, according to their usefulness in the face of extreme climate events, such as droughts, strong winds, and storms, as well as intense rains. These three types of extreme events were prioritized among participants in the workshops, as those affecting cocoa the most in their production zones. Practices are organized by phenological stage, but there are several practices, such as drainage or windbreaks, that are important at all stages. Today, Central America and the Caribbean is one of the regions most affected by extreme climate events in the world, and towards the future, it is expected that the occurrence of such events becomes even more frequent, in such a way that all cocoa plantations in the region, regardless of the climate-change impact degree, should take these practices into consideration when designing resilient plantations, to avoid further damage and be able to recover faster after these types of events.

Table 2 Practices according to extreme climate events

	Intense rains	Strong winds and storms	Drought
All stages	- Soil conservation with canals and coverage. Drainage works. - Windbreaks to prevent soil erosion and dryness in plants - Pruning for improved air circulation - Application of fungicides (*Trichoderma* spp.)	- Stronger infrastructure - Soil coverage - Planting trees with good anchorage - Natural and/or artificial windbreaks - Pruning to reduce the height of cocoa and other types of trees	- Soil coverage - Irrigation: water harvesting and water availability - Water infiltration works - Increased shade and/or reduced pruning
Nursery	- Elevate the terrain with tuff - Removal of plastic mesh screen and placement of plastic cover - Planting in terraces along contour lines - Thinning	- Micrografting - Use of fertilizers	- Selection of drought-tolerant varieties - Larger bags - Micrografting
Establishment	- Selection of an appropriate and protected site - Avoid planting during heavy rainfall periods - Deeper holes to plant seedlings - Adequate distance between plants for increased air circulation - Liming at planting	- Selection of an appropriate and protected site - Use of fertilizer is recommended	- Deeper holes to plant seedlings - Selection of less water-consuming shade trees
Production	- Shortening the production cycle - Transferring harvest to the collection center for the drying process - Artificial drying (oven or other alternative drying systems)	- Ensure the stability of the collection center	- Anticipate replacement nurseries

Costs and Benefits of CSC Practices

For a detailed overview of investments in CSC practices in economic terms, a Cost-benefit Analysis (CBA) should be performed. Cocoa farmers' investment capacity in Central America is generally limited. The decision to invest in their plots is determined, among other things, by this limitation and a lack of knowledge about the return on investment. Therefore, economic arguments in favor of investments in CSC practices, along with the support to understand the net present value of future income, may be crucial to increase the adoption rate of these practices. CBAs are ex-ante evaluations that involve some uncertainty; however, the comparison of income and expenditure flows can be useful for the decision-making process of farmers and other stakeholders in the value chain, to prioritize the implementation of certain practices. Net Present Value (NPV) is calculated as the sum of benefits minus costs each year, brought to the present using a discount rate (14% in our case), to find out the present value of the flow. Priority is usually given to practices with the highest NPV. In contrast, the Internal Rate of Return (IRR) is calculated as the discount rate that would make the NPV equal to zero; the higher the IRR, the better the investment. Business as usual (BAU) refers to the likely result of continuing with the practices currently carried out and proceeding without adopting CSC practices. Depending on the Discount Rate and the initial and recurring costs, NPV and IRR can be higher or lower. If NPV and IRR prioritize different practices (e.g., improved seeds show a higher NPV, but a lower IRR than agroforestry systems), the preferred measure is NPV, as it places more importance on the cost and benefit at the beginning of the investment period.

The table below shows CBAs performed for CSC practices in the Honduran cocoa sector. The data from these analyses were provided by Rikolto (Alemán, et al., 2017) and FHIA, among others. Practices were compared with a well-managed conventional reference system with some shade and crops along with cocoa. R software was used to calculate the cost and benefit flows, as well as NPV and IRR for every possible investment. The objective of these analyses is providing assistance designing interventions and supporting the adoption of these practices.

