ASSESSMENT OF AGRICULTURAL RESILIENCE UNDER CLIMATE CHANGE AND ITS RELATION TO FOOD INSECURITY AND MIGRATION IN THE NORTHERN TRIANGLE OF CENTRAL AMERICA

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Assessment of agricultural resilience under climate change and its relation to food insecurity and migration in the Northern Triangle of Central America

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CONTENTS

FIGURES AND TABLES

ACRONYMS AND ABBREVIATIONS

AGACO	Asociación de Ganaderos y Agricultores de Catacamas (Catacamas Cattle Raisers and Farmers Association), Honduras
AGAMAC	Asociación de Ganaderos de Marcovia Centro (Marcovia Central Cattle Raisers Association), Honduras
AGASURP	Asociación de Ganaderos de San Luis Petén (San Luis Peten Cattle Raisers Association), Guatemala
AIST	National Institute of Advanced Industrial Science and Technology
AMER	Agencia Municipal de Extensión Rural (Municipal Agency of Rural Extension), MAGA
AMLN	Asociación de Municipios de Los Nonualcos (Association of Municipalities of Los Nonualcos), El Salvador
Anacafé	Asociación Nacional del Café (National Coffee Association), Guatemala
APA	Asociación de Padres de Alumnos (Parents' Association of Students)
APROSACAO	Asociación de Productores de Sistemas Agroforestales con Cacao Orgánico – Olancho (Association of Producers of Agroforestry Systems with Organic Cocoa - Olancho), Honduras
ASALOSPM	Asociación Agropecuaria Loroqueros de San Pedro Masahuat (Agricultural Association "Loroqueros" of San Pedro Masahuat), El Salvador
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CAC	Consejo Agropecuario Centroamericano (Central American Agricultural Council)
CADC	Central American Dry Corridor
CASCADE	Ecosystem-Based Adaptation and Smallholder Coffee and Subsistence Farmers in Central America Project
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agricultural Research and Higher Education Center)
CEG	Centro de Estudios de Guatemala (Center for Guatemalan Studies)
CENTA	Centro Nacional de Tecnología Agropecuaria y Forestal "Enrique Álvarez Córdova" (National Center of Agricultural Technology “Enrique Álvarez Córdova”), El Salvador
CEPAL	Comisión Económica para América Latina y el Caribe (Economic Commission for Latin America and the Caribbean)
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres en América Central y República Dominicana (Coordination Centre for the Prevention of Natural Disasters in Central America)

CIRAD	French Agricultural Research Centre for International Development
COACAP	Coordinadora de Asociaciones Campesinas Agropecuarias de Petén (Coordinating Committee of Farmers' Agricultural Associations of Petén), Guatemala
COCASAM	Cooperativa Cafetalera Sanmarqueña (Sanmarqueña Coffee Cooperative)
CONAP	Consejo Nacional de Áreas Protegidas (National Council for Protected Areas), Guatemala
COODEPRO	Cooperativa Integral de Producción Vida y Esperanza (Integral Production Cooperative Vida y Esperanza), Guatemala
CRAC	Caja Rural de Ahorro y Crédito (Rural Savings and Credit Bank)
CRS	Catholic Relief Services
CSR	Corporate Social Responsibility
CWS	climate and weather services
DAGRO	Dirección del Desarrollo Agropecuario (Directorate of Agricultural Development), MAGA
DICORER	Dirección de Coordinación Regional y Extensión Rural (Regional Coordination and Rural Extension Directorate), MAGA
DICTA	Dirección de Ciencia y Tecnología Agropecuaria (Directorate of Agricultural Science and Technology), Honduras
DIGEGR	Dirección de Información Geográfica, Estratégica y Gestión de Riesgo (Geographic, Strategic and Risk Management Information Directorate), Guatemala
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FCC	Fertility Capability Classification
FEGASURH	Federación de Ganaderos y Agricultores del Sur de Honduras (Federation of Cattle Raisers and Farmers of Southern Honduras)
FENAGH	Federación Nacional de Agricultores y Ganaderos de Honduras (Federation of Farmers and Cattle Raisers of Honduras)
FEWS NET	Famine Early Warning Systems Network
FHIA	Fundación Hondureña de Investigación Agrícola (Honduras Foundation for Agricultural Research)
FIAES	Fondo de Inversión Ambiental de El Salvador (Environmental Investment Fund of El Salvador)
FIPAH	Fundación para la Investigación Participativa con Agricultores de Honduras (Foundation for Participatory Research with Honduran Farmers)
FSIN	Food Security Information Network

FUDI	Fundación para el Desarrollo Integral (Foundation for Integral Development), Guatemala
FUNDAECO	Fundación para el Ecodesarrollo y la Conservación (Foundation for Ecodevelopment and Conservation), Guatemala
FUNDE	Fundación Nacional para el Desarrollo (National Foundation for Development), El Salvador
GDP	Gross Domestic Product
GMA	Global Market Analysis
GNAFC	Global Network Against Food Crises
GT	Guatemala
HN	Honduras
ICC	Instituto Privado de Investigación sobre Cambio Climático (Private Institute for Climate Change Research), Guatemala
ICF	Instituto de Conservación Forestal (National Institute of Forest Conservation), Honduras
ICI	International Climate Initiative
ICTA	Instituto de Ciencia y Tecnología Agrícolas (Institute of Agricultural Science and Technology), Guatemala
IDB	Inter-American Development Bank
iDE	International Development Enterprises, Honduras
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IHCAFE	Instituto Hondureño del Café (Honduran Coffee Institute)
IICA	Instituto Interamericano de Cooperación para la Agricultura (Inter-American Institute for Cooperation on Agriculture)
INAB	Instituto Nacional de Bosques (National Forest Institute), Guatemala
INFOP	Honduras National Institute for Vocational Training (Instituto Nacional de Formación Profesional de Honduras)
IOM	International Organization for Migration
IPAD	International Production Assessment Division
IPCC	Intergovernmental Panel on Climate Change
IPM	integrated pest management
ISTA	Instituto Salvadoreño de Transformación Agraria (Salvadoran Institute for Agrarian Transformation)
IUCN	International Union for Conservation of Nature

MARN-KfW	Debt Swap for Adaptation to Climate Change project MAEN Guatemala - German KfW Development Bank
LHZ	livelihood zone
MAG	Ministerio de Agricultura y Ganadería (Ministry of Agriculture and Livestock), El Salvador
MAGA	Ministerio de Agricultura, Ganadería y Alimentación (Ministry of Agriculture, Livestock and Food), Guatemala
MAMBOCAURE	Mancomunidad de Municipios de la Botija y Güanacaure (Commonwealth of Municipalities of Cerro de la Botija and Güanacaure), Honduras
MAP	Mesoamerican Environmental Program
MARN El Salvador	Ministry of Environment and Natural Resources, El Salvador
MARN Guatemala	Ministry of Environment and Natural Resources, Guatemala
MAS+	Sustainable Agriculture Improvement Project
METI	Japan's Ministry of Economy, Trade and Industry
MITA	Mesa Intersectorial de Tierra y Ambiente (Intersectoral Land and Environment Roundtable), Petén, Guatemala
MSD	mid-summer drought
MTA	Mesa Técnica Agroclimática (Agroclimatic Technical Roundtable)
NASA	National Aeronautics and Space Administration
NTCA	Northern Triangle of Central America
OAS	Organization of American States
OIM	Organización Internacional para las Migraciones
OIREC	USDA ARS Office of International Research Engagement and Cooperation
PAHO	Pan American Health Organization
PROCAGICA	Central American Program for Integrated Coffee Rust Management
PROLENCA	Proyecto de Competitividad y Desarrollo Sostenible del Corredor Fronterizo Sur Occidental (Competitiveness and Sustainable Development of the Southwest Border Corridor Project), Honduras
RECLIMA	Upscaling climate resilience measures in the dry corridor agroecosystems of El Salvador Project
Red PASH	Red de Productores Artesanales de Semillas de Honduras (Network of Artisanal Seed Producers of Honduras)

SAG	Secretaría de Agricultura y Ganadería (Ministry of Agriculture and Livestock), Honduras
SECPLAN	Secretaria de Planificacion, Coordinacion y Presupuesto Secretaria de Planificacion, Coordinacion y Presupuesto (Planning, Coordination and Budget Secretariat), Honduras
SICA	Sistema de la Integración Centroamericana (Central American Integration System)
SPS	sanitary and phytosanitary
SV	El Salvador
UEAAS	Unidad Economía Ambiental y Agronegocios Sostenible (Environmental Economics and Sustainable Agribusiness Unit), CATIE
UGAM	unidad de gestión ambiental municipal (municipal environmental management unit)
UN SDG	United Nations Sustainable Development Goals
UNACIFOR	Universidad Nacional de Ciencias Forestales (National University of Forestry Sciences), Honduras
UNAG	Universidad Nacional de Agricultura (National University of Agriculture), Honduras
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
US, USA	United States of America
USAC	Universidad San Carlos de Guatemala (University of San Carlos de Guatemala)
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USDA ARS	USDA Agricultural Research Service
USDA FAS	USDA Foreign Agricultural Service
USDA NRCS	USDA Natural Resources Conservation Service
USGS	United States Geological Survey
USSEC	U.S. Soybean Export Council
WFP	World Food Programme
YCC	Youth Conservation Corps Program, USDA

FOREWORD

Agriculture is a source of livelihood for many people in the countries of El Salvador, Guatemala, and Honduras – the Northern Triangle region of Central America. It is a region suffering from the impacts of climate change, most notably an increasing occurrence of severe droughts, floods, and catastrophic storms, all of which have damaged agricultural production. These impacts have caused or compounded economic hardships, prompting internal and international migration, including irregular migration to the United States.

As stated in the U.S. Strategy for Addressing the Root Causes of Migration in Central America:

"The consequences of climate change are only projected to get worse, further disrupting growing cycles, upending farmer livelihoods, and exacerbating food insecurity and malnutrition."

