CIAT policy brief

Tortillas on the Roaster: Central America's Maize–Bean Systems and the Changing Climate

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Maize and beans are a vital component of human diets and culture in Central America. More than a million smallholder families grow these crops for subsistence, producing 70% of the maize and 100% of the beans consumed locally. Average yields are low, however – 1.5 t/ha for maize and 0.7 t/ha for beans – on the approximately 2.5 million hectares of land sown to these crops (40% of the total area harvested) in El Salvador, Guatemala, Honduras, and Nicaragua. In the years to come, a harsher climate together with soil degradation[1], widespread poverty, and rural people's limited access to services and infrastructure will pose challenging obstacles to production. By 2025, these pressures could result in total annual losses of maize and bean production in the four countries of around 350,000 t – with a gross production value of around US$120 million. To ward off this threat to the food security of some 100,000 households, effective adaptation strategies must be developed in collaboration with stakeholders in the maize and bean value chains. These strategies require strong public support and must draw on both scientific and community knowledge.

Key Messages

- Developing comprehensive adaptation strategies requires the use of global climate models downscaled to local resolution and complemented with long-term yield and economic data.
- Long-term climate change and variability will significantly impact maize and bean production in Honduras, El Salvador, and Nicaragua, while less dramatic effects are expected in Guatemala.
- In general, maize yields will be more affected than beans, but the latter will face yield reduction sooner.
- In poor rural households, smallholder farmers have little adaptive capacity for responding to climate change.
- Because climate change impacts will vary by location, adaptation strategies must be tailored to local conditions. Moreover, these strategies must be designed for entire value chains, with adjustments to local opportunities and challenges.
- Where agricultural expansion threatens biodiversity, strategies for protecting such areas should receive high priority.
- Introducing new crops/varieties requires investment in sustainable soil management and water harvesting.
- Investing in human and social capital is essential for the success of any adaptation strategy.

A recent study conducted by Catholic Relief Services (CRS), the International Maize and Wheat Improvement Center (CIMMYT), and International Center for Tropical Agriculture (CIAT) analyzed the impact of future climate conditions on maize and bean production in four Central American countries. The study aimed to guide decision makers at the local, national, and regional levels, as they define appropriate actions for particular locations and create an adequate policy framework for successful adaptation strategies in the rural sector. This study considered predicted long-term changes in climate conditions and did not include year-to-year climate variability. This policy brief summarizes the study's main findings.

Climate Impacts on Crop Production

Central America experiences a long dry season (up to 6 months) followed by a bimodal rainy season. In the future, the region's maize and bean farmers will have to cope with a far less favorable climate for agriculture. High temperatures (especially nighttime temperatures above 18 °C) and drought will substantially affect the biomass production and reproductive stages of maize and beans.

Climate change, soil quality, and maize production

Maize is highly sensitive to low soil fertility and water scarcity. Across Central America, soil degradation is reducing the capacity of soil to retain water and nutrients. In the face of more severe water stress in the future, improved soil management will be critical for enhancing crop resilience and minimizing yield reductions.

In Honduras and El Salvador, maize yields in all current production areas are expected to decline by 2025. In Honduras, the predicted production losses could amount to about 120,000 t annually, valued at about US$40 million. In El Salvador, the annual losses could reach 136,000 t, with a value of nearly $45 million. For Nicaragua, the figures are 34,000 t and close to $10 million in losses (Figure 1). Guatemala, on the contrary, can expect only small changes in average production, because climate change impacts will be

1. According to FAO statistics, 75% of agricultural land in Central America is degraded. See: Heerink N; van Keulen H; and Kuiper M. (eds). 2001. Economic policy and sustainable land use: Recent advances in quantitative analysis for developing countries. Springer Physika-Verlag. New York.