Table 3 Results of the cost-benefit analyses for some CSC practices in Honduras

Current Practice	Climate-smart Practice	Resulting Costs	IRR/NPV in comparison with BAU
	Organic fertilizer and integrated pest management		
Chemical fertilizers. Without integrated pest and disease management	Organic inputs and certification of organic production. On-farm preparation of natural fertilizer and integrated pest management. A 10% reduced harvest, but selling price increased by 49%	Reduced establishment costs Certification cost Lower cost of inputs Increased labor costs	+50% IRR +307% NPV
	Redesigned agroforestry system		
Production with shade	System with a high diversity of species. Long-term sustainability increases as trees with a functional structure are added. The amount of harvest is reduced	Increased labor costs Input costs increase by 90%	+33% IRR +285% NPV
	Improved seeds		
Conventional seeds	Hybrid or improved cocoa varieties from reliable sources. A 128% increased harvest and enhanced resilience	Establishment costs increased by 50% Increased harvest and post-harvest costs	+27% IRR +382% NPV
	Leguminous species		
Approximately 50% of farmers have leguminous species in their farms	System with *Gliricidia sepium*. Plant residues may be used as fertilizer	Increased establishment costs (USD 45) Increased labor costs	+0% IRR +4% NPV
	Integrated pest management		
Chemical pesticides and fungicides	Organic pesticides and increased manual labor to eliminate infected fruits. Manual weeding. The amount harvested remains unchanged	Increased labor costs Reduced input costs Increased establishment costs	-1% IRR -5% NPV
	Drip irrigation and drainage		
Without irrigation and without drainage	Distribution of drip irrigation through pipes. Harvest increased by 33%	The cost of the irrigation system and its installation is USD 2,500 Higher harvest and post-harvest costs	-25% IRR -131% NPV

Resilient Production at a Scale: Beyond Practices

A number of challenges still remain regarding the implementation of CSC practices in Central America. Among them, we can mention the lack of training on crop management and low investment capacity. In general, Central American cocoa is grown in small plots, between 0.25 and 3 hectares, and it is managed by very-low-income, indigenous communities or other ethnic minorities. Farmers' resources are very limited and thus, their capacity to adopt CSC practices is restricted; this is in addition to the exclusion schemes of vulnerable populations, such as women, making it necessary to raise awareness and promote their contributions to cocoa production and its resilience.

To cope with climate change and facilitate the adoption of practices to enhance the resilience and quality of cocoa production, an enabling environment is needed at the local level to disseminate information on climate and adaptation, as well as access to financing. Such enabling environments should be promoted by government and private organizations operating at state, national, and regional levels. Support for cooperatives and groups of cocoa producers can provide a basis for the creation of such environments.

The development of climate change, as well as pest and disease-resistant varieties, is one of the most common types of investment to enhance the resilience of production. The advantage of this investment is that it does not require much farmer training. However, the difficulties in the development of these varieties and the long-lasting field trials should encourage stakeholders to take into consideration other practices backed by scientific literature, like those contained here.

Some CSC practices, including the use of improved varieties, are dependent on frequent support to farmers and farmer groups. Drip irrigation systems or the establishment of natural or artificial windbreaks, for example, require access to finance and inputs. The creation of enabling environments in the long term will define the investments on future resilience.

The Cost-benefit Analyses (CBAs) are a tool to develop an economic argument in favor of or against an investment (see Table 3). CBAs are also useful to prioritize certain investments over others, according to the cost and expected benefit flows. The higher the investment, the higher the benefits should also be, as well as the shorter the term in which they are materialized.

Once the likely future climate conditions for the different cocoa production zones are known, as well as the level of effort needed to continue producing cocoa in the future, and the CSC practices that may be adopted, it is necessary to think about strategies beyond each farm. That is to say, stakeholders in every link of the chain and outside the chain should start thinking about long-term strategies to help the cocoa supply chain to be more resilient and respond better to changes in temperature and rainfall resulting from climate change.