The Root Causes Strategy, issued in July 2021 and directed by the President in Executive Order 14010, focuses on a coordinated approach to address the underlying causes that push Central Americans to migrate, and aims to build hope for citizens in the region that the life they desire can be found at home. A pillar of the Strategy is "Addressing Economic Insecurity and Inequality" under which a key objective is to "Build Resilience to Address Climate Change and Food Insecurity." In support of this objective, the United States Department of Agriculture's (USDA) Foreign Agricultural Service (FAS), in collaboration with the Tropical Agricultural Research and Higher Education Center (Centro Agronómico Tropical de Investigación y Enseñanza - CATIE), formed a multifaceted team comprised of technical experts from CATIE and four USDA agencies (Agricultural Research Service, Forest Service, Natural Resources Conservation Service, and FAS) to assess agricultural resilience to climate change in the countries of El Salvador, Guatemala, and Honduras, and its relation to food insecurity and irregular migration.

The assessment addressed three questions for the region:

1. **How resilient are agricultural systems in these countries to the effects of climate change?**
2. **a) Does a lack of agricultural resilience to the effects of climate change cause food insecurity and migration?**
   b) Does having agricultural resilience to the effects of climate change reduce food insecurity and the likelihood of migration?
3. **What specific kinds of interventions can increase agricultural resilience to the effects of climate change?**

The USDA-CATIE team reviewed existing literature, interviewed relevant experts, and conducted field visits, in-person workshops, and interactive focus group discussions with 237 participants from 16 municipalities across the Northern Triangle region. Participants included representatives from local governments and institutions, farmers and farm associations, non-governmental organizations, technical schools, and universities. This report highlights assessment findings and proposes several interventions that could help the people of the region involved in agricultural production to be more economically secure while remaining in their home countries. USDA and CATIE offer this report as a tool for informing all those seeking to develop or implement activities to improve agricultural resilience and food security in the face of climate change and to address the root causes of irregular migration from Central America.

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EXECUTIVE SUMMARY

The Northern Triangle of Central America (NTCA) is composed of three countries, namely El Salvador, Guatemala, and Honduras. Besides having common geographic features, the countries are characterized by increasing migration, and exposure and vulnerability to climate change. Agriculture is a significant sector that employs large numbers of rural population across the three countries. Concurrently, it is also heavily impacted by climate variability and climate change, which compounds the existing vulnerabilities of people employed in agriculture. The report is based on analyzing four main agricultural systems which are key for more than 80 percent of agricultural households in El Salvador, Guatemala, and Honduras: coffee, staple grains, livestock, and vegetables.

The objective of this report is to systematize primary data and existing knowledge about climate change impacts and vulnerability of the agricultural sector in the NTCA countries, specifically of coffee, staple grains, livestock and vegetables farmers, with an additional aim of having spatial detail on livelihoods and beneficiaries of interventions for building resilience and contributing to the U.S. Strategy for Addressing the Root Causes of Migration in Central America [1]. To our best knowledge, this report is the only one to use systems and livelihoods approach for an analysis of agricultural vulnerability, resilience, food security and migration, and to additionally provide a comprehensive inquiry that includes spatial specificity. The report links the results of the analysis with the existing, on-the-ground practices and it offers concrete proposals for actions in the NTCA.

The primary data used in this report was collected in eight locations in Guatemala, four locations in Honduras and two in El Salvador, through 25 interviews with key stakeholders, fourteen workshops (including participatory mapping) and twenty field visits. The research team worked with over 200 participants, of which farmers and farmers' cooperatives and associations constituted a significant proportion. Based on the field data, USDA and CATIE scientists' inputs, and complemented with reviews of relevant literature, this report highlights some of the key issues related to agricultural livelihoods, their resilience to the effects of climate change, and interlinkages of agricultural resilience, food security and migration, and it provides concrete suggestions for strategic interventions for increasing agricultural resilience in the NTCA.

Some of the main findings are:

Agriculture, heavily impacted by climate change, is a highly labor-intensive sector in the NTCA countries but contributes marginally to the nation's economies, offering limited economic growth and well-being opportunities. **Climate change adds to other factors, making the living conditions of small and medium-sized rural producers even more difficult**. This is especially evident in the Central American Dry Corridor on the Pacific slope, with a high percentage of the rural population dependent on agriculture.

Coffee, staple grains, livestock, and vegetables based agricultural systems provide the means for at least 80 percent of agricultural households in the NTCA. These systems spread across areas sharing similar socio-economic and biophysical contexts shaping the resilience of agricultural livelihoods.

Water deficit and excess, changes in rainfall patterns, increased temperatures, and pest and disease incidence are **the main climate impacts across agricultural systems**. Long-term impacts of climate change in agriculture are loss of crop-suitable areas and yields.

Resilience of agricultural systems is limited and with differences in their capacity to identify innovations on farming practices and for scaling and adoption (farm-level implementation) of resilience building practices.

Staple grain farmers are the least resilient across the region with high impacts from current climate variability and less capacity to identify and implement resiliency-building actions, in particular, those with small holdings and without secure tenure of their lands. Agroforestry coffee-based systems are the most important with better resilience but facing significant reductions in suitable growing areas in the coming decades due to rising temperatures.

Coffee and livestock farmers are more resilient than staple grains and vegetable producers. Access to water, food security, health services, basic literacy, and personal security is, in relative terms, high for coffee farmers and very high for livestock farmers, while for staple grains and vegetable farmers it varies between low and high across livelihood zones.

The data from the field work conducted for this assessment shows there is a link between food security and migration in some livelihood zones in Guatemala and Honduras. Specifically, in Guatemala small and medium-sized staple grain and coffee producers with very low to low food security have high emigration levels. In Honduras coffee producers with high to very high food security have very low to low migration levels. Food insecurity acts as a push factor for migration through different socio-economic factors.

Resilience generally improves food security because families can make on-farm adaptation investments. **Certain livelihoods are more resilient to the effects of climate change, and people who depend on those livelihoods will make different migration decisions based on needs, opportunities and the availability of supporting resources.**

Climate change does not act as an isolated migration driver. **There is no one root cause for migration, and any strategy to face migration must consider the combination of different factors** and how they interact in a specific geographic, social and livelihood context. Food security is a significant factor that needs to be considered.

This report shows the complexity of the relationship between climate change, agricultural resilience, and migration based on the cropping and livestock system level and livelihoods analysis. This perspective provides a solid ground for accounting for the differences in weather and climate impacts on levels of agricultural resilience, adaptation capacities, and risk management strategies that can be differentiated among the four agricultural systems (coffee, staple grains, vegetables, and livestock). Based on the findings that this report highlights, USDA and CATIE propose technical and supporting interventions (see Chapter 3 of this report) that are aimed at strengthening farmers´ resilience in the NTCA, which could, together with other initiatives, contribute to reducing the need for migration. The extended proposals are included in a separate document (the "Action Proposals").




INTRODUCTION

The Northern Triangle of Central America (NTCA) is the far north of the Central American isthmus. It comprises three countries: El Salvador, Guatemala, and Honduras (Figure 1), with more than 33 million inhabitants.

Figure 1. The Northern Triangle countries in Central America.

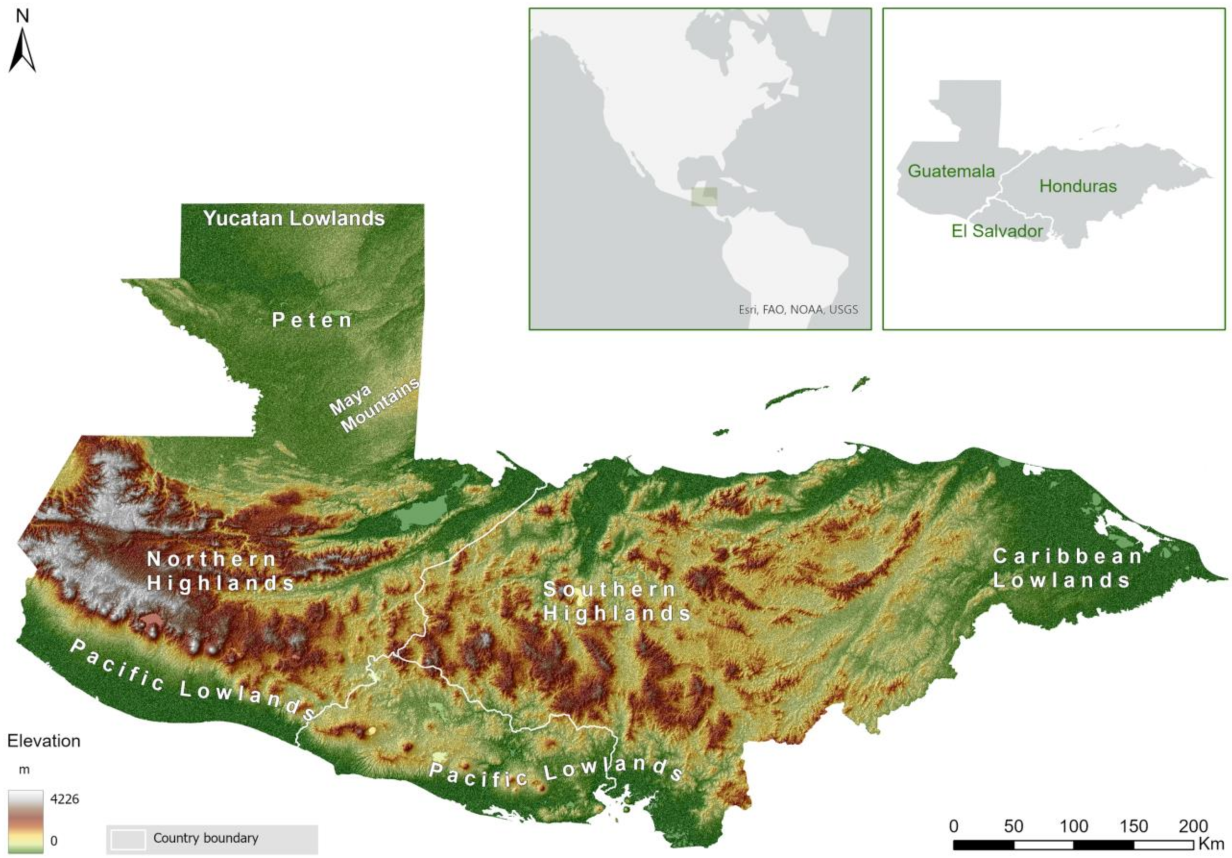


Figure prepared with the following data sources: DIVA-GIS Free Spatial Data [2] (state boundaries in main figure and inset map 2), ASTER GDEM Version 3 [3] (countries' digital elevation models) and Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community Light Gray Canvas [4] (base map for inset map 1).