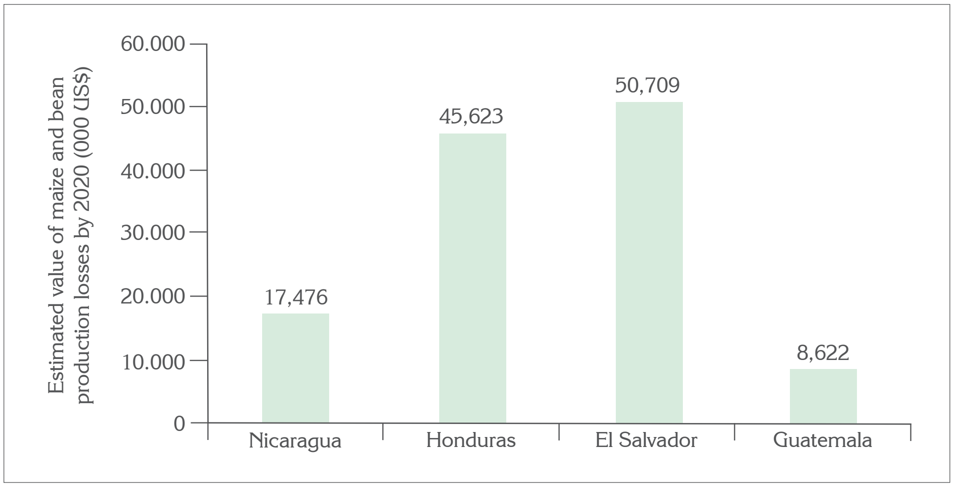

Figure 1. Estimated value of national maize and bean production losses by 2020.

softened by highland areas becoming more suitable for maize–bean production, particularly in Western Guatemala. However, maize yields will vary greatly across the study area, as indicated in Table 1, underlining the importance of enhancing soil management to reduce climate change impacts.

Climate change and bean production

Beans are very sensitive to drought stresses and high temperatures, especially high night temperatures, which reduce flowering and thus production. Under the predicted future climate scenarios, bean production in Central America could be reduced by more than 20%, with Nicaragua and Honduras, the main bean-producing countries, showing overall yield losses of 14% and 15%, respectively. El Salvador will suffer a reduction of 7%, while Guatemala might even increase its overall production because of the particular situation of highlands.

Losses in the gross production value of beans for all four countries are estimated at around US$20 million per year. In Nicaragua, annual bean production losses could amount to about 9,000 t by 2020, with an estimated value of $7 million. The figures are somewhat lower for Honduras and El Salvador – at 6,500 t and 5,200 t, respectively – with a total value of $6.2 million. Guatemala will see almost insignificant annual losses of 736 t, worth $526,000.

As in the case of maize, bean yields will vary within each of the study countries, as indicated in Table 2.

Climate Impacts at Household Level

Climate change effects will translate into significant losses for the smallholder farmers whose livelihoods depend on maize and bean cultivation. With rural poverty already at high levels – more than 30% of the population in Nicaragua and Honduras, 25% in Guatemala, and 20% in El Salvador[2] – declining income from these crops will significantly affect rural people.

The study included a vulnerability analysis conducted in selected areas of El Salvador, Honduras, and Nicaragua. Its results confirmed the considerable impact of lower maize and bean yields at the household level, especially in terms of access to food and the stability of food supplies. Rural households will have an especially hard time coping with climate change where infrastructure (equipment and roads) is inadequate, access to natural resources (water and land) is limited, financial resources are scarce, and social capital is very weak. Such is the case in El Salvador, where household vulnerability is highest, followed by Honduras and Nicaragua.

Study results suggest that low adaptive capacity is shaped by the interplay between various factors. In the areas studied, maize and bean production was among the main household activities, and these crops were found to be the main sources of energy, together with meat products (especially in El Salvador). The analysis also shows that maize and beans are an important income source in the four countries.[3]

2. Population living on less than US$2/day, according to 2008 estimates. See: IFAD. 2011. Rural Poverty Report. www.ifad.org/rpr2011/report/e/rpr2011.pdf
3. The vulnerability analysis identified in the focus areas some other alternative sources of income as well: poultry and egg production, as well as remittances and nonagricultural activities (El Salvador and Honduras).

Table 1. Predicted changes in the maize yields of El Salvador, Guatemala, Honduras, and Nicaragua.

