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Climate Risk Profile

CLIMATE RISKS TO FOOD SECURITY IN FOOD FOR PEACE GEOGRAPHIES

GUATEMALA

DOCUMENT OVERVIEW

Food security is essential to advancing sustainable development, strengthening resilience, improving nutrition, and reducing the need for humanitarian assistance in Guatemala. This Climate Risk Profile assists the Food for Peace (FFP) program to:

1. Better understand how climate change-related stressors—including extreme events—threaten Guatemala's food security.
2. Identify potential measures that the United States Agency for International Development (USAID)/Guatemala Mission, FFP, and emergency assistance might undertake in order to break the cycle of recurring food insecurity in Guatemala.

This document consists of four main sections:

- **Country Overview**, which provides context on food insecurity in Guatemala, and the major climate-related stressors that threaten food security.
- **Climate Summary**, which describes current and expected near-term changes in climate.
- **Livelihoods in Food for Peace Program Areas**, which describes FFP programming in Guatemala, as well as Guatemala's livelihood zones within FFP geographies. The section also includes a table (Table 2) that characterizes each livelihood zone's climate, crop production, main sources of food and income, and primary climate and non-climate hazards to food security.
- **Sector Impacts and Vulnerabilities**, which describes the major climate-related risks facing key sectors that affect food security:
    - Agriculture
        - Crop Production
        - Invasive Species
        - Pesticide Use and Storage
        - Food Processing and Storage
        - Livestock
    - Human Health: Nutrition, WASH, and Health Services
    - Sensitive Ecosystems

COUNTRY OVERVIEW

Guatemala has the fourth highest level of chronic malnutrition in the world and the highest in Latin America and the Caribbean; approximately 50 percent of Guatemalan children younger than five years of age are stunted due to chronic malnutrition. (1, 2) Indigenous populations—which are about 40 percent of the population—have much lower access rates to health services and higher rates of poverty, malnutrition, mortality, and food insecurity (1, 3). Within indigenous areas, such as the Western Highlands, nearly 70 percent of the population is chronically malnourished. (1, 2, 3, 4, 5)

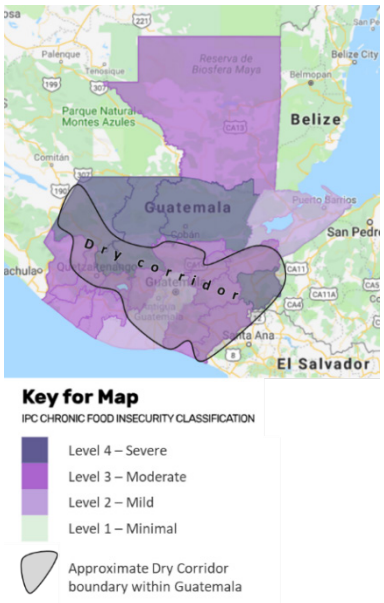

Figure 1. Chronic food insecurity in Guatemala departments, 2018–2023. Source: Modified from IPC, 2018.

Chronic malnutrition and food insecurity are driven by poverty, inadequate hygiene, inequality and exclusion, insufficient child stimulus and care, limited access to land, limited opportunities for income generation, and the high prices of staple foods. (3, 4, 6) Poverty—which is associated with malnutrition—has increased in recent years, from 51 percent in 2006 to 59 percent 2014; poverty levels are even higher for indigenous groups, at 79 percent. (3, 7) Recurrent drought further limits food security, particularly within the Dry Corridor (outlined in black in Figure 1). (1, 6) Deforestation has degraded lands and led to poor soil conditions, further limiting agricultural productivity and heightening sensitivity to extreme rainfall and landslides. (3)

From 2012 to 2016, consecutive years of drought in the Dry Corridor exacerbated food insecurity among poor households. (1, 6) Low rainfall resulted in several years of poor harvests, lost labor opportunities, and reduced household income. (1) In 2014, maize and bean harvests dropped by 50 percent in the Western Highlands and eastern Dry Corridor, leading the government to declare a state of emergency and provide food aid in affected areas. (1, 8, 9) As of late 2018, poor households in the Dry Corridor were still working to recover from indebtedness and lost assets. (1) Early 2019 has been drier than usual due to El Niño conditions, which are expected to persist through summer. (10) Climate-related stressors—including more frequent and intense drought, more variable rainfall, rising temperatures, more intense heat waves, and increased incidence of disaster events such as landslides and flooding—are expected to further aggravate food insecurity. (5, 11) The departments with the highest levels of chronic food insecurity include Chiquimula and four departments within the Western Highlands—Huehuetenango, Quiché, Alta Verapaz, and Totonicapán, as shown in dark purple (denoted as Level 4) in Figure 1. (1) Parts of these departments are also located in the Dry Corridor. (1)

CLIMATE STRESSORS AND PROJECTIONS

- Hotter and longer heat waves. 1.5°C–4°C increase in average temperatures.
- Projected increase in flood and storm—including hurricane—frequency and intensity.
- Projected reduction in dry season rainfall, and increase in intensity and severity of droughts and likelihood of forest fires.

KEY CLIMATE IMPACTS

Agriculture

Reduced water supply and longer dry seasons.
More frequent and intense flooding and reduced soil fertility.
Shifts in timing of planting and growing seasons.
Change in prevalence of pests and pathogens.

Human Health: Nutrition, WASH, and Health Services

Reduced availability and ease of accessing health services.
Reduced nutrition.
Reduced availability of clean drinking water.
Increased risk of waterborne diseases.

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This document was prepared under Environmental Compliance Services (ECOS) Task Order No. DCHA-004 and is meant to provide a brief overview of climate risk issues. The key resources at the end of the document provide more in-depth country and sectoral analysis. The contents of this report do not necessarily reflect the views of USAID.

CLIMATE SUMMARY

Guatemala lies in the tropics and has elevations that range from sea level to more than 4,000 meters (m), producing a diverse set of climates. (11, 12) Lower lying areas are typically warmer and more humid, while the highlands are typically cooler and drier; average annual temperatures range from 25°C to30°C in coastal areas, to 20°C in the highlands, and to 15°C at higher altitudes. (11) Guatemala also is highly prone to climate-related disasters, including hurricanes, floods, landslides, and droughts; globally, it has the fifth highest economic risk exposure to three or more natural hazards, with more than 83 percent of the country's gross domestic product (GDP) located in areas at risk of natural hazards. (13)

Figure 2. Regions of Guatemala. Source: USAID, 2017

Guatemala experiences two distinct seasons: a dry season (November–April) and a rainy season (May–October). (11) In July or August, the rainy season is interrupted by a 5- to 15-day break of little to no rain called the *canícula*. (11) Average annual rainfall varies substantially across the country, ranging from 600 millimeters (mm) in the eastern Dry Corridor to 5,000 mm in the humid coastal areas. (11) The central highland plateau receives an average of 1,600 mm per year, although higher altitudes, areas along the country's volcanic range, and parts of Alta Verapaz can receive more rainfall (3,500–4,000 mm per year). Guatemala also experiences hurricanes on its Pacific coast from May to October, and on its Atlantic coast from June to November. (11)

Interannual variability in precipitation is largely dictated by El Niño Southern Oscillation (ENSO) events. During El Niño years, temperatures rise, rainfall drops, and the *canícula* lengthens. Conversely, during La Niña years, temperatures decrease and rainfall increases. (11) Guatemala's Dry Corridor is particularly vulnerable to drought; from 2012 to 2016, the region experienced one of the worst droughts in the country's history. (14)

Over the past decades, Guatemala has experienced an increase in temperatures and in the frequency and intensity of ENSO-related drought and flooding events. (11) Through 2030, temperatures are projected to continue to rise, and extreme weather conditions are likely to continue to intensify, with more frequent and prolonged heat waves and drought, as well as increased frequency and severity of extreme rainfall events. (5, 11) Table 1 summarizes these climate trends.

Table 1. Climate conditions and projections. Projections are based on the model ensemble average for Representative Concentration Pathway (RCP) 4.5 and RCP 8.5.