All three countries of the NTCA are affected by moderate or severe food insecurity, affecting women disproportionally more than men [5]. The COVID-19 pandemic has only contributed to this [5], and climate change is affecting the region adversely, contributing to accumulating vulnerabilities [6].

Agriculture, heavily impacted by climate change, is a highly labor-intensive sector in the NTCA countries. The sector employs nearly 30 percent of the population in Guatemala and Honduras) but contributes marginally to the nation's Gross Domestic Product (GDP), offering limited economic growth and well-being opportunities due to challenges it is facing such as increase in prices of inputs, low wages, low prices of products, and climate impacts. Nevertheless, agriculture is still the basis of food security and income for rural communities. The dependency on agriculture, coupled with the regional instability and adverse effects of climate change, presents a challenging environment for improving the living conditions of the growing populations of the three countries.

The geography of the NTCA is dominated by mountainous formations which form the Central American isthmus. This geological origin determines the NTCA´s landscapes which are characterized by mountains with steep slopes and land with shallow soils, but there are some regions with flat soils usually formed by the deposition of sediments or seabed rise [7]. This geophysical and hydrometeorological setting makes the area prone to frequent earthquakes, volcanic eruptions, tsunamis, floods, droughts, tropical storms and hurricanes, and El Niño-Southern Oscillation (ENSO) associated phenomena such as alterations in temperature and precipitation [8].

The NTCA has two broad climatic areas: the Pacific and the Caribbean slopes. A seasonal or monsoonal rainfall regime dominates the first one with several dry months. This area extends along the Pacific coast, where a part of the Central American Dry Corridor (CADC) is located. The second one is located along the coast of the Caribbean Sea and is characterized by permanent rains [9,10]. The predominance of the mountainous relief coupled with the mentioned climatic regimes makes the region suitable for a wide variety of microclimates and biodiversity. Likewise, it presents a challenge and requires a search for specific solutions for agricultural production and ecosystem services provision in such complex landscapes.

These unique landscape characteristics increase the complexities of the impact of climate change, which coupled with poor agricultural practices in the region pose threats to job creation and economic opportunities. Yields of rain-fed crops, such as maize and coffee, are forecasted to decrease [43, 50]. As yields drop, rural populations highly dependent on these crops are likely to migrate as a livelihood strategy to peri-urban areas or the USA. National-level investments and innovations are needed to address the negative effects of climate change and ensure the agriculture sector has the potential to become a stronger base for regional economic growth.

The objective of this report was to systematize primary data and existing knowledge about climate change impacts and vulnerability of the agricultural sector in the Northern Triangle of Central America countries, with aiming of having spatial detail on different livelihoods and beneficiaries of potential interventions to build resilience, and to contribute to the U.S. Strategy for Addressing the Root Causes of Migration in Central America.

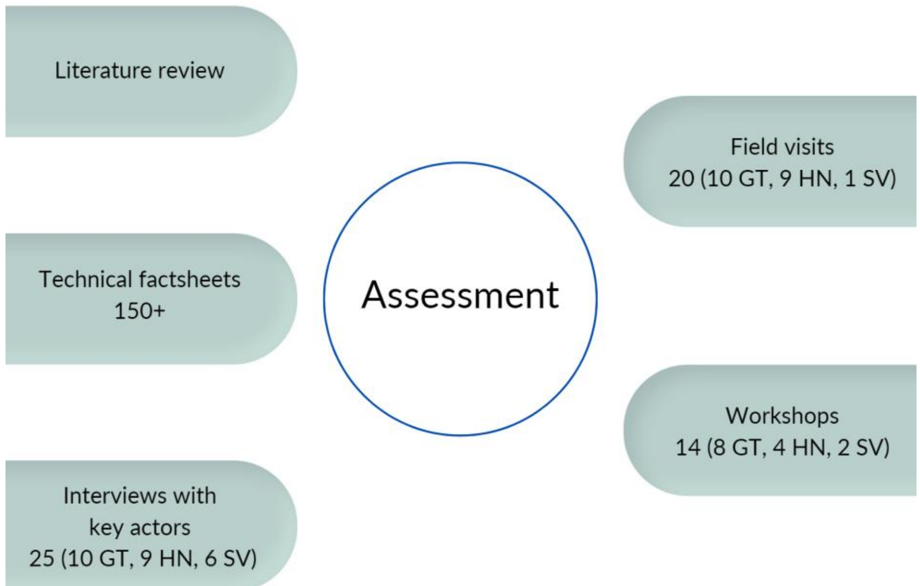
The assessment consisted of participatory workshops, technical factsheets production and reviews, interviews with key informants and actors, farm field visits, and literature review. Overview of the workshop process and how the data collected links with this report is shown in Figure 2, and the overview of the work process developed for this assessment is presented in Figure 3.

Figure 2. Methodology overview.

PARTICIPATORY WORKSHOPS

	Identification and characterization	Mapping	Climate risks and impacts	Survey
Step description	Workshop participants identify main agricultural systems and define the dominant farm size, tenure type and access to irrigation for each of the system.	Participants identify spatial distribution of the agricultural systems in livelihood zones.	Common climate risks for each of the systems are identified, including their frequency and level of impact.	Adaptive capacity and migration survey is conducted for each agricultural system separately.
Chapter	1.2 Cropping and livestock systems in NTCA and their geographic distribution	1.2 Cropping and livestock systems in NTCA and their geographic distribution	1.3 Climate impacts on cropping and livestock systems in the NTCA	1.4 Farmers' adaptive capacity 2.2 Does a lack of agricultural resilience to the effects of climate change cause food insecurity and migration?

Figure 3. Overview of the work process developed for the assessment.



- Systematizing country-specific and regional research **literature**
- Collecting **technical agronomic factsheets** from the different agricultural research institutes in the three countries to obtain detailed technical information on agronomic practices that can be promoted to build resilience.
- **Interviewing** key decision makers at the national level across the three counties related to agriculture, forestry, and environment sectors.
- **Visiting** interventions in the field of local institutions such as the Institute of Agricultural Science and Technology (ICTA) in Guatemala, the Directorate of Agricultural Science and Technology (DICTA) in Honduras, and the National Center for Agricultural and Forestry Technology (CENTA) in El Salvador, that promote practices to build resilience in the agriculture sector.
- Conducting **workshops and participatory mapping** exercises in the three countries to identify different cropping and livestock systems and their socioeconomic characteristics.

This report focuses on showing results from the primary data collection conducted through interviews and workshops in several livelihood zones throughout the three countries. The field data is complemented by findings from scientific literature and practitioners’ reports.

1 How resilient are agricultural systems to the effects of climate change?

Chapter 1 – Highlights

- **Coffee, staple grains, livestock, and vegetable-based agricultural systems sustain at least 80 percent of agricultural households in the NTCA**. These systems spread across areas sharing similar socio-economic and biophysical contexts shaping the resilience of agricultural livelihoods. Farm size and land tenure are critical determinants of resilience across livelihoods as they define resource availability and conditions for resilience building.

- **Coffee and livestock farmers are more resilient than staple grains and vegetable producers.** Access to (good quality) water throughout a year, food security throughout a year, access to health services, basic literacy, and personal security is, in relative terms, high for coffee farmers and very high for livestock farmers, while for staple grains and vegetable farmers it varies between low and high across livelihood zones.

- **Water deficit and excess, changes in rainfall patterns, increased temperatures, and pest and disease incidence are the main climate impacts across agricultural systems**. The most important climate impacts of agricultural systems vary throughout different livelihoods zones:

- Staple grain producers are perceived as the ones who experience the highest impacts from climate variability across all zones, from water deficit and excess inducing food insecurity.

- Vegetable growers are perceived as the ones who experience the highest impacts from water deficit in El Salvador across Dry Corridor areas and from water excess in higher altitude areas across the NTCA, inducing loss of crop quality and quantity.

- Water deficit drives the most critical impacts on coffee-based agroforestry systems in mid-altitude areas of Guatemala and excess of water (e.g., severe storms and flooding) across all other coffee areas across the NTCA with effects on quality and quantity of the produce and loss of income and crop areas.

- The most important impacts on livestock result from the water deficit affecting pasture productivity in Honduras and El Salvador, increasing the vulnerability of livestock growers.

- More and more farmers are engaging with the production of emerging cash crops (vegetables for export, fruits, coffee, and cacao) due to market demand.

- **Long-term impacts of climate change in agriculture are the loss of crop-suitable areas and yields**. Climate change impacts on coffee indicate significant reductions in coffee-suitable areas by

2050. Also, suitable areas and yields of staple grains (maize, beans, and sorghum) are expected to be reduced. Climate change will also induce significant changes in forests and natural ecosystems and therefore, in the environmental services they provide to agriculture.

- **Access to resources for adoption and scaling (farm-level implementation) farming practices differs among agricultural systems**. Staple grain farmers are the least resilient as they have the weakest capacity to implement resilience-building measures. Livestock producers are relatively more resilient in Honduras and El Salvador, except for smallholding systems. Agroforestry systems are relatively more resilient. Lack of access to water, health, education, and safety varies across regions, limiting the capacity for long-term planning as short-term resilience building is the main priority.