How to Create an Enabling Environment within a Cooperative or Community

- Availability of climate information for decision-making
- A sound plan for fertilizer use and other farming practices
- Supply of genetic material suited to the features of the zone
- Rapid information systems to mitigate the effects of climate change
- Standardization of good practices
- Training of cocoa farmers
- Traceability
- Training and provision of seed for the production of other crops in transformation zones

Conclusions

Cocoa has a long and rich history in Central America and the Caribbean. However, it is projected that in the next decades there will be important changes in climate suitability for the crop in many zones, in which it is currently grown. Climate suitability maps show a reduction in the suitability of many regions. The areas requiring systemic or transformational adaptation will be more commonly observed in the coming decades and they will adversely affect the livelihoods of over 25,000 farmers in the region, through reduced productivity and increased production costs of their cocoa farms.

Analyses suggest an urgent need for a shift from the current practices to CSC practices adapted to the climate features of each zone. The participatory methodology used in the workshops held in Guatemala, El Salvador, Honduras, Nicaragua, and the Dominican Republic lay the foundations for the development and implementation of "no-regret" CSC practices.

Interventions at different technological, organizational, institutional, and policy levels should take into consideration the barriers to adoption of these recommended practices, such as the limited access to inputs, lack of knowledge and training, and high investment costs.

Methodology Used in Workshops

The workshops were held in 2018, with the participation of stakeholders from the cocoa value chain, and they were delivered by staff from Rikolto, WCF, and CIAT. They applied a participatory methodology to engage participants in pre-planned tasks to share and broaden their knowledge. The workshops had two stages. In the first stage, the climate-change impact degree maps were shown and explained. In the second stage, the participants engaged in discussions aligned with four pre-planned tasks. The goal of the second stage was finding topics in which participants agreed and to prioritize certain farming practices over others in terms of their capacity to enhance resilience in each impact zone. The effects of extreme climate events on cocoa plantations were also discussed.

The practices identified in the workshops were consolidated and compared with literature to confirm their strengths in climate adaptation. The literature included papers published in scientific journals, as well as technical bulletins and communications. Moreover, further information on practices was gathered through interviews with important stakeholders from the value chain and experts from the sector. Climate-smartness scores are based on the contribution of each practice to the three pillars that support climate-smart agriculture. This rating may be used to prioritize certain practices over others (see the table containing the scores in the Annex).

The workshops were held in Honduras (20 participants), Nicaragua (34), El Salvador (26), Guatemala (33), and the Dominican Republic (26). We thank the farmers who produce cocoa, cooperatives, exporters, representatives of development and research institutions, and chocolate companies (e.g., Ritter Sport, Chocolate Halba, Rizek Cacao S.A., CONACADO y Roig S.A.) for attending and for their contributions during the workshops.

Our goal is to provide an overview of research to guide the implementation of CSC practices in Central America and the Caribbean. To achieve the objectives of increasing productivity and adaptation, while reducing or eliminating greenhouse gas emissions, stakeholders should take into account impact gradient maps, the costs and benefits of CSC practices, and workshop outcomes.

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Complementary Reading

- Bunn, C; Lundy, M; Wiegel, J; Castro-Llanos, F. (2019). Climate Change Impacts on Cocoa Production in Central America and the Caribbean. International Center for Tropical Agriculture (CIAT), Cali, CO. 35 p. https://hdl.handle.net/10568/105604