Parameter	Current Conditions and Recent Trends (since the 1960s)	Projected Changes (2030)
Temperature	• Increases in maximum temperatures by 0.2°C and in minimum temperatures by 0.3°C per decade • Increase in the number of hot days by 2.5% and the number of hot nights by 1.7% per decade[1]	• Mean temperatures are projected to increase by 0.9°C to 1.0°C by 2030, with the greatest warming occurring in March, toward the end of the dry season. The largest increases are expected in the north, Caribbean coast, east, and southern coast. • Monthly maximum daily maximum temperatures are projected to increase by 1.3°C to 1.5°C (RCP 4.5 – RCP 8.5). • Annual number of hot days and hot nights are projected to increase. • More frequent and prolonged heat waves

Parameter	Current Conditions and Recent Trends (since the 1960s)	Projected Changes (2030)
Drought 	• Increased frequency and intensity of El Niño events, leading to frequent and severe droughts in the Dry Corridor	• More frequent and prolonged droughts • Decreases in summer precipitation, largely in central highlands, west, and eastern regions • Expansion of semi-arid climate regions
Extreme Events 	• Increase in average annual rainfall by 13% to 27%, with the largest increases in the north and the Pacific coast • Irregular start of rainy season and more intense rain in short periods of time	• Increased incidence and intensity of extreme rainfall events and floods • Increased incidence of heavy rainfall events followed by dry days

Sources: USAID 2013, USAID 2017

[1]Hot days are those where the maximum temperature exceeds 35°C (95°F). Hot nights are those where the minimum temperatures exceed 20°C (68°F).

LIVELIHOODS IN FOOD FOR PEACE PROGRAM AREAS

FFP PROGRAMMING

In Guatemala, the USAID FFP program aims to provide cash transfers to vulnerable households in the Dry Corridor, increase agricultural production and livelihood opportunities, and prevent malnutrition.

The FFP target departments include Huehuetenango, Quiché, El Progreso, Zacapa, and Chiquimula (outlined in bright blue in Figure 3). FFP departments of interest include seven nearby contiguous departments, including San Marcos, Quetzaltenango, Totonicapán, Baja Verapaz, Jalapa, Jutiapa, and Santa Rosa (outlined in light blue in Figure 3). FFP investments target departments with food insecure households that are adopting negative coping strategies—such as using savings or selling assets—to meet their food needs.

Figure 3. Guatemala departments (outlined in gray), FFP target departments (outlined in bright blue), and FFP departments of interest (outlined in light blue).

FFP supports and partners with a variety of initiatives to alleviate food insecurity, including:

- Save the Children, which provides cash for food in the Quiché Department, and trains vulnerable households on agricultural best practices, livelihood strategies, and nutrition. (1)
- Catholic Relief Services, which provides cash transfers for food in the Chiquimula, El Progreso, and Zacapa departments, and provides training on increasing agricultural production and livelihood opportunities, improving financial literacy, and preventing malnutrition. (1)
- Two multi-year development programs aimed at strengthening community food security and resilience to shocks. (1)

LIVELIHOOD ZONES IN FFP PROGRAM AREAS

Agriculture is Guatemala's largest economic sector, making up 14 percent of GDP, 50 percent of export earnings, and 31 percent of total employment. (11) Guatemala's largest export is coffee, which is mostly cultivated by small-scale farmers predominantly in livelihood zones[1] GT05, GT07, GT08, GT10, and GT11, all of which are in FFP program areas. Sugarcane is the next largest export and is mostly produced by large-scale industrial operations. The country's other cash crops include bananas, African palm, cardamom, rubber, fruits, and vegetables. Notably, large-scale agriculture employs many people in rural areas. In the livelihood zones that the FFP program focuses on (GT03, GT05, GT06, GT07, GT08, GT10, and GT11), better-off and middle-income households mainly earn income through trade and business, crop and livestock sales, and remittances, while poorer households earn income mainly through agricultural labor. (8)

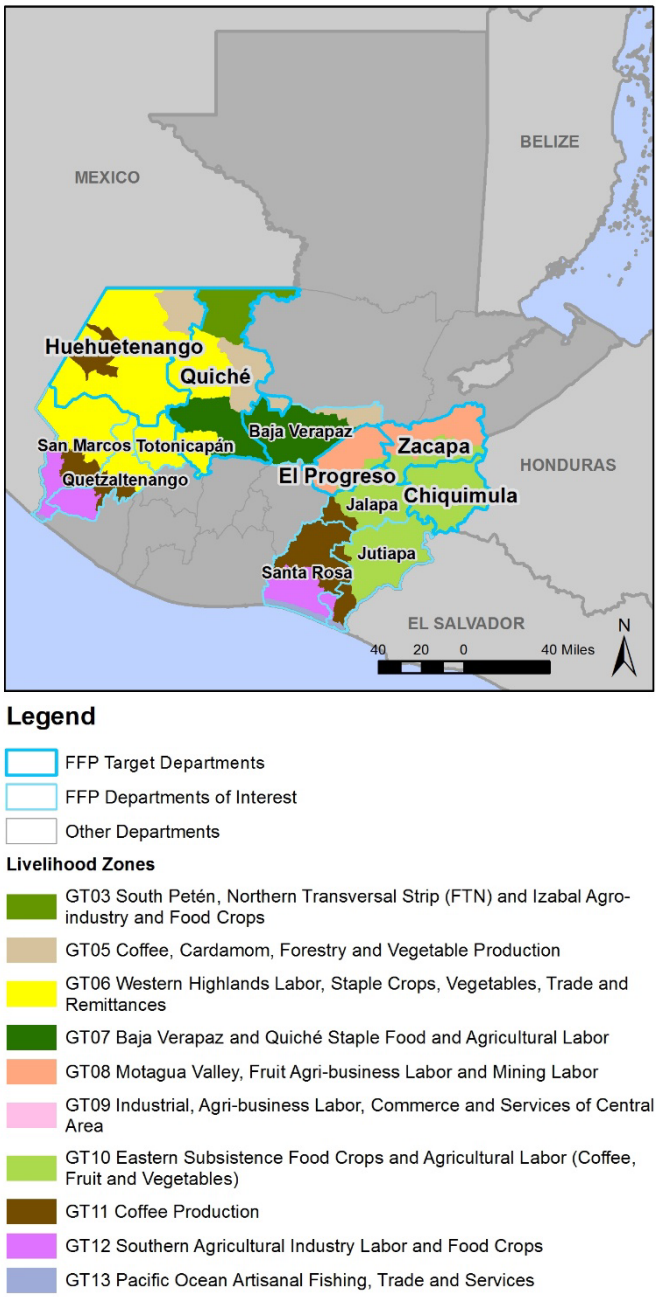

Figure 4. Livelihood zones within FFP target departments and departments of interest. Source: FEWS NET 2017

Wealth is linked to land ownership and the ability to expand agricultural operations and invest in business ventures. (8) Land ownership is concentrated among the very wealthy, with 2 percent of commercial producers owning 57 percent of agricultural land—these farms generally grow cash crops for export rather than crops that contribute to the Guatemalan food supply. (9) Meanwhile, smallholder farmers (who make up 92 percent of farmers) cultivate low-value staples (i.e., maize and beans). (9) There are many extremely poor households that lack access to land, making them completely dependent on agricultural labor, petty trade, and/or remittances for income. (9)

All economic groups primarily obtain food through market purchases, strongly tying food security to household income. Households typically grow 10 percent to 20 percent of their food, mainly consisting of maize and beans. Relative to other income groups, better-off households typically meet a greater proportion of their food needs through purchases. Middle-income and poor households meet a greater proportion of food needs through household crop production and wild

[1] Livelihood zones define areas within which people broadly share similar livelihood patterns.

foods (i.e., seasonal fishing, hunting, and/or gathering). Very poor households are even more reliant on wild foods. (8)

Because households rely heavily on agriculture for both food and income, and because 71 percent of agriculture is rainfed, household food security is heavily affected by variability in precipitation and temperature, including flooding events, drought, and frost. (11)

Figure 5 provides a seasonal calendar of events related to Guatemala's agricultural sector, including planting times (in green), rainy seasons (in medium blue), dry/lean seasons (in red), harvests (in yellow), hurricane and frost seasons (in dark blue), and labor needs (in gray).

Table 2 summarizes the seven livelihood zones in FFP target departments, which include most of those within FFP departments of interest, as shown in Figure 4.[2] The table describes climate and terrain, crops produced and primary sources of food and income, and climate and non-climate stressors that impact food security, including those that impact crop production, food processing and storage, and human health.