1.1 Introduction

This chapter describes how resilient agricultural systems are to the effects of climate change **with the focus on the rainfed cropping and livestock systems, livelihood description and analysis in the NTCA**. It begins with a classification and description of these systems. The resilience of those systems depends on different factors. Therefore, this chapter organizes these factors into two parts: the impacts of these processes on prioritized agricultural systems, and their adaptive capacity. Survey and workshops results, quotes from interviews, and comments collected during fieldwork complement this review.

1.2 Cropping and livestock systems in the NTCA and their geographic distribution

Famine Early Warning Systems Network (FEWS NET) Livelihood Profiles Reports for each country of the NTCA [11–13] provide a broad characterization of people who share similar means of securing livelihoods, combining agricultural production and labor (wages) by grouping them into livelihood zones (LHZs). In total 13 LHZs based on coffee, staple grains, and livestock production were prioritized in this report (Table 1 and Figure 4) because of their rainfed condition, their evident greater vulnerability to climate change, the importance for food security and income, and the proportion of agricultural land they occupy. Nine livelihood zones encompass staple grain-based cropping systems and livestock systems distributed in the lowlands of the Pacific and Caribbean slopes. Four livelihood zones encompass coffee-based-cropping systems distributed across medium and high-altitude areas. The sale of agricultural labor, although present in both groups of agricultural systems, is more critical for staple grains and livestock group, while the cultivation of vegetables is complementary in both. Agro-industrial crops or coastal resources are the basis of other livelihood zones of the NTCA (See Annex 2).

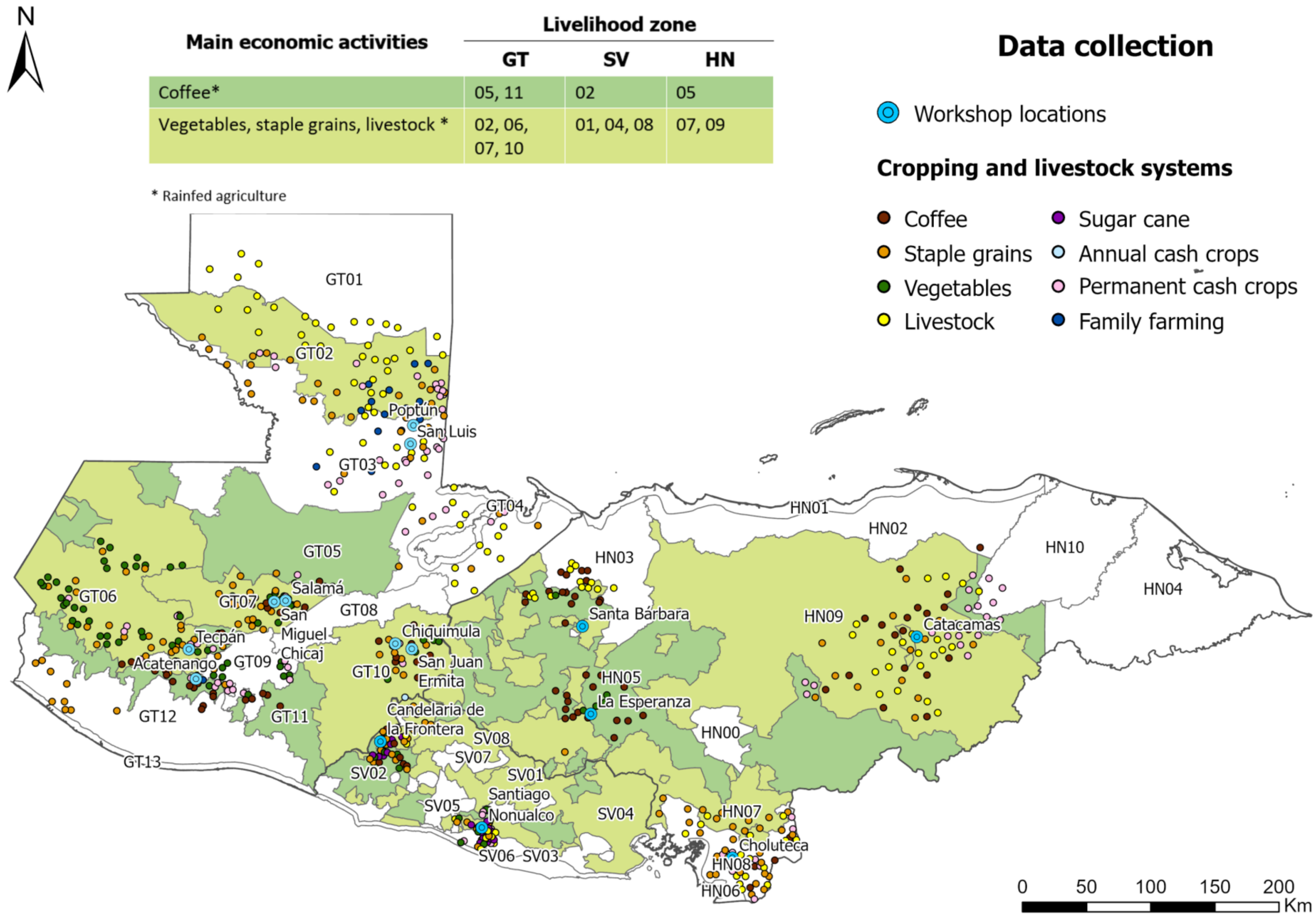
FEWS NET defines **livelihood zones** as "geographical areas within which people share broadly the same patterns of access to food and income and have the same access to markets" [9]. Livelihoods integrates biophysical, agronomic, social and economic variables. See Annex 2 for more information.

In this report, **agricultural systems** encompass **cropping systems** (crops and crop arrangements), and **livestock systems** (different types of livestock and livestock arrangements) and related management techniques.

Table 1. Livelihood zones in the NTCA sustained in rainfed agricultural systems. Prepared with the FEWS NET livelihood zone descriptions [11–13].

Livelihood zone code and name	Agricultural system
SV02 Coffee, staple grain, labor, and tourism GT05 Coffee, cardamom, forestry, and vegetable production GT11 Coffee production HN05 Mountainous coffee and vegetables	coffee
SV01 Staple grain and labor SV04 Eastern staple grain and livestock SV08 Northern staple grain and livestock GT02 Central Petén staple foods and cattle farming labor GT06 Western highlands labor, staple crops, vegetables, trade, and remittances GT07 Baja Verapaz and Quiché staple food and agricultural labor GT10 Eastern subsistence food crops and agricultural labor (coffee, fruit, and vegetables) HN07 Subsistence grains and remittances HN09 Grains and livestock	staple grains and livestock

Figure 4. Prioritized livelihood zones and data collection in various workshop locations. Figure prepared with the FEWS NET livelihood zone spatial data [14–16]



Besides prioritized agricultural systems (coffee, staple grains, livestock, and vegetables), the participants mapped other prevalent systems: sugar cane, annual cash crops (peanut in Guatemala), permanent cash crops (cardamom, cacao, rubber, loroco, and pineapple in Guatemala and fruit trees in Honduras), and family farming concentrated in northern Guatemala (GT02) which refers to home gardens, usually small in size (less than 0.25 ha) where people grow a variety of fruits and vegetables for their own consumption.

Agricultural systems of selected livelihood zones were characterized and prioritized through experts' knowledge systematized through field workshops. ***Agricultural systems based on staple grains, coffee, vegetables, and livestock (in this order) were the most frequently prioritized in the different livelihood zones*.** Cropping and livestock systems were prioritized according to the following criteria: importance for food security, economic value, cultivation area and the number of producers involved.

Field data (summarized in Table 2) show the characteristics of these systems in terms of farm size, land tenure, and irrigation. Field data (summarized in Table 3) also show that some agricultural systems are declining, and others are emerging in response to climate, market, technology, incentives, and labor availability. All these factors are critical for the resilience of cropping and livestock systems.

Interventions to help farmers to be more resilient and food secure must take into account the agricultural systems (coffee, staple grains, vegetables or livestock), the size of the farm, (small, medium, or large) and whether the farmer is an owner or a tenant.

> *The promoted practices depend on land tenure since families who rent land have different needs than those who own their land. (High-level interview, GT)*

Table 2. Farmers type by country based on agricultural systems, farm size, land tenure, and irrigation. Source: Field workshops.

Agricultural system	Farm size	Land tenure						Irrigation
		El Salvador		Guatemala		Honduras		
		Owner	Tenant	Owner	Tenant	Owner	Tenant	
Coffee	Small	X		X		X		No
	Medium	X		X		X		
	Large	X		X		X		
Staple grains	Small	X	X		X	X	X	No
	Medium	X	X		X	X	X	
	Large	X	X	X		X	X	
Livestock	Small	X	X	X		X	X	No
	Medium	X	X	X		X	X	
	Large	X	X	X		X		
Vegetables	Small	X	X	X		X		Yes

> *Tenant farmers do not invest in adaptation measures. (High-level interview, El Salvador)*

Table 3. Agricultural systems trends. Source: Field workshops.

Agricultural system	El Salvador	Guatemala	Honduras	Trend drivers		
				Climate	Inputs	Markets
Staple grains	↓	↓	↓	Variability	Inputs costs	X
Coffee agroforestry systems	↓	↓	↓	Suitability variability	Inputs costs, lack of labor force	[Low prices]
Coffee agroforestry systems with fruits and timber trees		↑	↑	Suitability		X
Vegetables	0	0	0			Local markets
	↑	↑	↑		Irrigation, controlled environments	International markets

↓ decreasing area or number of families involved, ↑ increasing area or number of families involved, 0 stable

Maps with the spatial distribution of the prioritized agricultural systems, including their farm sizes, were prepared to guide geography specific potential interventions that could increase agricultural resilience (Chapter 3). **Data from the participatory mapping sessions of the field workshops was used as a primary source and the census data was used to extrapolate to other areas for which the data from workshops was not collected (Figures 4-7).** See Annex 3 for methodological details.