Change in maize yield (%) - poor soil simulation				Change in maize yield (%) - good soil simulation			
Country	All municipalities	Municipalities with 50% of total production	Municipalities with expected yield loss >10%	Country	All municipalities	Municipalities with 50% of total production	Municipalities with expected yield loss >10%
El Salvador	-34	-33	100%	El Salvador	-2	-2	0%
Guatemala	-6	-18	50%	Guatemala	5	-6	9%
Honduras	-29	-34	100%	Honduras	-12	-17	71%
Nicaragua	-15	-5	59%	Nicaragua	-10	0	47%

Red indicates expected high yield loss.

Table 2. Predicted changes in bean yields for El Salvador, Guatemala, Honduras, and Nicaragua.

Average change in bean yield (%)			
Country	All municipalities	Municipalities with yield loss > 50% of total production	Municipalities with expected yield loss >10%
El Salvador	-7	-7	8%
Guatemala	4	0	5%
Honduras	-14	-19	57%
Nicaragua	-14	-2	53%

Switching to alternatives (such as cattle rearing in Honduras) can prove to be a double-edged sword. This creates alternative livelihoods, which may diminish household vulnerability to the consequences of lower maize and bean production. But the alternatives may pose a threat to natural resources, especially where many families become dependent on livestock rearing.

Yet, household vulnerability is not just about dependency but also about shortages. The study revealed that countries with better adaptive capacity – Honduras and Nicaragua – generally have more capital of different types. The majority of smallholder farmers own their land and have access to irrigation and good road networks as well as financial capital (credit of some sort), though with some restrictions.

In contrast with those countries, El Salvador scored low in adaptive capacity. The country's road network is usable only during the dry season, greatly restricting access to land and markets. Moreover, land tenure is weak. Most smallholder maize and bean farmers rent land from other farmers, who most likely own livestock and thus have more financial capital. Land and livestock owners also enjoy better access to government subsidies (seeds and fertilizers), leaving maize and bean farmers in a particularly difficult situation. The countries of study showed a weak land tenure scheme that hampers investment in sustainable land use. This situation is aggravated by the fact that many times incentives provided by public institutions do not reach those that need them the most.

While all three countries – El Salvador, Honduras, and Nicaragua – suffer from shortages of human and social capital, these are particularly pronounced in El Salvador and somewhat less in Honduras. Such shortages are reflected in low educational levels (i.e., low high-school attendance) and limited information on climate change and adaptive capacity (with the exception of Honduras). The situation is slightly better with respect to social capital, except in El Salvador, where family members tend not to be involved in any type of organization. Participation in social organizations and strengthening of these collective structures would foster cooperation and diminish the prevalent fierce competition between farmers. These measures would also help connect farmers to markets and incentives (such as subsidies), thus reducing their dependency on local input distributors and intermediaries.

Adaptation: When, Where, How, and with Whom

Given the future scenarios for Central America's maize and bean production in the face of climate change, what should governments and communities do?

The way to go: Five adaptation pathways

Coping with the expected impacts of climate change on Central America's maize and bean production is not an insurmountable challenge. Comprehensive adaptation strategies that are shaped to specific contexts can mitigate the risk of yield declines and economic losses. But there is no one-size-fits-all approach for adapting to climate change. It will impact different areas in different ways (Figure 2), so strategies must take into account local opportunities and challenges. Below we suggest five adaptation pathways that can be adjusted and combined in response to local conditions and needs.

Sustainable intensification: Since agricultural production in Central America relies mostly on rainfall, a central requirement for achieving sustainable intensification in the face of climate change is to use rainwater efficiently. This depends on plant water availability, soil and plant evaporation, and plant water uptake capacity. All these factors are linked to soil management, water harvesting, and plant nutrient management. Finally, investments in sustainable soil and plant nutrient management, as well as water harvesting schemes should be considered together with introducing new crop varieties, such as beans with tolerance to heat stress.

Diversification: Another farm-level adaptation strategy involves the diversification of agriculture to multiply food and income sources. Integrated aqua-agro-silvo-pastoral systems can produce a wide range of products for local consumption and the market. Better integration of crops and animals enhances nutrient cycling, resulting in higher crop yields, better soil and water quality, increased biodiversity together with lower greenhouse gas emissions and increased carbon sequestration. Trees and shrubs offer sources of bio-energy, fruits, nuts, horticultural nursery stock, wood fiber, and livestock shelter. Agroforestry systems also provide a means to restore degraded lands, incorporate livestock, and improve microclimates.