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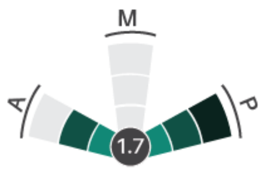
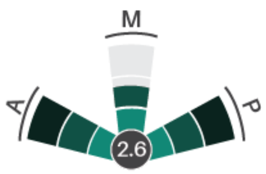
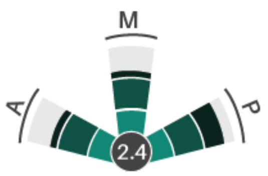
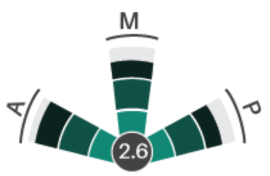
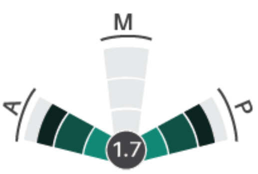
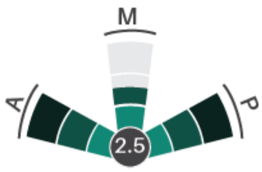
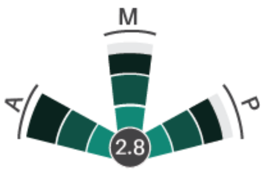
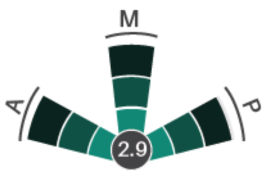
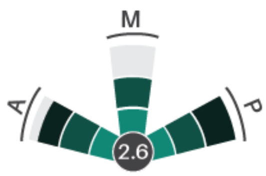
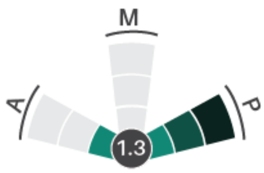
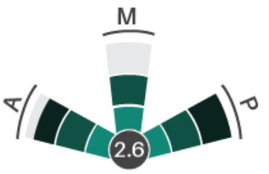
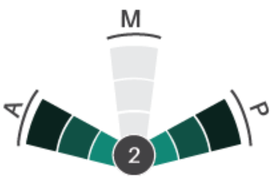
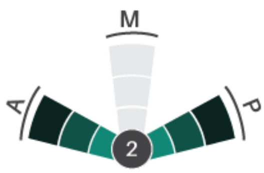
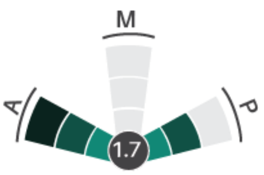
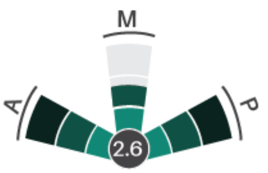
The Decision and Policy Analysis (DAPA) team at CIAT performed the analyses presented here, under the leadership of Christian Bunn, and with support from Pablo Fernández Kolb and Fabio Castro-Llanos. Contact: c.bunn@cgiar.org

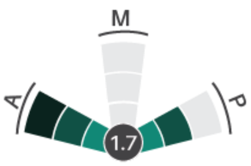
Note: Impact gradient icon was adapted from: “Setting” by Juan Pablo Bravo and “cocoa” by Amos Kofi Commey, The Noun Project.

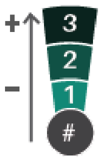
Annex 1 Climate-smart Agriculture Farming Practices

CSC Practice	Climate Adaptation	Adaptation (A)	Mitigation (M)	Productivity (P)
Improved nurseries *Improvement of substrate conditions for planting and use of fertilizers*	 High investment Low returns	Reduced seedling mortality due to heat, drought, or intense rains Reduced impact of climate conditions on plant development	No impact	Improved growth Higher quality production Increased productivity
Resistant varieties *Improved seeds or clones resistant to drought, heat, diseases...*	 Poor knowledge High returns	Maintains crop yield over long periods without rain and droughts Higher tolerance to heat Less plant stress reduces the incidence of pests and diseases	Lower emissions due to a reduced need of fertilizers and pesticides	Improved growth Increased productivity
Site selection *Only slightly sloped to prevent runoff* *Distance to water sources appropriate to have access, but also be able to avoid damages from flooding*	 Poor knowledge High returns	Reduces the negative impact of flooding Improved water access in droughts	Reduced deforestation Reduced need for fertilizers due to less runoff	Improved growth Reduced incidence of pests and diseases also in the post-harvest stage
Windbreaks *Organic (e.g., biennial or perennial species) or artificial to reduce wind speed in the plantation*	 High returns	Protection against strong winds Prevention of soil erosion and landslides Maintains crop yield in extreme climate events	Increased carbon in the plantation from organic barriers Increased carbon content in the soil	Improved growth Improved flowering Reduced incidence of pests and diseases
Planting improvements *Cocoa planted in deeper holes filled with fertilizer and lime*	 Poor knowledge High investment High returns	Increased tolerance to extreme climate events Lengthened crop lifespan	No impact	Improved growth Increased productivity