Staple grain-based cropping systems: Include maize, beans, and upland rice in Guatemala, maize and beans in Honduras, and maize, beans, upland rice, and sorghum in El Salvador. Most staple grain producers (the most prominent group of farmers and most vulnerable, as will be shown later in this chapter) cultivate as tenants in minimal and rented areas (Table 2). Climate variability effects and increasing agricultural input costs drive down the production in staple grain-based cropping systems across all countries (Table 3).
Maize and beans, domesticated crops in the region, are traditional foods, and the habit of consuming them is deeply rooted in the NTCA countries [17]. Most are cultivated on small, rented land extensions, on hillsides, and, consequently, with low investment, so average yields are low in the region [18]. Guatemala has the highest percentage of families dedicated to staple grain production (43 percent), followed by Honduras (31 percent) and El Salvador (25 percent) [19]. Staple grain production by rural families is primarily for self-consumption. World Food Programme's (WFP) Food Security Assessments of the past three years reveal that not only has there been little surplus for sale in the market, but rural families have generally not produced enough to cover their basic food needs. Adding to this hardship, the income of agricultural day laborers is low [19]. Maize and beans account for more than 53 percent of the farming land in the NTCA, according to the last agricultural census of each country [20–22].

In El Salvador, smallholder staple grain producers dominate across the zones the northwestern part of the country with a mix of small and medium, and medium and large farm sizes. In Guatemala in GT05, GT10, and some parts of GT06 and GT11 most farms are large in size. In the Peten region (GT02) and in the central part of the Northern Highlands (GT07), dominant farm sizes range from small to large. Large farms dominate in Honduras HN05 zone, while small ones in HN09, with the eastern part of the zone having a mix of small, medium, and large farms. For spatial distribution across the countries see Figure 5.

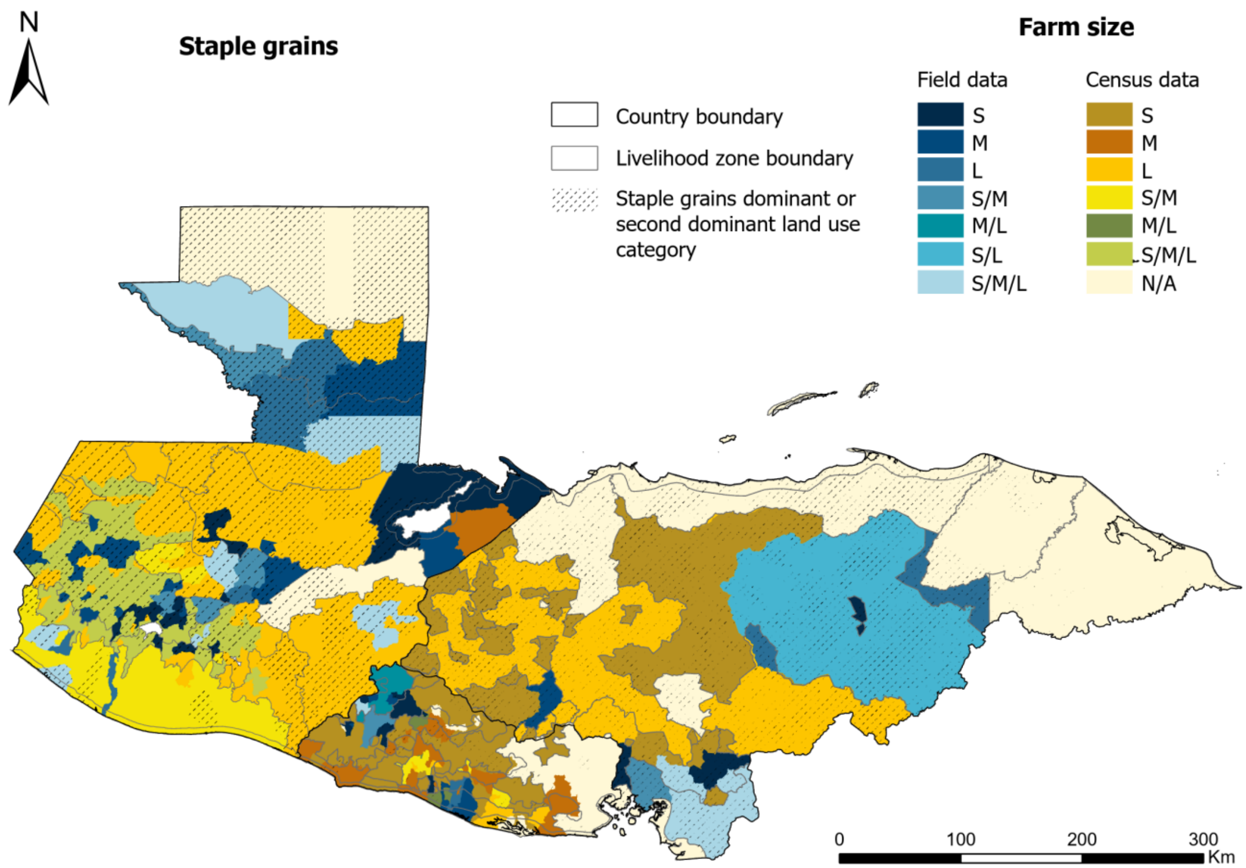


Figure 5. Staple grain - based cropping systems in prioritized livelihoods of the NTCA with extrapolated field data. Farm sizes: S-small, M-medium, L-large. Source: Map based on the results of the participatory mapping sessions in field workshops and data from national agricultural censuses [20–22].

Coffee-based cropping systems: Most coffee producers cultivate in small and medium areas but they own their land or have the security of tenure through e.g., long-term informal agreements (Table 2). In areas exposed to water stress, coffee cultivation is decreasing, while it is increasing in high-altitude regions along with the cultivation of fruit trees (Table 3). Agroforestry systems are a traditional strategy for water stress and temperature variations. Coffee-based agroforestry systems are the basis of income for small and medium-scale producers and the provision of temporary labor [23] since the 19th century, so they are also a basis for food security in the region. Coffee cultivation in Central America is mainly based on Arabica coffee and competes commercially with cheaper coffees (Asia and Brazil) or high-quality coffees (Colombia and Africa). Climate change effects (as will be shown later in this chapter), pests and diseases, together with management costs, land use change, and variations in international prices, are drivers that affect the sustainability of these systems. Coffee accounts for nearly 18 percent of the farming land in the NTCA, according to the last agricultural census of each country [20–22].

Mixed small and medium, and medium and large farm sizes of coffee-based cropping systems dominate in Guatemala, particularly zones GT05, GT06, GT10 and GT11, with some smaller areas on the southern and eastern edges of the Northern Highlands where smallholders dominate.

The data for El Salvador shows the dominance of smallholder coffee growers across the livelihood zones, with exceptions of field data showing mixed small and large, and medium and large areas in SV01 and SV02. In Honduras, the southern slopes of the Southern Highlands are dominated by smallholders in the HN07 livelihood zone. In HN05 there are mostly large coffee farms, while HN09 shows a mix of small, medium, and large producers. See Figure 6 for spatial distribution.

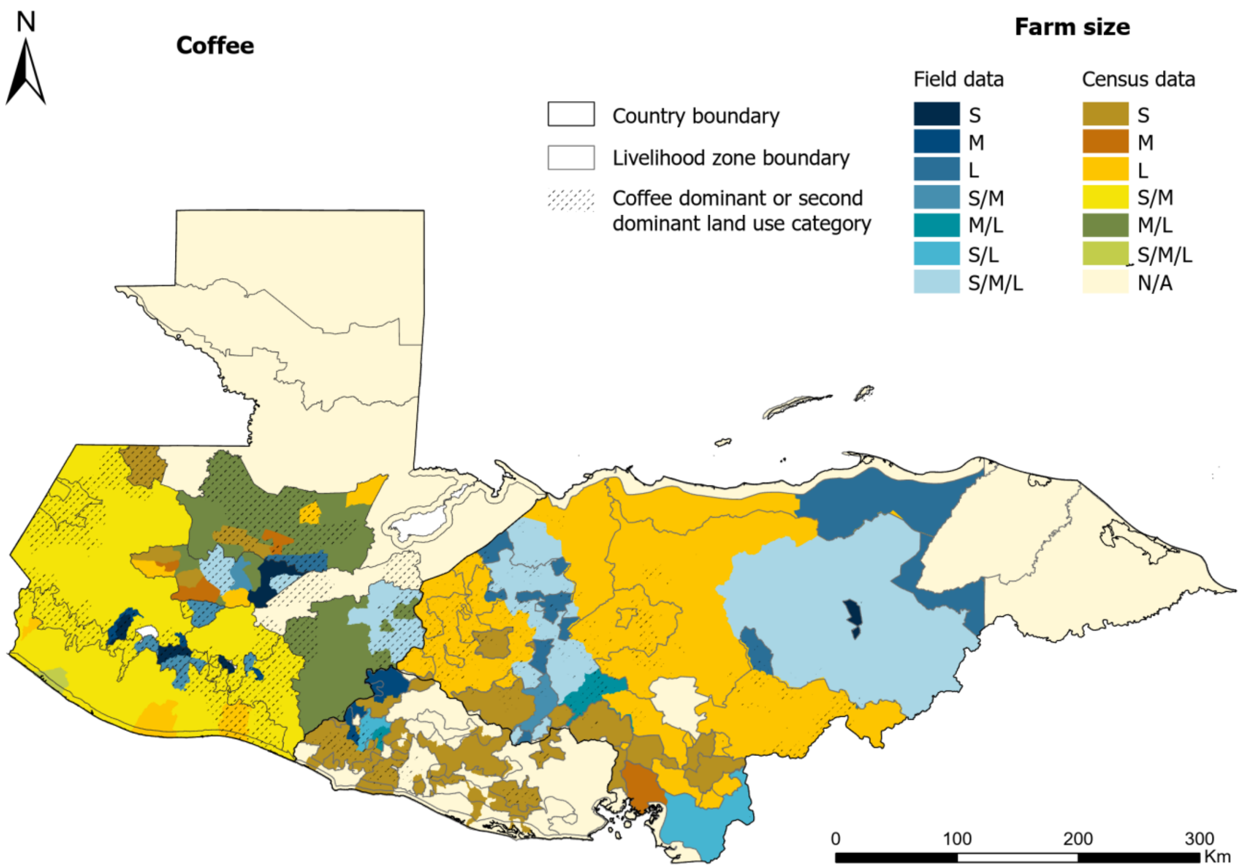


Figure 6. Coffee-based cropping systems in prioritized livelihoods of the NTCA with extrapolated field data. Farm sizes: S-small, M-medium, L-large. Source: Map based on the results of the participatory mapping sessions in field workshops and data from national agricultural censuses [20–22].