Sustainable expansion: In agriculture, the word "expansion" is synonymous with the occupation of land for agricultural purposes. In the study, we do not use this term to refer to the expanding agricultural frontier, which often leads to widespread deforestation,

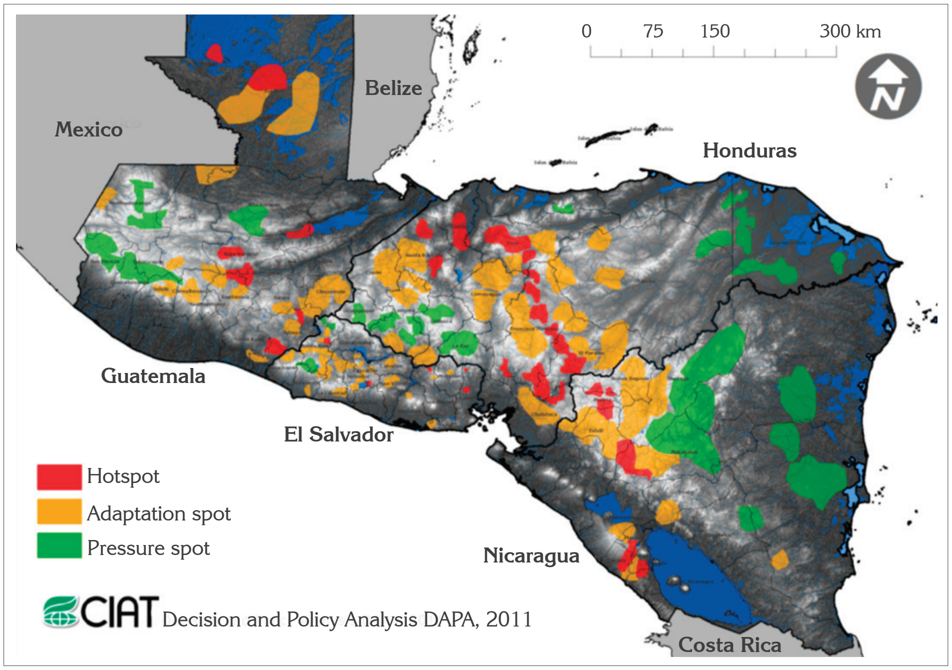

Figure 2. Bean focus areas (El Salvador, Guatemala, Honduras, and Nicaragua).

Hotspots

These are areas where adaptation measures are not likely to work because of climatic changes along with low land suitability for maize and bean production. In these regions, yield reductions are expected to be very high, and action must be taken now to reduce the vulnerability of rural families. They will need to transition out of current production systems – e.g., from maize-based to sorghum-based systems, livestock, or agroforestry.

El Salvador: Cuscatlán, La Unión, San Miguel, and Santa Ana.

Guatemala: Baja Verapaz, El Progreso, Zacapa.

Honduras: Alauca, Choluteca, El Paraíso, Liure, Morolica, Soledad, Yorito, and Yoro.

Nicaragua: Madriz, Masaya, Matagalpa.

Adaptation Areas

These are areas where maize and bean systems can be adapted. They require well-coordinated strategies for adapting farms and landscapes with multi-stakeholder cooperation.

El Salvador: High potential for adaptation strategies in most areas.

Guatemala: The major bean-producing departments of the southeast (Jutiapa, Chiquimula, Santa Rosa, and Jalapa), and North (except Petén, which is mainly for *Apante* production).

Honduras: Areas east and west of the dry corridor and in the departments of Copán and Lempira.

Nicaragua: Areas along the dry corridor between Madriz and Masaya (departments of Carazo, Diriamba, La Conquista, Granada, Diriomo, Diria, Rivas, Belén, and Potosí).

Pressure Areas

Some areas are likely to become more suitable for maize and bean cultivation, possibly putting wetlands, forests, or protected areas at risk of uncontrolled agricultural expansion.

Judging from past and recent experience in the region, these areas may be lost over the next decade, as a result of climate change impacts and factors such as population increase and land tenure problems.