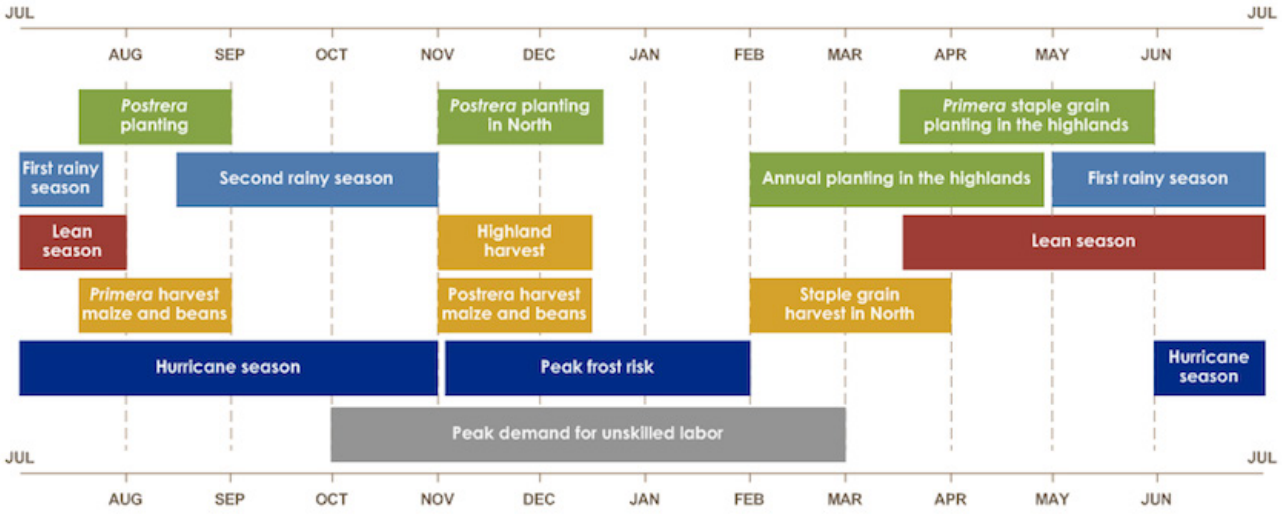

Figure 5. FEWS NET seasonal calendar for Guatemala. Source: FEWS NET 2013

[2] GT12 and GT13 make up a portion of several departments of interest, but are not present in FFP target departments, and therefore are not included in the table.

Table 2. Livelihood zones, climate and terrain, economic activities and sources of food and income, stressors on food security, and poorer household strategies for coping with food insecurity in Guatemala's FFP program areas.

Livelihood Zone	Climate and Terrain	Zone Description	Main Stressors on Food Security	Impacts to poorer households
South Petén, Northern Transversal Strip, and Izabal Agro-Industry and Food Crops (GT03)	Flat and fertile land, with good levels of humidity and rainfall, and a long wet season that extends into January. Highly productive and includes two of the longest rivers in Guatemala—La Pasión and Usumacinta. Annual rainfall: 2,000 mm/year	**Main economic activities** • Agricultural production for export • Cattle ranching **Main sources of income for poorer households** • Local labor in agri-business • Crop sales **Sources of food for poorer households** • 20% crops • 60% market purchases • 20% wild foods/animal products	**Crop production** • Dry spells and delay of start of rainy season, particularly damaging when sowing has started (May–July) • Heavy showers and flooding (Oct–Nov), localized flooding along main river that can delay next sowing period or damage crops still in the ground (sweet potatoes and cash crops) • Hurricanes, occurring approx. every 3 years, damage crops/pastures • Crop pests (mostly after the dry season), such as stalk borer, rootworm, chimilca slugs that attack maize and beans, and grubs and ants • Expansion of African palm production; areas dedicated to food production converted to palm plantations, also results in river pollution **Nutrition** • Consumption of aflatoxin-contaminated maize	• Loss of income results in a need to find other sources of income, generally through: ○ Taking out loans and going into debt ○ Migrating elsewhere for employment ○ Selling charcoal ○ Selling wild foods
Coffee, Cardamom, Forestry, and Vegetable Production (GT05)	Mountainous zone, including the Chamá mountain range (200 kilometers long, ranging 1,000–1,500 m above sea level). Includes large forested areas with high-value wood. Annual rainfall: 2,000–4,000 mm/year, depending on the altitude	**Main economic activities** • Coffee, cardamom, and vegetable production • Forestry initiatives **Main sources of income for poorer households** • Local agricultural labor • Crop sales (maize, beans, coffee, and vegetables) **Sources of food for poorer households** • 60%–70% market purchases • 30% crops	**Crop production** • Dry spells at the start of the rainy season (May–July); especially affect maize and beans • Frost, which is especially damaging to vegetable crops • Pests affecting cardamom, especially cardamom thrips disease (*Sciothrips cardamomi*) • Coffee rust, whose range has expanded due to rising temperatures • Fluctuations in the price of cash crops (cardamom and coffee) **Food processing and storage** • Heavy rain and flooding lead to landslides (esp. Sept–Nov), blocking roads and increasing transportation costs **Nutrition** • Consumption of aflatoxin-contaminated maize	• Loss of income results in a need to find other sources of income, generally through: ○ Taking out loans and going into debt ○ Selling assets and reducing savings ○ Migrating elsewhere for employment
Western Highlands Labor, Staple Crops,	Mostly lies 1,000 m above sea level and consists of highland plains and escarped mountains and volcanoes, including the	**Main economic activities** • Vegetables, potatoes, and fruit production • Cross-border trade **Main sources of income for poorer households**	**Crop production** • Delayed rainfall and extended dry spells (esp. during the *canícula*) damage crops • Increases in temperature (esp. during the *canícula*) can damage crops	• Loss of income results in a need to find other sources of income, generally through: ○ Taking out loans and/or mortgaging

Livelihood Zone	Climate and Terrain	Zone Description	Main Stressors on Food Security	Impacts to poorer households
Vegetable, Trade, and Remittances (GT06)	highest in the country (4,000 m above sea level). Parts of the zone are covered in forest and pine trees unique to the area. Annual rainfall: 500–5,000 mm/year	• Local and migratory agricultural labor • Remittances • Crop sales **Sources of food for poorer households** • 80%–90% market purchases • 10%–20% crops	• Flooding and landslides in June–Oct damage crops and lead to roadblocks • Frost (Nov–Dec), hail (May–June), and strong winds (July–Oct) damage crops **Nutrition** • Consumption of aflatoxin-contaminated maize	assets and going into debt ○ Selling assets and reducing savings ○ Migrating elsewhere for employment
Baja Verapaz and Quiché Staple Food and Agricultural Labor (GT07)	Mostly mountainous with some valleys; contains a diversity of forests, including dry subtropical, subtropical broadleaf, and coniferous. Wood is used for timber and firewood. Several rivers flow through the area. Average rainfall: 600–700 mm/year in central and southern parts and 1,500 mm/year in the north	**Main economic activities** • Vegetables and sugarcane production **Main sources of income for poorer households** • Local and migratory agricultural labor (coffee plantations) **Sources of food for poorer households** • 90% market purchases • 10% crops	**Crop production** • Drought decreases crop yields, increasing the cost of staple foods and requiring replanting when the harvest fails; especially damaging after sowing • Flooding and landslides (Aug–Oct) damage crops and block roads, leading to increased transportation costs • Coffee rust, whose range has expanded due to rising temperatures • Frost, which is especially damaging to vegetable crops • Fluctuations in staple food costs **Nutrition** • Consumption of aflatoxin-contaminated maize	• Loss of income results in a need to find other sources of income and reduce expenditures, generally through: ○ Taking out loans and going into debt ○ Selling assets, and spending and reducing savings ○ Removing children from school to help generate income, limiting their education ○ Engaging in illegal activities (e.g., opium poppy production, drug trade) ○ Eating less-preferred and cheaper foods, potentially reducing health and increasing consumption of aflatoxin-contaminated maize ○ Migrating elsewhere for employment
Motagua Valley, Fruit Agri-Business Labor, and Mining	Constitutes part of the Dry Corridor and surrounded by mountains (*Sierra de las Minas* to the north and *Sierra del Merendón* to the south), so	**Main economic activities** • Agri-business (coffee, melons/watermelons, other fruits, and vegetables) • Mining • Timber processing	**Crop production** • Drought (most likely May–July) and flooding affect food production; drought can especially wipe out maize and beans • Crop plagues and diseases, particularly for coffee (coffee rust) and fruit; range of coffee rust has expanded due to rising temperatures	• Loss of income results in a need to find other sources of income and reduce expenditures, generally through: ○ Selling livestock and reducing savings