Tree selection and propagation *Selection of trees with high productivity and high quality*	 Low investment High returns	Increased tolerance to extreme climate events	Lower emissions due to reduced use of fertilizers and pesticides	Higher quality harvest Increased productivity Reduced damage from pests and diseases
Agroforestry systems *Species diversification and multiple strata*	 High returns	Reduced damage from extreme climate events Lengthened crop lifespan Improved soil structure	Increased carbon insetting with additional plants in the plot Lower emissions due to reduced use of fertilizers and pesticides	Enhanced quality of production Reduced damage from pests and diseases Income diversification
Shade management *Planting trees to provide shade. Pruning cocoa and other trees*	 High returns Difficult to adopt	Regulates extreme temperatures and protects against intense rains Protection against strong winds Improved water retention and infiltration	Increased carbon insetting Lower emissions due to reduced use of fertilizers and pesticides	Enhanced quality of production Reduced damage from pests and diseases Increased soil fertility
Soil management *Use of organic fertilizers, canals, planting distance, soil restoration, leguminous species*	 Wealth of knowledge High returns	Reduced soil erosion Improved soil structure and fertility Regulates extreme temperatures and reduces the damage from intense rains	Lower emissions due to reduced use of fertilizers and pesticides Increased carbon insetting from leguminous species	Improved growth Reduced post-harvest losses
Fertilization based on soil analysis *Chemical analysis of soil properties and its composition*	 High investment High returns	Faster recovery after extreme climate events	No impact	Improved growth Enhanced quality of production

Cocoa nutrition *Organic matter, Ca++ and K++, use of fertilizers, mycorrhizae*	 Poor knowledge High investment High returns	Maintains crop yield in extreme climate events	Lower emissions due to reduced use of chemical fertilizers	Increased productivity Enhanced quality of production
Water Harvesting *Rainwater collection and conservation, wells, natural reservoirs, canals, etc.*	 Poor knowledge High investment Difficult to adopt	Increased drought resistance Reduced temperature variability Increases or maintains crop yield during droughts	No impact	Improved growth Increased flowering and fruit load Enhanced quality of production
Irrigation *Water and irrigation system management to reduce the negative impact of droughts and periods without rain*	 Poor knowledge High investment Difficult to adopt	Increased drought resistance Regulates extreme temperatures Increases or maintains crop yield during extreme climate events Lengthened crop lifespan	No impact	Improved growth Increased flowering and fruit load Enhanced quality of production Reduced incidence of pests and diseases
Drainage works *Drainage systems to reduce excess water in the plantation. Terracing and barrier planting design*	 Easy to adopt	Reduced damage from floods and intense rains	No impact	Reduced incidence of pests and diseases
Integrated pest management *Weeding, phytosanitary pruning, proactive measures against* Phytophthora palmivora	 Poor knowledge	Increased tolerance to extreme climate events due to an improved plant health	Lower emissions due to reduced use of herbicides and pesticides	Reduced incidence of pests and diseases Enhanced quality of production

	Low investment High returns Easy to adopt			
Artificial drying *Environmentally friendly artificial drying to be used during high humidity periods. Solar drying*	 High investment Easy to adopt	Prevents damage from fermentation process due to excessive humidity or heat	No impact	Enhanced quality of production Reduced incidence of pests and diseases Reduced post-harvest losses



Total smartness points (#)

(A) Adaptation
(M) Mitigation
(P) Productivity

Find the Spanish versión of this ítem in: https://hdl.handle.net/10568/103487