Pressure areas are concentrated in the Atlantic region, close to the El Salvador border, and at higher altitudes in Guatemala.

land degradation, increased greenhouse gas emissions, migration, and social conflicts. Rather, expansion is referred to as an increase in the endowment of natural, physical, financial, human, and social capital at the farm level. The *Apante* areas offer the possibility of converting deforested and degraded grazing land into cropland through the promotion of sustainable intensification and reversal of land degradation.

Strengthening human and social capital: Investing in human and social capital is a powerful strategy for climate change adaptation. Information, knowledge, education, and social organization are essential for successfully implementing the above-mentioned strategies for climate change adaptation. Farmer organizations play an important role in fostering cooperation among farmers and in linking them to markets and extension services.

Off-farm income: Many Central American smallholder farmers earn off-farm income from activities during the dry season. Since rural areas generally provide only limited opportunities for income generation, people tend to migrate to urban areas or outside Central America. Income diversification in rural areas is essential for lowering the vulnerability of rural communities, reducing migration, and improving the quality of life of smallholder producers.

Table 3 illustrates possible adaptation strategies tailored for scenarios where different levels of impact, vulnerability, and adaptive capacity are combined.[4]

4. In this case, impact refers to the effects of climate change on crop production; adaptive capacity refers to household's ability to manage climate change impacts and is strongly linked with the availability of different types of capital; vulnerability is a combination of impact and adaptive capacity and reflects the extent to which a household is likely to experience harm due to the exposure to external factors (climate change).

Table 3. Strategies for different focus spots and levels of impact, vulnerability, and adaptive capacity.

Focus spot (hot/ adaptation)	Impact	Vulnerability	Adaptive capacity	Strategy
Hot	High	High	Low	Off-farm income, including migration to non-agricultural activities; strengthening social capital.
Hot	High	High	Medium	Off-farm income; sustainable expansion; strengthening social capital.
Hot	High	Medium	High	Sustainable intensification; diversification; strengthening social capital.
Adaptation	Medium	High	Low	Sustainable intensification; sustainable expansion; strengthening social capital.
Adaptation	Medium	Medium	Medium	Sustainable intensification; sustainable expansion; diversification; strengthening social capital.
Adaptation	Low	Medium	Low	Sustainable expansion; strengthening social capital.
Adaptation	Medium	Low	High	Sustainable intensification; diversification; strengthening social capital.
Adaptation	Low	Low	Medium	Sustainable expansion; strengthening social capital.
Adaptation	Low	Low	High	Any strategy.

Policy Recommendations

- Identifying climate "hotspots" and adaptation pathways helps inform National Development Plans, which should prioritize interventions and put communities at the center of adaptation policy. Key steps in the process include strengthening the human and social capital of producer organizations.
- National censuses and systems to capture agro-climatic information must be strengthened. Accurate and timely data (dealing with social, economic, climatic, and soil factors) are key for research, decision making, and policy design.
- As land suitability for particular crops changes, production will shift to new areas. Some of the new production areas may be located in environments that provide critical ecosystem services. For instance, the Bosawás National Reserve in Nicaragua has been classified as the largest unaltered rainforest ecosystem in Central America, yet studies have shown that it is also an area highly vulnerable to land use changes.[5] The presence of the projected pressure spots inside the protected area may seriously affect the Mesoamerican Biological Corridor (Figure 3). For such areas, timely conservation activities must be planned to reduce the pressure from agricultural expansion.
- On the Atlantic coast areas, which in most cases will become more suitable for maize and beans in the future, it is relevant to establish agricultural land use zoning, which sets clear limits as to areas under conservation, while also promoting sustainable agricultural practices.
- Environmental and production management requires not only a national but also an eco-regional approach combined with local adaptation measures. Such is the case where eastern Guatemala fits into the agroecology of Santa Ana and Ahuachapan in El Salvador.
- Policies that strengthen the incentives of farm communities (rather than individual farmers) to improve soil management can help make production systems more resilient under a more adverse climate. These policies can include technical training, providing tools and/or inputs to