Livelihood Zone	Climate and Terrain	Zone Description	Main Stressors on Food Security	Impacts to poorer households
Labor (GT08)	topography varies from low-level valley plains to mountains 2,900 m above sea level. Contains both deciduous and evergreen forests and vegetation. Annual rainfall: ~1,300 mm/year, wetter and cooler climates in higher altitudes	**Main sources of income for poorer households** • Local agricultural labor • Local mining labor • Migratory labor (Guatemala City and Petén) **Sources of food for poorer households** • 80%–90% market purchases • 10%–20% crops	• Fluctuations in the price of cash crops, especially coffee **Human health** • Human illness (most common May–June) stresses household income **Nutrition** • Consumption of aflatoxin-contaminated maize	○ Reducing expenditures on non-essential items and foods, potentially harming health and increasing consumption of aflatoxin-contaminated maize ○ Migrating elsewhere for employment ○ Appealing to migrants outside the country for support
Eastern Subsistence Food Crops and Agricultural Labor (Coffee, Fruit, and Vegetables) (GT10)	Hilly and rugged, with steep slopes and floodplains; includes some volcanoes. Mostly covered in conifer, broadleaf forests, and dry shrub forests, as well as perennial grasslands used as livestock fodder. Encompasses some of the Dry Corridor. Annual rainfall: 800–1,500 mm/year	**Main economic activities** • Coffee, fruit, and vegetable production • Staple crop production **Main sources of income for poorer households** • Local agricultural labor • Migration to coffee production areas in Honduras **Sources of food for poorer households** • 40%–50% market purchases • 30%–40% crops • 10% animal products	**Crop production** • Drought, with uneven rain distribution from May–Oct and a dry spell in July/Aug, resulting in crop losses, a reduction in the demand for labor, an increase in food prices, and a reduction in water reserves • Excessive rain caused by tropical events (Oct–Nov), resulting in saturated soil, overflowing rivers, and landslides • Crop pests (May–Nov), mostly affect rainfed cereals; also coffee rust, whose range has expanded due to rising temperatures. **Nutrition** • Consumption of aflatoxin-contaminated maize	• Loss of income results in a need to find other sources of income and reduce expenditures, generally through: ○ Reducing surplus expenses, potentially harming health ○ Selling livestock and reducing savings ○ Purchasing food and agricultural inputs on credit, resulting in debt ○ Reducing expenditures on non-essential items and foods, potentially reducing health ○ Migrating elsewhere for employment ○ Appealing to the community for support ○ Gathering and selling firewood and recycled materials
Coffee Production (GT11)	Two distinct geographic areas:	**Main economic activities** • Coffee and fruit production **Main sources of income for poorer households**	**Crop production** • Droughts (Apr–Aug), especially bad after budding of coffee flowers	• Loss of income results in a need to find other sources of income and reduce

Livelihood Zone	Climate and Terrain	Zone Description	Main Stressors on Food Security	Impacts to poorer households
	1. Volcanic and mountainous terrain 1,300–2,000 m above sea level, rich and fertile soils 2. Highlands up to 2,000 m above sea level and arid Topography ranges from flat to steep volcanoes. Mainly volcanic soils, with large amount of natural irrigation, making the land very fertile. Contains coniferous forests, broadleaf forests and mixed forests. Annual rainfall: 1,000–4,000 mm/year, depending on the altitude	• Crop sales (coffee and fruits) • Local agricultural labor • Remittances **Sources of food for poorer households** • 80% market purchases • 20% crops	• Prolonged rains (May) lead to floods that saturate soil and cause crop losses • Pests and diseases, such as coffee rust. Coffee rust has occurred every year since 2012 and usually in the rainy season. Coffee rust's range also has expanded due to rising temperatures. • Transition to other crops; replaces coffee plantations with monoculture crops that deplete the soil of nutrients • Price and demand fluctuations in domestic and international markets, approx. every 3 years, result in fluctuations in labor demand **Food processing and storage** • Violence and theft are predominant during harvest time **Nutrition** • Consumption of aflatoxin-contaminated maize	expenditures, generally through: ○ Searching for alternative casual labor ○ Going into debt by relying on credit and loans ○ Migrating elsewhere for employment

Source: FEWS NET 2016

SECTOR IMPACTS AND VULNERABILITIES

AGRICULTURE

Agriculture is one of Guatemala's main economic sectors. (14) Since 2000, agriculture has employed at least one-third of Guatemalans, and in 2015, it accounted for 45 percent of exports. (14) In the livelihood zones where FFP focuses its programming (i.e., those with vulnerable populations), many households are smallholder farmers who rely on agriculture for food and income. As a result, household agricultural productivity heavily affects the food security and nutrition levels of these vulnerable populations. (14)

The following sections describe food insecurity drivers, including climate-related drivers, in various agriculture components, including crop production, invasive species, pesticide use and storage, livestock, and food processing and storage.

Crop Production

Because crop production provides a livelihood for most households, stresses on crop production have significant effects on income levels and the ability to purchase food. Reduced crop productivity also limits households' ability to meet their food needs through subsistence farming. (8) Crop productivity is limited mainly by the following stressors:

- **Governance, technological, and financial stressors.** One of the most significant factors limiting food security and crop production is a failure at the national level—in part due to weak government systems and political instability—to implement policies, plans, and programs that support agriculture. (4, 6) For example, there are low levels of extension services provided. (9) As a result, there is limited support for smallholder farmers, who typically produce maize and beans inefficiently, using unimproved varieties, basic production techniques, and poor nutrient management. (9) Limited government support has also resulted in poor post-harvest farming infrastructure throughout the country, which may contribute to the widespread maize aflatoxin contamination, described further in the Food Processing and Storage section. (9, 14, 15) Furthermore, farmers have limited access to finance, hindering investment in improving agricultural technology and infrastructure. (14) An unfavorable regulatory environment, which is particularly complex and suffers from corruption, further curbs agricultural investments. (14) A lack of agricultural insurance limits farms' ability to manage the risk of low crop yields. (14) In addition, land is concentrated among the wealthy elite who run commercial operations, limiting opportunities for poorer households. (16)

- **Environmental degradation.** Deforestation and over-exploitation of forest resources, which have degraded lands and led to increased erosion and poor soil conditions, further limits agricultural productivity. (3, 9, 14) Degradation has also increased sensitivity to climate stressors, such as extreme rainfall and the resulting landslides. (8, 9, 11)

- **Climate stressors.** Guatemala's agriculture is characterized by high climatic variability, including drought and heavy rains, which creates challenges for agriculture. (9, 14) In 2018, along the Dry Corridor, a delayed rainy season followed heavy rains damaged more than half of subsistence farmers' maize and bean crops. (17) Crop production is particularly sensitive to drought due to a lack of water storage and irrigation; only 18 percent of agricultural land is irrigated, the majority of which belongs to large landowners. (9) Furthermore, because smallholder crops are largely grown on mountainous terrain, extreme rainfall can trigger erosion and landslides that degrade soils and damage crops (8, 11)

Excessive rainfall also can result in flooding and soil waterlogging, damaging crops that are still in the ground. (8) Landslides and flooding can be especially severe when rainfall follows drought conditions, and their severity has been exacerbated by deforestation. (8, 9, 11) Maize is frequently contaminated by aflatoxins in Guatemala, which can be driven by unseasonable rains or drought during the growing season or harvest, and by humid conditions during storage. (18, 19) In addition, temperature increases have shifted ideal agro-ecological zones and increased the range of pests, such as coffee rust, described below. (9)

- **Crop pests.** Many crops are damaged by pests. For example, cardamom is affected by cardamom thrips, and coffee is affected by coffee rust, or the *roya* fungus. Because coffee is one of Guatemala's most exported cash crops, this is especially problematic for the country's economy. (8, 14)

Temperatures are projected to rise while extreme events—such as heat waves, droughts, and heavy rainfall—are expected to become more frequent and severe, further stressing Guatemala's crop production. (11) In addition, these changes may exacerbate other hazards with the potential of damaging crops, such as landslides and forest fires. (8, 10,20) The hazards may also exacerbate aflatoxin contamination. (18) Table 3 summarizes the main climate sensitivities and adaptive characteristics of Guatemala's staple crops (maize and beans) and crops with the greatest gross production value that are not primarily produced by large landowners (maize and coffee).

Table 4 summarizes the major climate-related risks facing the agricultural sector and potential adaptation responses to address these risks. The adaptation measures are intended to both improve crop production to prevent food security emergencies and bolster long-term agricultural development and resilience to climate risk.

Table 3. Climate sensitivities and adaptive characteristics of staple crops and crops with the greatest gross production value.