Vegetable-based cropping systems: Most vegetable producers cultivate in small and medium farms, and many small farmers use irrigation. Like coffee producers, vegetable producers own their land or have the security of tenure through e.g., long-term informal agreements (Table 2). Vegetable-based cropping systems for local markets are stable, but those focused on exportation are increasing (Table 3).

In Guatemala, there is a considerable fragmentation of dominant vegetable-based cropping systems regarding farm size in all livelihood zones for which the data was available. In the western part of El Salvador, in the zone SV02, most vegetable growers are smallholders, while a mix of small, medium and large farms is found across the zones in the central part of the country. In Honduras, large vegetable farms dominate in

HN05, and medium in HN07, with some areas across the two zones where most farmers are smallholders. Figure 7 shows spatial distribution of dominant farm sizes across the NTCA.

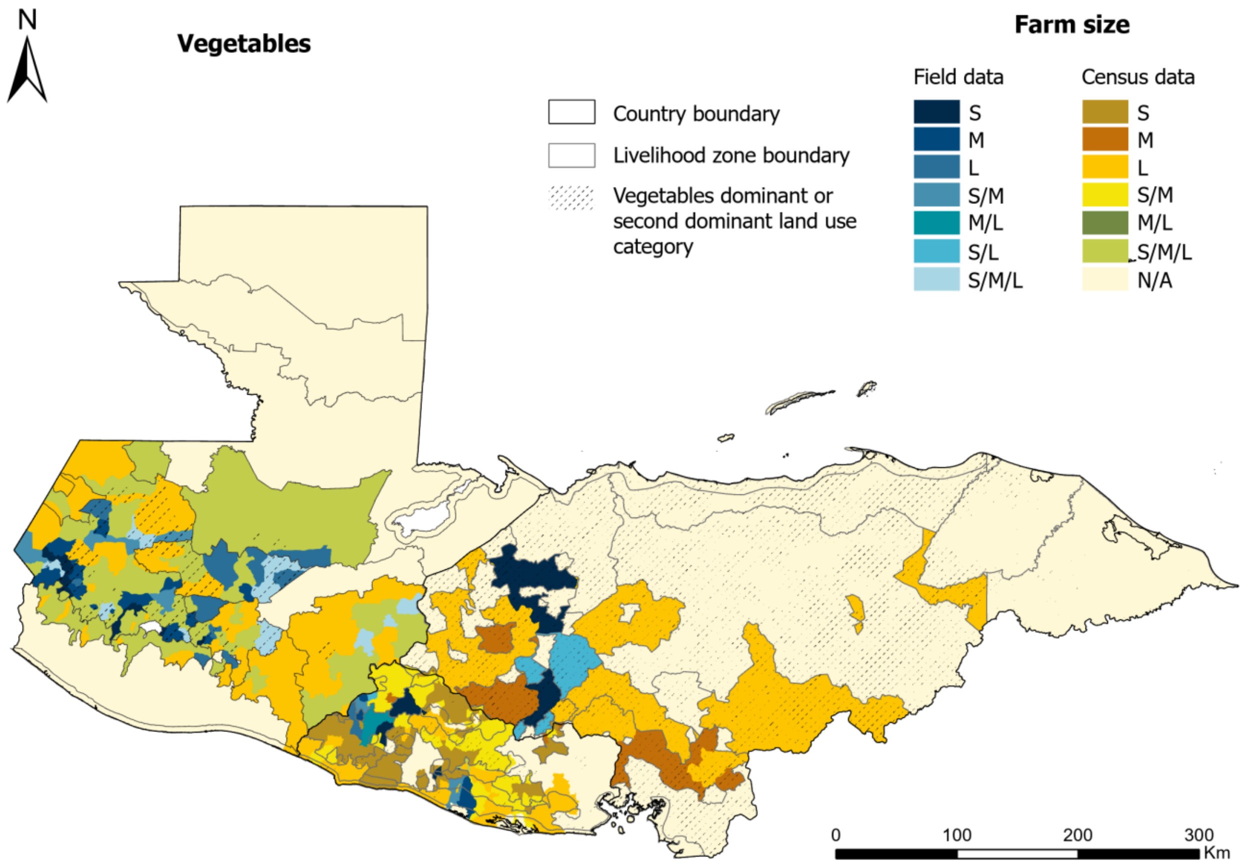


Figure 7. Vegetable – based systems in prioritized livelihoods of the NTCA with extrapolated field data. Farm sizes: S-small, M-medium, L-large. Source: Map based on the results of the participatory mapping sessions in field workshops and data from national agricultural censuses [20–22].

Livestock-based systems: Most livestock farmers own small and medium farms. Like coffee and vegetable producers, they own their land or have secure tenure, while in El Salvador, they mostly own the animals, but they are tenants of pastures (Table 2).

Zone GT02 of the Peten region in Guatemala consists of municipalities where most livestock farmers have medium or large farms. In El Salvador, smallholder livestock farmers dominate across the zones (notably in SV01), with some exceptions in the northwestern part of SV01 where mixed medium and large farmers are found. Honduras shows a diverse landscape of livestock systems across the livelihood zones. Large farms dominate in HN05, while in HN09, there is a mix of small, medium, and large farms. Dominant farm sizes are shown spatially in Figure 8.

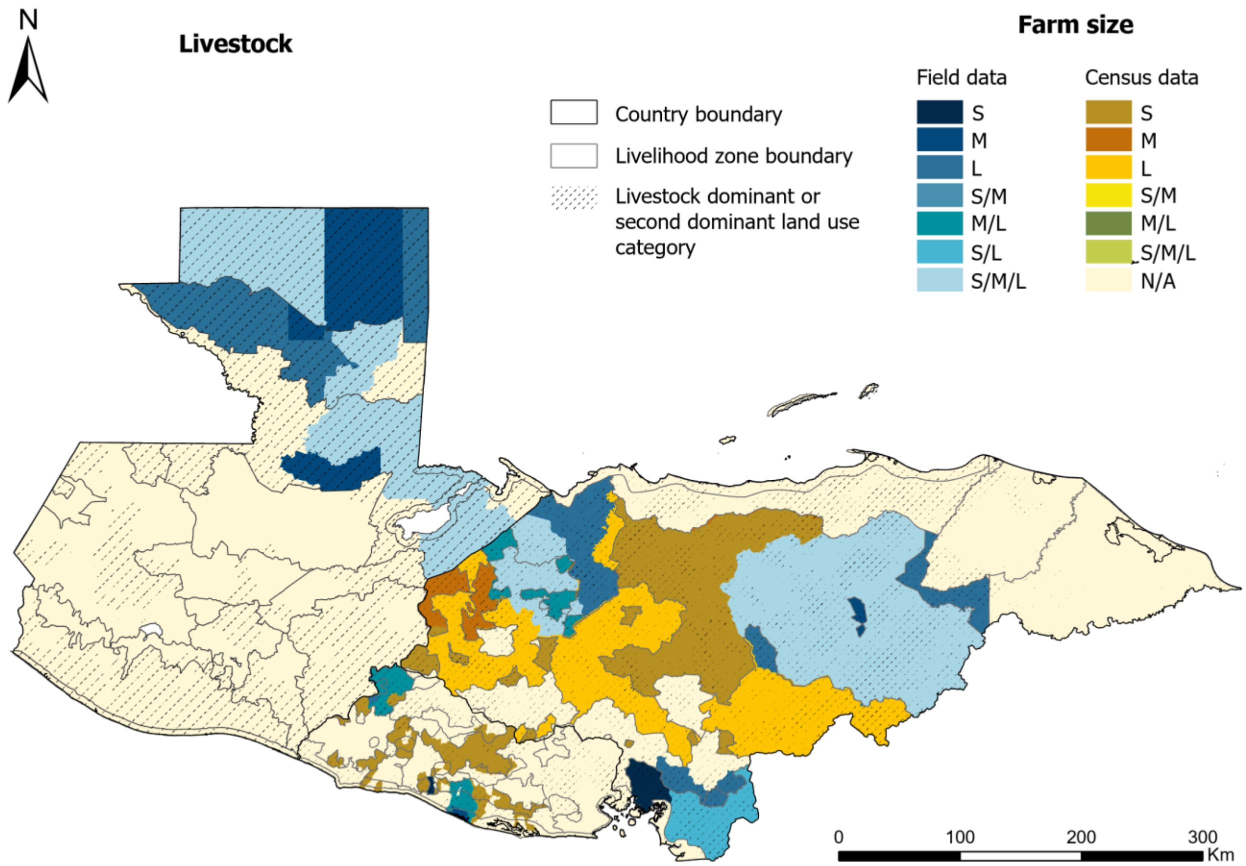


Figure 8. Livestock systems in prioritized livelihoods of the NTCA with extrapolated field data. Farm sizes: S-small, M-medium, L-large. Source: Map based on the results of the participatory mapping sessions in field workshops and data from national agricultural censuses [20–22].