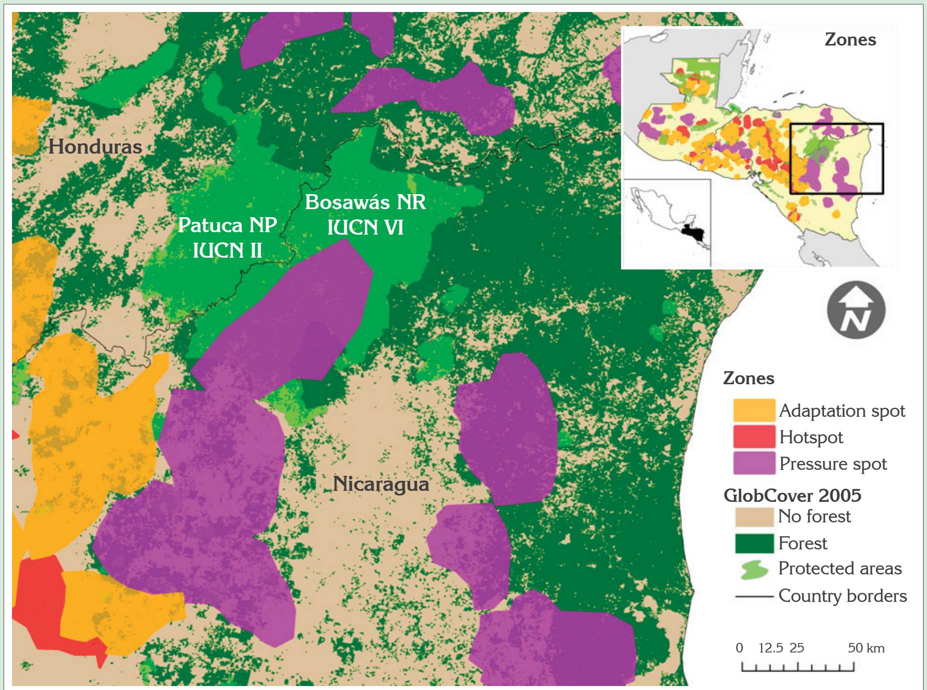

Figure 3. Bean focus areas (Honduras and Nicaragua).

5. Roiz, R. Caracterización Zona de Bosawás. Programa para la Consolidación del Corredor Biológico Mesoamericano. MARENA-SICA/CCAD-PNUD-GEF-GTZ-PNUMA-Banco Mundial. www.bio-nica.info/biblioteca/RoizCaracterizacionBosawas.pdf

producers, small-scale conservation infrastructure, and tax exemptions for best environmental practices. These will be effective, however, only if land tenure issues are resolved, meeting a key condition for sustainable adaptation to climate change.

- Policies that put credit within the reach of maize and bean producers are critical not just for climate change adaptation but also for enabling these farmers to escape from the poverty trap.
- Agricultural extension services must be strengthened on the basis of a thorough re-assessment of their strategies and practices. They must assign high priority to strengthening the adaptive capacity of the most vulnerable groups, but this must be done in such a way as to encourage communities to generate their own solutions. Climate change adaptation can thus become a social learning process, in which best practices from one location can be transferred to others with similar climate and socio-economic conditions (regional cooperation).
- Since poor farmers will be hurt most by decreases in maize and bean yields, they will need new options for crop diversification together with additional sources of off-farm income as well as stronger social safety nets.
- Improved varieties are also a relevant adaptation choice in Central American countries. Some recent drought-resistant bean varieties include CENTA Ferromás (El Salvador), ICTA Petén (Guatemala), and INTA Fuerte Sequía (Nicaragua). The national agricultural research institutions should put in place the adequate mechanisms for the adoption of these varieties, especially in the areas that will be future hotspots.
- Monitoring and evaluation strategies should be designed for the transfer of agricultural technologies, so that the main bottlenecks to technology adoption can quickly be identified. More research is needed to identify those constraints and address them effectively.
- Strong mass media strategies are needed to inform all producers (literate and illiterate) about the challenges and opportunities for maize and bean production in the face of climate change.
- Water harvesting should be promoted through investment in the required infrastructure (e.g., reservoirs), accompanied by support for community-based water use schemes. This should offer some possibilities to shift production into the dry season with irrigation (case of the Jamastrán River Valley in Honduras).

Further reading

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For more information

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