Crop	Climate Sensitivities	Adaptive Characteristics
Maize	• Dry spells at the start of the rainy season are especially damaging when they occur when sowing has begun (May–July). (8) • Drought harms maize production. From 2014–2016, drought resulted in maize production losses. (14) • Drought and unseasonable rains can trigger aflatoxin production. (18)	• The International Maize and Wheat Improvement Center is developing heat- and drought-tolerant maize varieties that have adapted to low-nitrogen environments. (21)
Beans	• Dry spells at the start of the rainy season are especially damaging when they occur when sowing has begun (May–July). (8) • Prolonged rains create floods that cause crop losses. (8)	• The International Center for Tropical Agriculture is breeding common beans for heat stress tolerance. (21)
Coffee	• Prolonged rains (May) lead to floods that saturate soil and cause crop losses. (8) • Droughts are especially problematic after budding of coffee flowers (Apr–Aug). (8) • Indirect sensitivity to rising minimum temperatures, which enable coffee rust to spread to higher altitudes. In 2012, 20% of Guatemalan coffee production was lost due to a coffee rust epidemic. (14) • Indirect sensitivity to more frequent heat waves and heavy rainfall as intense heat, followed by intense rainfall, increases the prevalence of coffee rust. (22)	

Table 4. Crop production climate risks and responses.

Climate Risks	Potential Adaptation Responses

Drought and dry spells resulting in reduced yields or crop failure (8)	• **Use seasonal forecasts** to predict and prepare for droughts and dry spells, including those driven by El Niño events.
	• **Increase water availability:**
	  • **Create water storage and irrigation systems** in order to increase water availability during drought periods.
	  • **Harvest water** to capture excess runoff, especially since much of the precipitation in Central America occurs within a few months. (21)
	• **Improve soil water retention:**
	  • **Improve soil management** to maximize water retention throughout the soil profile. Increase soil organic matter and infiltration rates by retaining plant residue on the soil surface, managing mulch, and using minimal- to no-tillage systems. Maintain permanent soil cover to reduce evaporation. Proper soil management can increase water efficiency by 25%–40%. (21)
	  • **Implement resilient agroforestry** techniques, such as tree alley cropping, to provide tree crops as long-term income, and riparian buffers or windbreaks to prevent erosion and water loss. (23, 24)
	  • **Improve plant nutrient management** to increase water efficiency by 10%–15%. (21)
	  • **Reduce deforestation** in the Western Highlands in order to enhance water availability and improve soil water retention. (23)
	• **Reduce sensitivity to drought:**
	  • **Distribute drought-resistant crop varieties** to increase the ability to cope with drought.
	  • **Intercrop** maize with drought-tolerant crops to provide a secondary crop for income if the primary harvest (maize) fails. (25)

Heavy rain triggering erosion and landslides that reduce soil fertility and damage crops (8)	• **Use seasonal forecasts** to predict and prepare for heavy rainfall events that are associated with La Niña events.
	• **Prevent erosion and landslides:**
	  • **Implement agroforestry**, including tree alley cropping, to provide trees as long-term income, improve soil fertility, and prevent erosion and landslides. (26, 27)
	  • **Implement terraces** on slopes in order to prevent erosion and prevent floodwaters from washing away crops. (25)
	  • **Plant cover crops** in order to prevent erosion. (25)
	• **Implement early warning systems and monitoring**, through weather stations, to help farmers prepare for extreme events. (28)

Heavy rain causing flooding and soil waterlogging that damages crops (8)	• **Use seasonal forecasts** to predict and prepare for heavy rainfall events that are associated with La Niña events.
	• **Prevent flooding and waterlogging:**
	  • **Implement agroforestry**, planting trees near crops to improve soil structure and permeability, and reduce crop waterlogging.
	  • **Implement riparian buffers** along rivers to prevent flooding.
	• **Create seed banks** that distribute seeds which better tolerate waterlogging. (28)
	• **Implement early warning systems and monitoring**, through weather stations, to help farmers prepare for extreme events. (28)

Drought or unseasonable rains trigger aflatoxin production (18)	• **Breed aflatoxin-resistant** maize varieties. (18) • **Implement irrigation** and other drought-management strategies (described above) to avoid water stress. (18)
Hail damaging crops (8)	• **Create seed banks** that distribute hail-tolerant seeds. (28)
Strong winds damaging crops (8)	• **Promote the use of hedges** and establish natural barriers in order to protect crops. (25) • **Implement cover crops** in order to reduce erosion. (25) • **Implement resilient agroforestry** techniques, such as tree windbreaks. (23, 24)
Rising temperatures resulting in crop	• **Implement agroforestry** using trees to shade crops that cannot tolerate high temperatures, but can tolerate shade. (23, 24, 25) • **Stagger planting times** to avoid periods of extreme heat. (25)

Climate Risks	Potential Adaptation Responses
failure or migration (28)	• **Create seed banks** that distribute heat-tolerant seeds. (28)
Rising temperatures resulting in an expansion of coffee rust territory	• **Establish sustainable cultivation** that controls for fungal attacks (i.e., coffee rust). (25) • **Develop fungicides** to combat coffee rust. (22) • **Develop coffee varieties that are resistant to coffee rust**. • **Migrate coffee crops to higher altitudes** in order to avoid coffee rust. (14) • **Transition to producing other crops**. (14)
Increased frequency and intensity of droughts heightening the risk of forest fires, which may damage crops	• **Implement early warning systems and monitoring**, through weather stations, to help farmers prepare for extreme events. (28) • **Implement messaging campaigns** to prevent human-induced forest fire ignitions. • **Enhance the ability to combat forest fires**.
Cross-cutting risks that lead to crop losses	• **Improve crop insurance and other financial mechanisms** to support farmers when crops are lost. • **Build institutional capacity** within local governments to support farmers in adapting to climate change. • **Build value chain capacity** to adapt to climate change.

Invasive Species

To date, invasive species have not been a significant threat to Guatemala's agriculture. However, climate change is expected to intensify climate stressors—such as extreme heat, drought, and forest fire—resulting in conditions that allow invasive species to proliferate. Higher temperatures may cause some invasive species to spread geographically or become active for longer portions of the year, while weeds that tolerate severe drought may gain a competitive advantage against crops. (29, 30, 31)

Table 5 summarizes the notable risks of invasive species facing Guatemala's agricultural sector and potential adaptation responses to address these risks. The adaptation measures are intended to help eradicate or control population growth of the invasive species while protecting agricultural crops.

Table 5. Spread of invasive species climate risks and responses.

Climate Risks	Potential Adaptation Responses
Solenopsis geminate **(fire ant) can colonize agricultural systems, such as coffee and sugarcane plantations, in hot climates. (30)**	• **Preventative measures**, such as effective quarantine, continuous monitoring, and immediate response upon finding newly established populations (31) • **Chemical baits** laced with hydramethylnon to help control populations (31)
Chromolaena odorata **(weed) can become a fuel that promotes forest fires when dry, and is also a major weed in plantations and croplands, including for coffee plants. (30)**	• **Slashing** to control weeds (31) • **Chemical control**, using herbicides during the seedling stage (31) • **Biological control** agents, such as *Pareuchaetes pseudoinsulata* or *Cecidochares connexa* (31)
Ceratitis capitata **(Mediterranean fruit fly) can lay eggs in fruit or damage crops, and may become active earlier in the year if winters become warmer. (32)**	• **Foliage baiting or cover spraying** old fruit to prevent the spread of flies (32) • **Biological control** using the sterile insect technique (32)
Bidens pilosa **(herb) can survive severe droughts and spread as a weed in agricultural areas. (32)**	• **Hand weeding** (32) • **Herbicides**, especially broad-leafed plant herbicides (32)

Pesticide Use and Storage

Guatemala may see a spread in crop pests in the face of climate change. For example, potato tuber moths, which infiltrate the skin of potato tubers, have shorter life cycles in hot weather, allowing more generations to appear each year. Thus, as temperatures increase, moth populations may multiply. (38) As described in the Crop Production section, as temperatures warm, the range of coffee rust increases. Furthermore, coffee rust is most prevalent when intense heat is followed by intense rainfall; both conditions are projected to become more likely, which may increase the prevalence of coffee rust and the resulting crop damage. (8)

With increased occurrence of pests in agricultural crops, the need for pest management is expected to increase. A survey of smallholder farmers in Central America found that 17 percent of farmers currently implement increasing pesticide use as an adaptation strategy. (30) Furthermore, pesticide use, measured by its trade value, increased by 112 percent from 2000 to 2013 in Guatemala. (14) However, pesticide use can be problematic as pesticides have unintended hazardous effects on human and ecological health. (33)

Table 6 summarizes the primary pests that affect Guatemala's major crops and the potential non-pesticide adaptation responses to address these risks. Table 7 summarizes the major climate risks with the potential to exacerbate the prevalence of pests and increase the environmental contamination from the use of pesticides, and adaptation measures intended to address these risks.