1.3 Climate impacts on cropping and livestock systems in the NTCA

Climate related events can have significant impacts on cropping and livestock systems and, consequently on people's livelihoods. Two events in the Central American Dry Corridor that had significant humanitarian impacts were El Niño associated droughts in 2015 and 2019, destroying crops, particularly of subsistence farmers, and leaving millions of people in need of urgent food assistance. These two years saw the largest increase in the rate of Central Americans traveling to the USA [24].

It is expected that climate change will increase the frequency and intensity of El Niño events [25], which will lead to adverse consequences for people in the affected areas. Climate change can also make more areas favorable for diseases affecting crops. That was seen in the 2012-2014 outbreak of coffee rust which particularly affected smallholders. The increases in nighttime temperatures throughout the NTCA formed favorable conditions for the occurrence of the disease in higher altitudes where it was previously not common [24]. Other impacts of climate variability and gradual climate change are clearly visible, as the erosion and landslides due to extreme rainfall events observed in various livelihood zones during field visits. Erosion reduces soil productivity and induce landslides that damage farms, crops and cause serious infrastructure and environmental issues.

Text Box 1 synthesizes scientific literature on climate trends over the past decades in the region, as well as projected changes.

Text Box 1. Trends of climate variability and gradual climate change in the NTCA

The NTCA is a **climate change hotspot** under future scenarios which signal agreement on temperature increase and precipitation reduction [26–28]. Historical trends in climate across Central America indicate general warming during most of the second half of the 20th century [29], a general increase in the frequency of warm nights and days, and a decrease in cool days and nights. Warming is more prominent during the wet season, reducing seasonal temperature contrasts. Data from the 1950-2018 period show similar trends with a significant increase in warm days and a decrease in cool nights [30]. By the end of the century, models show a significant rise in temperature and heat waves across all NTCA and through all seasons [31].

Mid-summer drought (MSD) in the NTCA, a key climate feature defining agriculture in the region, has intensified across the region. MSD represents a relative minimum rain peak during July-August between the two maxima [32]. MSD intensification means more prolonged and frequent MSD events, MSD events with more consecutive and total dry days, more extreme wet events, and less precipitation during the rainy seasons. MSD intensification is expected mainly over the Pacific slope across the NTCA [33] with an earlier onset [34]. Modeling experiments indicate a potential link between deforestation and MSD across the region [33].

Rainfall pattern trends are not very clear. Still, there is evidence of an increase in rainfall intensity despite the high inter-annual variability in rainfall. Increase and decrease trends are found towards the Caribbean and Pacific slopes of the NTCA [35]. Rainfall intensity shows a significant increase in the intensity of extreme and very extreme events across Central America [30]. Also, historical trends show an increased rainfall intensity for most of the second half of the 20th century [29], and the studies for the 1950-2018 period show a significant increase contribution of very wet days on total annual precipitation [30] over the NTCA. Significant decreasing trends over most of the NTCA were found for the number of heavy precipitation days [30], in contrast with trends for the whole of Central America.

The latest generation of climate models, Coupled Model Intercomparison Project 6, shows agreement on temperature increase and precipitation decrease by the end of the century under high radiative warming scenarios [36]. There is also a high agreement that precipitation will decrease over most of the NTCA from the March to August period [31].

Impact assessments with regional coverage results from global studies have a resolution that is too coarse for the size and shape of this region [37,38]. But there is a high model agreement on significant reduction in water availability [28,39], in particular highly populated watersheds increasing their water stress [40] and reduced potential vegetation growth [28].

> *The agricultural sector [in El Salvador] is one of the sectors heavily affected by climate change, it is also the sector with the greatest need for adaptation. In June 2020, there was $8 million in infrastructure losses and $22 million [losses] in staple crops, vegetables, and fruits. (High-level interview)*

Climate impacts on crops suitable areas have emphasized impact assessments on staple grains and coffee, showing a significant decrease in suitable areas and yields. Summary tables based on field data explain findings combined with literature review in the case of staple grains and coffee-based cropping systems.

Staple grains cropping systems (Table 4) show high impacts across all regions of climate extremes (water excess and deficit, precipitation pattern changes). Also, most studies estimate that gradual increase in temperatures will have high impacts in El Salvador and long-term changes with significant reductions in suitable areas of those crops (Table 3 and Annex 1 - Crop suitability). The combination of effects can cause crop failure and decreased food security in the affected communities.

Table 4. Climate variability and climate change impacts on staple grains cropping system across different livelihood zones of the NTCA, based on the perception of participants in workshops. Long-term impacts are based on literature review.

Livelihood zone	Water deficit: drought, MSD	Water excess: extreme rainfalls	Erratic rainfall	Higher temperature	Other effects	Long-term
SV01, SV02	H ↓ grain development, ↑ harvest loss	H ↑ harvest loss	--	--	Crop failure	Long-term impacts of climate change include loss of suitable cultivation area [41,42,43] and reduction in yields [42,44] for maize and beans in all three countries.
SV01, SV02	H ↑ costs	H	--	H	Propensity to pests and diseases	
GT10	H ↓ quality ↓ quantity	H ↓ quality ↓ quantity, loss of soils	H ↓ quantity	--	Crop failure, ↓ food security among small-scale farmers.	
GT02,	H ↓ quality ↓ quantity, ↑ costs, no sowing	H ↓ quality ↓ quantity ↑ costs	--	--	Propensity to pests and diseases	
GT06, GT11,	H ↓ quality harvest loss	H decay, pests, and diseases, harvest loss	M	--	Crop failure, ↓ food security	
GT06,	M ↓ quantity	M ↓ quantity	M	--		
HN05, HN07, HN09	H harvest loss, loss of seeds	H ↓ quality, loss of harvest, out-of-date germination	--	--	Crop failure, ↓ food security	
HN05	H ↓ quality ↓ quantity	H ↓ quality ↓ quantity, decay of beans, landslides, propensity to pests and diseases	ND ↓ quality ↓ quantity, ↑ costs	--	Crop failure, ↓ food security	

Impacts: L – low, M – medium, H – high; MSD: mid-summer drought. Different assessments of the same cropping systems in different workshops explain different results for same livelihood zones. ↓ decrease, ↑ increase, ND: no data.

> *Climate related impacts also generate losses gradually, where the impact of slow growth in crops after an event is not estimated, as well as the progressive drop in yields and agricultural production due to temperature increases, and the reduction of land suitability for coffee cultivation. (High-level interview)*

Data from workshops show farmers in **coffee cropping systems** identifying water and temperature climate change effects (Table 5). Coffee-based agroforestry cropping systems show high impacts from water deficit (mid-altitude in Guatemala) or excess (all other coffee areas) affecting quality and quantity of produce with losses on income and crop area, indirect effects of climate on pest and disease incidence, perceptions on the impact of gradual increases in temperature on flowering, and significant reductions in suitable areas and yields in the next 30 years.

Table 5. Climate variability and climate change impacts on coffee-based agroforestry systems in different livelihood zones of the NTCA, based on the perception of participants in workshops. Long-term impacts are based on literature review.

Livelihood zone	Water deficit: drought, MSD	Water excess: extreme rainfalls	Erratic rainfall	Higher temperature	Other effects	Long-term
SV01, SV02	H - wilt, ↑ costs	H ↓ quality, ↓ quantity, ↑ costs, susceptibility to coffee rust	M affects flowering	--	Propensity to pests & diseases (coffee-rust, coffee berry borer) Income losses	Long-term impacts of climate change include loss of suitable cultivation area [42 45 46 47 48 49] and reduction in yields [50] in all three countries.
GT05, GT07	H ↓ quality ↓ quantity, susceptibility to pests and diseases, ↑ costs	M ↓ quality ↓ quantity, propensity to pests and diseases, ↑ costs	--	--	Crop failure, food insecurity among small-scale farmers	
GT10			--	Floral abortion, less production	Propensity to pests & diseases (coffee-rust, coffee berry borer) Income losses ↓ cropping system area	
GT06,	--	L ↓ quality, propensity to *ojo de gallo*	L-M ↓ quality ↓ quantity, coffee berry borer	M ↓ quality, leaf loss, coffee-rust	Propensity to pests & diseases, relocation to higher elevations.	
GT07	L ↓ quality ↓ quantity, susceptibility to coffee berry borer	H ↓ quantity (harvest loss) Propensity to coffee rust	--	M ↓ quality ↓ quantity, ↑ costs	Propensity to pests & diseases (coffee-rust, coffee berry borer) Income losses ↓ cropping system area	
HN05	M ↓ quality ↓ quantity, affects flowering	M-H ↓ quality, ↓ quantity , infrastructure damages↑ costs, Propensity to coffee rust	M ↓ quality, ↓ quantity affects flowering	--	Propensity to pests and diseases (coffee-rust, coffee berry borer) Income losses	

Impacts: L – low, M – medium, H – high. MSD: mid-summer drought. Different assessments of the same cropping system in different workshops explain different results for same livelihood zones. ↓ decrease, ↑ increase

> *Climate change is worsening already degraded land from burning, slashing, and fertilizers. (Workshop, Guatemala)*

> *Nowadays, there are very few actual seasons. It is either very dry or very rainy. Excess rain and excess drought negatively affect the soil. (Workshop, Honduras)*

Livestock systems *show high impacts from water deficit inducing loss of pasture productivity inducing selling of animals (capital loss). Also, high temperatures affect animals' weight and milk production (*

Table 6).

> *During the dry seasons there is food scarcity so we must ensile [forage]. On the other hand, when there is excess rain there is [fodder loss] due to rotting. (Workshop, El Salvador)*

Table 6. Climate variability and climate change impacts on livestock systems across different livelihood zones of the NTCA, based on the perception of participants in workshops.