Table 6. Major crop pests and potential non-pesticide responses to address these risks.

Crop	Major Pests and Livelihood Zones Affected	Impacts on Poorer Households	Adaptation Strategies
Coffee	• Coffee rust, or *roya* fungus has occurred every year since 2012 and usually in the rainy season, resulting in a declaration of a national emergency in 2013 (GT05, GT07, GT08, GT10, and GT11). (8) • Coffee berry borers also adversely affect coffee bean quality. (34)	• Reduced household income from crop sales (8) • Reduced employment available for laborers, and increased need to find alternate source of income (8) • Transition to growing other crops (e.g., fruit) and rust-resistant coffee varieties, and clearing plantations to sell wood products (8)	• Avoid high planting density and have proper placement, and weed and shade management to reduce humidity, which makes coffee fungus rapidly develop. (35) • Provide proper nutrition to maintain healthy coffee plant defenses. (35)
Cardamom	• Cardamom thrips are the most destructive and persistent cardamom pest (GT05). (8)	• Reduced household income from crop sales (8) • Reduced employment available for laborers, and increased need to find alternate source of income (8)	• Natural remedies, such as neem oil and the *Lecancillium psalliotae* fungus, have effectively controlled cardamom thrips. (36, 37)
Fruit	• Fruit pests and diseases, such as whitefly, thrips, and fusarium, can increase costs and the rate of rejections due to crop damages (mainly GT08, but also GT06 and GT10). (8)	• Reduced household income from crop sales (8) • Reduced employment available for laborers, and increased need to find alternate source of income (8)	• Increasing wild food harvest can lessen the dependence on fruit for sustenance and income. (25)
Vegetables	• Potato tuber moths (38) • Whitefly, thrips, and fusarium can adversely affect yield, and increase costs and the	• Reduced household income from crop sales (8)	• Some natural enemies of the moth, such as *Phthorimaea operculella*,

Crop	Major Pests and Livelihood Zones Affected	Impacts on Poorer Households	Adaptation Strategies
	rate of rejections due to crop damage (GT06, GT07, GT08, and GT10). (34)	• Increased labor demand due to a need to rotate crops to different areas to escape pests (8) • Increased cost of crop production due to a need to purchase pesticides (8)	can be used as biological control agents. (38)

Table 7. This table includes (1) climate risks that may (a) increase the prevalence of pests, (b) reduce the effectiveness of pesticides, or (c) increase human or environmental health risk from pesticides, and (2) adaptation responses to address these risks.

Climate Risks	Potential Adaptation Responses
Increasing temperatures and higher frequency and severity of extreme precipitation events, **which** can increase the spread of pests, requiring more pesticide use	• Use integrated pest management, which does not use pesticides as the primary tool to fight pests. • Encourage and support farmers in participating in lucrative organic overseas markets that require lower pesticide residues. • Apply biological controls. • Apply pesticides as appropriate.
Increasing frequency and severity of extreme precipitation events, which may result in high moisture and pests in food storage	• Keep the storage area clean. (40) • Put pest-repelling plant parts (e.g., tobacco, neem leaves) with the stored food. (40) • Bring in cats to hunt pests. (40) • Heat or cool airtight storage areas to kill pests. (40)
Increasing precipitation volatility (transitions from drought to exceptionally wet periods), which results in a spread of migratory pests	• Have “no pesticide” boundaries to keep villages and waterways safe. • Set up pre- and post-spraying environmental monitoring. • Test pesticide users consistently in case of overexposure.
Reduced effectiveness and/or shelf life due to climate stressors **(40)**	• Encourage adoption of non-pesticide integrated pest management, and non-chemical cultural and biological controls. (39) • For pesticides distributed or activated by water, promote pesticide storage in watertight containers, high ground that will not flood, and covered areas. (40) • For pesticides distributed or activated by water, promote the monitoring of pesticides to check for leakage and contamination, particularly during rainy seasons. (40) • For pesticides sensitive to heat, store in cool locations. (39)
Increased extreme rainfall rinsing topical pesticides away and reducing pesticide effectiveness and increasing environmental contamination through runoff and groundwater infiltration (40)	• Encourage adoption of integrated pest management, and non-chemical cultural and biological controls. (39) • Apply systemic pesticides rather than topical pesticides. (40) • Provide training on pesticide application (appropriate timing and quantity). (40) • Use seasonal weather forecasts to plan the timing of pesticide application (avoid applying before rain is expected). (40) • Reduce runoff by leveling fields and implementing runoff capture systems. (40) • Avoid pesticide application near surface waters, areas with high water tables, or intertidal areas. (39)
Increased risk of crop damage when applying certain pesticides (e.g., sulfur) in hot conditions (39)	• Encourage adoption of non-pesticide integrated pest management, and non-chemical cultural and biological controls. (39) • Avoid applying pesticides during hot conditions to prevent leaf burn. (39)
Increased environmental contamination due to increases in intense winds (40)	• Encourage adoption of non-pesticide integrated pest management, and non-chemical cultural and biological controls. (39) • Use seasonal weather forecasts to plan the timing of pesticide application, and avoid applying immediately before or during windy conditions. (40)

Climate Risks	Potential Adaptation Responses
	• Encourage application in the morning and evening to minimize the drift of pesticide sprays. (39)
Increased health hazards due to rising temperatures (e.g., farmers may be less willing to use personal protective equipment, tissue irritation may worsen) (39, 40)	• Encourage adoption of non-pesticide integrated pest management, and non-chemical cultural and biological controls. (39) • Encourage adoption of less toxic pesticides and improved application methods. (40) • Increase the availability of comfortable, affordable personal protective equipment. • Increase the availability of safer use training. • Discourage pesticide application when temperatures exceed 36°C. (39)

Food Processing and Storage

Guatemala faces challenges in its agricultural infrastructure, namely crop storage and road infrastructure. In 2016, Guatemala received the lowest possible score—a zero—for the existence of adequate crop storage facilities in the Economist Intelligence Unit's Global Food Security Index. (14) Poorer farmers especially lack post-harvest storage facilities, which results in food crop losses, particularly in hot weather, which is projected to increase. (8) A lack of storage facilities means that farmers cannot store food past the harvest season, which may result in food insecurity in post-harvest months. This also means that better-off households, which often do have storage facilities, can sell off-season crops at a higher price, while poorer households are forced to sell them during the harvest season when prices are lower. (8) Poor storage also encourages the growth of aflatoxins, particularly in hot, humid climates; aflatoxin contamination of maize has historically been a widespread issue in Guatemala. (15, 18, 19)

Climate-related extremes have posed risks to post-harvest processes in the past. Extreme events, such as heavy rainfall, can cause damage to facilities involved in post-harvest processing, and cause flooding and landslides that block Guatemala's roads, preventing transportation and distribution of food. (41) Road quality also is typically so poor that fresh produce incurs substantial damage in transit. (16) Compared to Latin America and Caribbean countries, Guatemala already ranks below average in terms of its road infrastructure extent and quality. (14) As climate change is projected to increase the incidence of extreme storm and flooding events in the future, post-harvest damage to crops and infrastructure is likely to increase as well. (8) Rising temperatures and changes in humidity also may accelerate food spoilage and the growth of aflatoxin. (34)

Table 8 summarizes the risks to post-harvesting processes faced from climate change and potential adaptation responses to address these risks.

Table 8. Post-harvest climate risks and responses.

Post-Harvest Component	Climate Risks	Potential Adaptation Responses
All Post-Harvest Components	• **Extreme events**—such as floods, landslides, and storms—can damage infrastructure and food products, disrupting post-harvest processes and potentially increasing costs. (8, 41)	• **Use existing seasonal forecasts (e.g., FEWS NET)** to prepare for climate impacts. • **Establish or make use of existing early warning systems** to enable preparation for extreme weather events (e.g., elevating food products so that if flooding occurs, they are protected; modifying transportation schedules or routes). (23) • **Retrofit existing infrastructure** to protect against flooding and landslides (e.g., improved drainage, improved road paving, barriers to protect against landslides, revegetation efforts to reduce the likelihood of landslides).

Post-Harvest Component	Climate Risks	Potential Adaptation Responses
		• **Incentivize the development of new infrastructure away from high-risk locations** (e.g., coastal areas, areas prone to flooding and hurricane damage, very hot and very humid areas).
	• **Aflatoxin contamination** is driven by more frequent drought and unseasonable rains. (18)	• **Use appropriate post-harvest practices**, including appropriate drying; maintaining proper storage; and preventing grain exposure to moisture during storage, transport, and marketing. (18) • **Separate contaminated kernels** from non-contaminated kernels. (18) • **Detoxify grains** (e.g., through ammonia) if the grain is for animal feed. (18)
Processing, Packaging, and Storage	• **Altered effectiveness of fumigants** due to increases in temperature and changes in humidity (42) • **Accelerated spoiling** due to increased temperatures and changes in humidity (8, 34)	• **Improve access to and the affordability of fumigants** that are effective despite projected increases in temperature and changes in humidity. • **Improve access to and the affordability of processing and packaging practices and materials** that will preserve food products despite projected increases in temperature and changes in humidity. (23, 43) • **Increase access to and the affordability of climate-controlled storage**.
Transportation and Distribution	• **Heavy rain and flooding** leading to landslides (esp. Sept–Nov), blocking roads and increasing transportation costs (8)	• **Alter transportation routes and schedules** to adjust to heavy rain, flooding, and landslides. • **Improve the extent and quality** of the transportation network so that there are additional, more resilient options for transporting food.

Livestock

The role of livestock production varies greatly throughout Guatemala by department. Livestock sales provide little to no income for most households in FFP program areas; small animals, such as chicken, goats, and rabbits, are considered to be important assets to vulnerable households as they act as insurance or "savings accounts" that can be used during lean periods. (8) However, livestock sales provide about 60 percent of household income for better-off households in GT03, and around 20 percent to 25 percent of household income for middle-income households in GT03 and better-off households in GT10 and GT11. (8) Livestock also provide milk and meat for households. Most households, particularly poorer ones, are more likely to own only poultry and pigs. Higher income households may own cattle, horses, and small ruminants, such as goats and sheep. (8) In some livelihood zones (namely GT07, GT08, GT10, and GT11), better-off households do not own livestock, rather they purchase meat as needed.

Livestock are vulnerable to multiple climate stressors, including extreme heat, drought, and heavy precipitation events. The Guatemalan Ministry of Agriculture estimates that when Hurricane Stan hit the country in 2005, all small livestock were affected in some areas of the western departments. (44) Rising temperatures can create heat stress for cattle, causing them to produce less milk or increasing morbidity and mortality, which, in turn, produces less meat. (24) Higher temperatures may also increase the spread of disease vectors, both among livestock and between livestock and wildlife, and more prolonged droughts can constrain water supplies for livestock farmers. (45, 46)

While climate stressors can result in harmful effects to livestock, it also can exacerbate the damage that livestock farming has on the environment. Future patterns of drought and heavy precipitation may result in more erosion and soil degradation on overgrazed lands. (45) Heavy precipitation also

can result in increased runoff; when combined with improper manure storage, this may degrade water quality. (45) Furthermore, to control disease outbreak, farmers may slaughter wildlife or separate wildlife from livestock in ways that impede wildlife migration, reducing biodiversity outside the farm. (45) These impacts should be avoided when developing climate adaptation strategies for livestock production.

Table 9 summarizes the risks to livestock from climate change and potential adaptation responses to address these risks. The adaptation measures are intended to help farmers adapt their livestock production to climate stressors, while minimizing the harmful effects that livestock farming can have on the environment.

Table 9. Livestock climate risks and responses.

Climate Risks	Potential Adaptation Responses
Increased heat stress on livestock, resulting in decreased meat and milk production, and increased morbidity and mortality (24)	• **Implement resilient agroforestry** techniques, such as tree silvopasture, to provide more shade. (23, 24) • **Diversify livestock varieties** to increase heat wave tolerance. (46) • **Improve feeding practices** (e.g., modifying diet composition, changing feeding times and/or frequency, incorporating agroforestry species into the animal diet) to improve the efficiency of livestock production. (46)
Increased temperature and more variable rainfall exacerbating land degradation caused by livestock farming (45)	• **Control overgrazing** using quota systems matched to carrying capacity. (45) • **Avoid livestock farming on marginal lands**, which may contain more erosion and landslide risks. (45) • **Avoid grazing following rainfall events**, which compacts moist soil and reduces its ability to absorb moisture. (45) • **Balance livestock species** for better plant management as different livestock species graze different areas and plants. (45) • **Conduct herder-managed natural regeneration** of trees and grasslands. (45) • **Restore the protection** of grassbanks. (45) • **Construct** side hill ditches, terraces, living barriers, or similar diversion or water-trapping structures. (45)
Prolonged droughts constraining water supply and increased flooding affecting water quality (45)	• **Consider groundwater balance and potential climate change implications** (including drought and seawater intrusion into coastal aquifers) before investing in more wells and boreholes. (45) • **Balance livestock species** for better water management; goats tend to do better in low water conditions than cattle. (45) • **Capture and facilitate the infiltration of rainfall** in rangeland. (45) • **Manage manure** by applying it to crop fields or using an anaerobic digester. (45) • **Treat manure** if manure cannot be economically transported. (45) • **Reduce runoff** through the use of side hill ditches, terraces, living barriers, or similar diversion or water-trapping structures. (45) • **Diversify livestock varieties** to increase drought tolerance. (46)
Increasing temperature exacerbating the spread of diseases among livestock (45)	• **Create boundaries between healthy livestock** and sick livestock or wildlife. (45) • **Reduce contact between livestock and wildlife** during the movement of livestock from one location to another. (45) • **Change livestock species and breeds** to minimize their overlap in preferred fodder with that of local wildlife, reducing contact between livestock and wildlife. (45) • **Diversify livestock varieties** to increase tolerance to heat-related diseases. (46)
Damage to crops from **increased heat, drought, and flooding**, perhaps **result**ing **in**	• **Diversify livestock feed varieties** to increase drought and heat tolerance. (46)

Climate Risks	Potential Adaptation Responses
increased feed prices (45)	
Strong winds (July–Oct), resulting in stress on livestock (8)	• **Implement resilient agroforestry** techniques, such as windbreaks, to provide shelter for livestock. (23, 24)

HUMAN HEALTH: NUTRITION, WASH, AND HEALTH SERVICES

Although the health of the general Guatemalan population has improved significantly over the past decades, the health status of poor and indigenous Guatemalans continues to be among the worst in the Western Hemisphere; indigenous Guatemalans comprise close to half of the country's total population and much of the population in two of the FFP target departments (Quiché and Huehuetenango). (47) Climate impacts contribute to poor health conditions, aggravating malnutrition; adversely affecting water, sanitation, and hygiene (WASH) infrastructure, services, and practices; and compromising healthcare services.

Guatemala has the sixth highest rate of chronic malnutrition (stunting) in the world, at 47 percent, with the prevalence reaching around 70 percent in indigenous areas, including Quiché and Huehuetenango. (3) Stunting is most severe among children with mothers who are less wealthy, less educated, indigenous, adolescent, and who recently gave birth to another child. (3) Malnutrition is thought to be aggravated by widespread consumption of aflatoxin-contaminated food, particularly maize. (4, 9) Climate change-driven reductions in crop productivity may further aggravate malnutrition and poverty levels, particularly in the Western Highlands and the Dry Corridor, which have experienced recurrent drought. Furthermore, drought and high temperatures typically stimulate aflatoxin production, indicating that climate change may increase the prevalence of aflatoxin-contaminated foods. (48)

In addition, the prevalence of stunting also increases with age, indicating that poor sanitation and hygiene practices likely contribute to stunting. (3) While much of the population (91 percent) has access to piped drinking water, the quality of this water is relatively poor—only 15 percent of water supplies are disinfected. (49) In addition, one-quarter of Guatemalans lack access to a water supply at home, which is problematic as increased distance from a water supply is linked to increased rates of disease, namely diarrheal disease and respiratory infections. (49) Furthermore, more than half of Guatemalans lack access to improved sanitation, which is linked to increased rates of childhood diarrheal disease and stunting. (49) Rural, poor, and indigenous populations have the lowest rates of access to improved drinking water and sanitation. (49) Climate change has the potential to aggravate poor WASH infrastructure, services, and practices, thereby adversely affecting health and nutrition. More frequent and intense extreme rainfall events and flooding may limit access to clean water by damaging water supply and sanitation infrastructure; reducing the ability to travel to water supplies; and increasing contamination of water supplies, driving an increase in cholera and other waterborne diseases. (8, 11) Conversely, drought may reduce the availability of water sources and discourage handwashing and improved hygiene practices, increasing the spread of infectious diseases, such as gastrointestinal illness. (11)

The healthcare system faces profound challenges driven by limited resources, infrastructure, personnel, and supplies of medicines and materials; these challenges are especially an issue within areas that are remote, rural, and indigenous. (47) In the past, frequent natural disasters have damaged health infrastructure. (49) More frequent and intense extreme events may further compromise the availability of and access to healthcare infrastructure and services. For example, more frequent and intense hurricanes, extreme rainfall, and mudslides may damage health

services and water supply infrastructure. Climate stressors also may drive an increase in the prevalence of diseases, further stressing the healthcare system. Drought brings an increased risk of leishmaniasis, hantavirus, and respiratory infections. (11) Increasing temperatures may drive a rise in the risk of vector-borne diseases, such as malaria and dengue, due to the enhanced range and more rapid breeding and maturation periods of mosquitoes. (11)

However, measures can be taken to improve nutrition levels; WASH services, infrastructure, and practices; and healthcare services in order to improve human health.

Table 10. Climate risks and potential adaptation responses for human health: Nutrition, WASH, and health services.

Climate Risks	Potential Adaptation Responses

Reduced nutrition driven by direct climate impacts to agriculture and food quality	• Improve access to nutritious foods:
	  • Implement the adaptation responses described in previous Agriculture sections.
	  • Continue to execute USAID's Feed the Future: Fomenting Agriculture Incomes and Resilience Project, which improves the agricultural incomes and resilience of small farmers in the Western Highlands (existing USAID effort).
	  • Increased availability and affordability of diverse, nutrition-rich foods in local markets.
	• Reduce prevalence of aflatoxins in foods and treat aflatoxin poisoning:
	  • Prevent contamination through growing toxin-resistant varieties, crop rotation, soil tillage, chemical and biological control, and insect control that can minimize aflatoxin production. (50)
	  • Remove contaminated material from food through physical processes (e.g., sorting, flotation, dehulling, steeping, milling, heating, irradiation) or chemical processes (e.g., acid, alkaline, oxidation, reduction, ammoniation processes). (50)
	  • Improve storage to prevent the growth of aflatoxins (e.g., through the use of ultra-hermetic airtight containers, climate-controlled storage). (51)
	  • Treat exposed individuals (e.g., through prophylactic treatment in areas with chronically high aflatoxin exposure). (50)
	• Improve the health and nutrition levels of women and children:
	  • Improve healthy behaviors to reduce chronic malnutrition (existing USAID effort known as Feed the Future).
	  • Improve access to and the quality of family planning and reproductive health information, education, counseling, and services for underserved populations, with an emphasize on youth (existing USAID strategy). (47)
	  • Improve access to and the quality of care for mothers and newborns during pregnancy, childbirth, and the post-partum period. This includes access to skilled birth attendants and practices that reduce maternal and neonatal, infant, and child morbidity and mortality (existing USAID strategy). (47)
	  • Increase access to micronutrient supplements; the treatment of childhood illness; and education on improved infant and young child feeding practices, nutritional practices and better hygiene, nutrition, and health behaviors (existing USAID strategy). (47)
	  • Use the "Thousand Day Window" approach, focusing interventions on the period from pregnancy to the child's second birthday to improve nutrition levels (existing USAID strategy). (47)
	  • Support public-private alliances to address maternal and child nutrition issues (existing USAID strategy). (47)
	• Empower organized civil society associations with the capabilities to carry out advocacy and social accountability oversight of health, education, and nutrition services (existing USAID strategy). (47)

Reduced water quality and availability due to	• Improve water quality: • Prevent deforestation and promote reforestation in order to improve water quality and prevent further degradation.

Climate Risks	Potential Adaptation Responses

drought and damages to water supply infrastructure	• Manage aquifers to increase the quality of groundwater.
	• Improve water availability:
	  • Build new dams to increase water supply capacity.
	  • Construct community cisterns to catch and store rainwater.
	  • Improve soil management to increase rainfall infiltration into groundwater.
	  • Retrofit existing and build new water infrastructure in a manner in which it can withstand expected extreme rainfall, erosion, and hurricanes.
	  • Integrate climate information into water supply system planning. (43)

Increased risk of waterborne diseases and aggravation of malnutrition (**more intense rainfall and lack of improved sanitation may cause increased risk of WASH infrastructure damage and water source contamination**, **and a risk of waterborne diseases**)	• Integrate climate information into WASH system planning. • Climate-proof the water supply and sanitation systems. • Improve access to potable water (existing USAID strategy). (47) • Provide improved sanitation facilities. • Improve water and sanitation infrastructure and services to prevent contamination of the water supply. • Improve water treatment to disinfect potentially contaminated water supplies. • Improve hygiene practices, such as handwashing. • Encourage community-wide approaches to water supply and sanitation services and hygiene interventions, and focus on facilities in public spaces and institutions. • Create contingency plans for a loss of water treatment and sanitation systems during extreme events. (43)

Reduced access to and increased disruption of health services due to stress from extreme weather disruptions that flood or damage the transportation or healthcare infrastructure	• Improve the capacity to prepare for and respond to extreme events:
	  • Implement early warning systems.
	  • Increase the capacity of healthcare and emergency services to support disaster planning and management. (43)
	• Improve the climate resilience of healthcare infrastructure:
	  • Improve flood management, landslide control, and drainage systems. Where possible, focus on natural and nature-based flood management practices, such as those outlined in the World Wildlife Fund and USAID Flood Green Guide.
	  • Following infrastructure damage, rebuild infrastructure to be climate resilient. (43)
	  • Restrict development in high-risk areas (e.g., floodplains, areas prone to landslides, areas projected to be inundated by sea level rise). (43)
	• Improve access to climate-sensitive healthcare services:
	  • Increase the availability of health services, particularly in rural, poor, indigenous communities in order to respond to heightened health risks.
	  • Develop and improve climate-sensitive vector control programs. (43)
	  • Increase public awareness about how to respond to the climate-driven spread of vector-borne diseases. (43)

SENSITIVE ECOSYSTEMS

Important ecosystems—including mangroves, rainforests, and coniferous forests—are already stressed by deforestation, which has eliminated half of Guatemala's forest cover. (11) This degradation compromises ecosystem services that benefit agriculture—such as improved groundwater quality—and also increases sensitivity to climate hazards. Climate change is expected to stress ecosystems through a variety of avenues. (11) Increasing temperatures and more variable rainfall are expected to cause coniferous forests to become dry forest ecosystems, with dry forest cover doubling by mid-century. (11) These changes are projected to increase the

risk of forest fires, adversely affect watershed health and agroforestry, and aggravate drought severity. (11) More frequent and intense rainfall events also have the potential to exacerbate erosion and landslides, further stressing ecosystems. (11) More frequent and intense drought has the potential to harm the health of mangroves, which are sensitive to low water flows during the dry season. (11) On the other end of the spectrum, more frequent and intense precipitation is expected to increase sedimentation, which also harms mangroves. (11) Rising sea levels are expected to lead to flooding and erosion that damage wetlands and estuaries which support fisheries. (11)

Table 11. Climate risks and potential adaptation responses for sensitive ecosystems and endangered species

Climate Risks	Potential Adaptation Responses
Loss of mangroves, rainforests, coniferous forests, agroforestry livelihoods, coastal defense, and carbon sinks	• Combine enforcement and incentives to prevent deforestation and encourage reforestation and agroforestry to avoid further loss of forests. • Implement programs that pay or provide nutritious food in exchange for participants preserving mangroves, forests, and key ecosystems.
Increased risk of forest fires due to expansion of dry forests	• Prevent forest fire ignitions through public awareness campaigns. • Implement forest management that mitigates forest fire risk.
Increased coastal erosion, coastal flooding, and degradation of wetlands and estuaries	• Implement programs that pay or provide nutritious food in exchange for participants preserving wetlands and estuaries. • Implement natural infrastructure to prevent coastal erosion and coastal flooding.
Damage to mangroves from low water flows and sedimentation **Cross-cutting risks around environmental degradation**	• Discourage deforestation and encourage reforestation and agroforestry to improve watershed health and reduce sedimentation. • Improve watershed management in order to reduce erosion. • Undertake conservation, natural resource management, and environmental protection efforts that both improve the health of ecosystems and reduce emergency assistance needs (e.g., undertake efforts that reduce the severity of landslides and flooding following extreme rainfall events). • Partner with community-based organizations and existing conservation efforts, such as those done by the International Union for Conservation of Nature.

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