Livelihood zone	Water deficit: drought, MSD	Water excess: extreme rainfalls	Erratic rainfall	Higher temperature	Other effects
SV01, SV02	H ↓ fodder, ↓ milk production, ↑ diseases	ND ↓ milk production	--	L ↑ weight loss, ↓ milk production	
GT10	H ↓ fodder, ↑ costs, ↑ diseases		--	--	
GT02	L ↓ fodder, ↑ costs	L Infrastructure damage	--	--	
HN07, HN09	L ↓ fodder, ↑ costs, ↑ diseases	M ↓ grazing areas and milk production, ↑ diseases	--	L animal stress, ↑ weight loss, ↓ milk production	

Impacts: L – low, M – medium, H – high; MSD: mid-summer drought. No long-term effects were found in the literature. ↓ decrease, ↑ increase, ND: no data

Vegetables cropping systems show high impacts from water deficit (Dry Corridor areas) of excess (higher altitude areas), effects on crop quality, quantity of crop production and indirectly through pests and disease incidence (Table 7).

Table 7. Climate variability and climate change impacts on vegetable cropping systems across different livelihood zones of the NTCA, based on the perception of participants in workshops.

Livelihood zone	Water deficit: drought, MSD	Water excess: extreme rainfalls	Erratic rainfall	Higher temperature	Other effects
GT06, GT11	--	H ↓ quality ↓ quantity, ↑ costs	--	--	Susceptibility to pests and diseases.
HN05	M ↓ quality ↓ quantity	H harvest loss	--	--	Susceptibility to pests and diseases.
SV01, SV02	H ↓ quality ↓ quantity, ↑ costs	--	--	--	Susceptibility to pests and diseases.
SV01, SV02	H ↓ quality ↓ quantity, ↑ costs	H ↓ quality ↓ quantity, ↑ costs	--	--	

Impacts: L – low, M – medium, H – high; MSD: mid-summer drought. Different assessments of the same cropping systems in different workshops explain different results for same livelihood zones. No long-term effects were found in the literature. ↓ decrease, ↑ increase

Climate change effects are driving down staple grains production across all three NTCA countries. But climate change is also changing the suitability of permanent crops. In areas exposed to water stress, coffee cultivation is decreasing, while it is increasing in high-altitude regions, together with the cultivation of fruit trees. Emerging cropping systems could provide short-term resilience-building alternatives (perennials, such as coffee-based agroforestry systems and fruit trees). However, their relevance as a long-term response is still unknown, except for coffee. Markets influencing input costs, availability, and final incomes are a major driver for cropping systems changes. For example, falling coffee prices may affect the cropping system (and consequently migration responses) differently. Coffee-producing families may be forced to reduce investment in the cropping system through, for example, buying fewer inputs and hiring fewer workers for specific tasks. This will negatively affect the productivity of the cropping system, further exposing it to the incidence of rust and other diseases. Likewise, staple grain farmers who sell their labor for coffee harvesting and other tasks in the coffee plantations, having less employment or payment, prefer to migrate in search of work or switch to an activity other than agriculture.

1.4 Farmers' adaptive capacity

Text box 2. Resilience or adaptive capacity?

Adaptation, vulnerability, and resilience are related and complementary terms in climate change and development discussions but have different disciplinary origins [51,52].

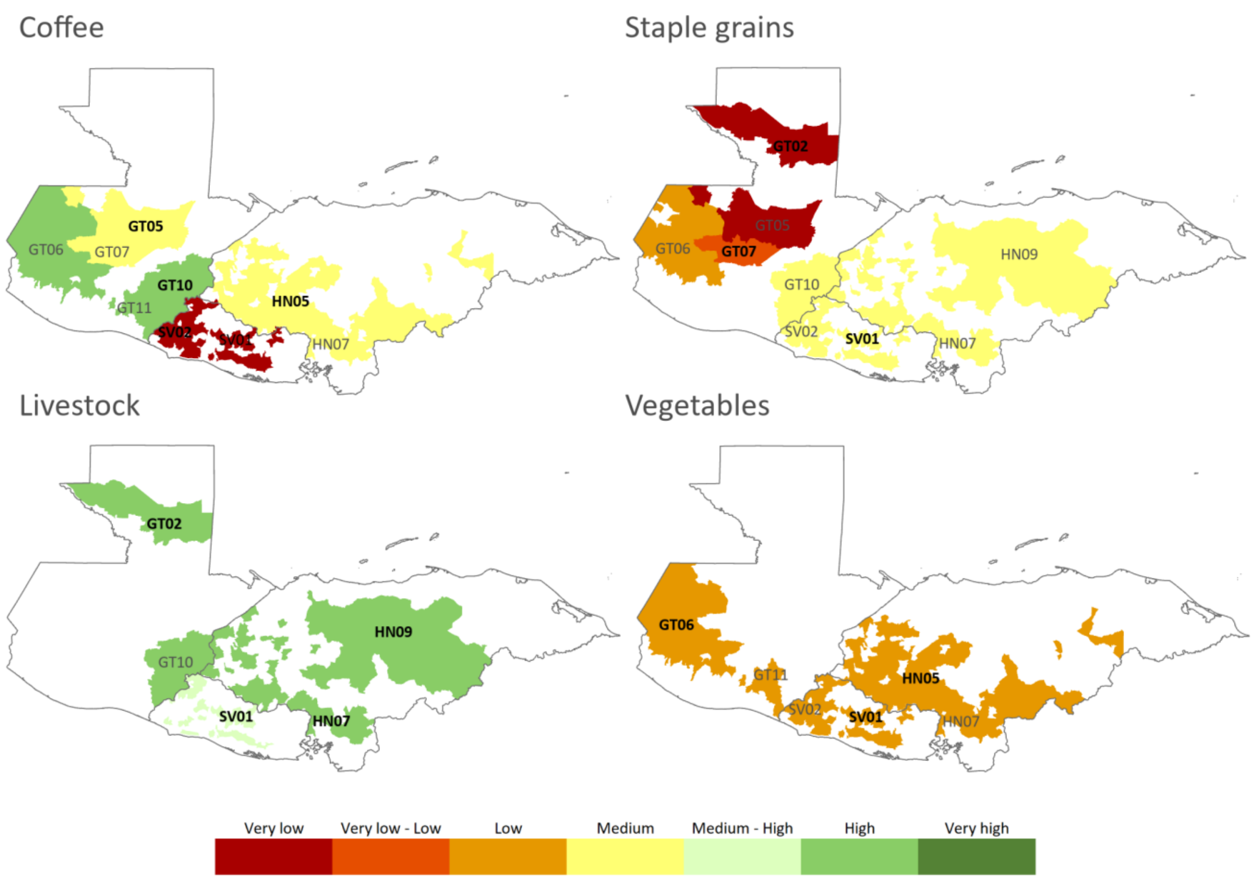
This document defines resilience as the capacity of a system to maintain its functions when faced with change [51]. Namely, cropping and livestock systems keep their functions of providing food security, income, and sources of labor in the face of climate change. This document also assumes that adaptive capacity refers to the ability of farm families and their organizations to access and use different resources to reduce their vulnerability. This assumption is very close to the concept of resilience [51]. Therefore, adaptation measures and strategies are related to vulnerability reduction, which can be interpreted as maintaining the resilience of cropping and livestock systems.

To estimate adaptive capacity of coffee, staple grains, livestock and vegetable farmers we used different indicators to assess water access, food security, health, education, personal security, technical assistance and agroclimatic information, infrastructure and agricultural inputs, availability of labor and financial capital. The data was collected during the participatory workshops through a survey that was conducted separately per agricultural system and prioritized livelihood zones across the three countries.

The final adaptive capacity level was calculated based on all the indicators. The level is qualified according to proportion ranges as very low (0-20 percent), low (20-40 percent), medium (40-60 percent), high (60-80 percent), and very high (80-100 percent). The percentage ranges correspond to the fraction of families in respective livelihood zone in each agricultural system who have the indicators' condition satisfied.

The results (Figure 9) show that coffee and livestock farmers are more resilient than staple grains and vegetable producers. The least resilient are staple grains farmers in Guatemala, with very low adaptive capacity levels in zones GT02 and GT05, and low to very low in GT06 and GT07, and medium in Honduras and El Salvador. Vegetable producers have low adaptive capacity across the prioritized zones in all three countries. They also experience high climate change impacts, as shown in the previous section. Livestock farmers appear the most resilient with high adaptive capacity in Guatemala and Honduras, and medium to high in El Salvador. Access to (good quality) water throughout a year, food security throughout a year, access to health services, basic literacy, and personal security is high, in relative terms, for coffee farmers and very high for livestock farmers, while for staple grains and vegetable farmers it is between low and high across livelihood zones. Field interviews point out that the current technical assistance emphasizes permanent crops in Guatemala and coffee and livestock in Honduras. Agroclimatic services are only available to specific groups related with the private sector, and no cropping or livestock system has access to soil data. As the survey showed, all farmers coffee, staple grains and vegetables have very low use of irrigation, low availability of facilities and infrastructure for production and storage, lack of infrastructure for water storage, poor access to improved seeds/varieties, and limited access to roads and transportation options for commercialization of products. For livestock farmers these values are medium but vary across the livelihood zones, from very low to high. Across the zones for staple grains and vegetable farmers there is a lack of agricultural labor and limited financial capital, including access to value chains, access to agricultural credit, income diversification opportunities, and reception of remittances.

Figure 9. Small and medium-sized cropping and livestock farmers' adaptive capacity conditions in the NTCA countries.



Livelihood zones in bold are the ones where the production of respective system is the main agricultural activity according to FEWS NET characterization [14–16].

Other differences among agricultural systems across countries are:

- Coffee-based agroforestry systems are generally the most resilient alternatives in Guatemala and Honduras, but for small and medium-sized coffee farmers in El Salvador adaptive capacity is very low. Coffee producers in El Salvador additionally experience high levels of climate change impacts, while in Guatemala and Honduras, they are medium to low.
- Staple grains producers and smallholders (grains, vegetables, and livestock) are the least resilient and face multiple climate variability impacts. As the field data showed, staple grains producers experience high climate change impacts across the zones.
- Access to water is a general limitation for adaptation across all agricultural systems.

2 Food security and migration in the Northern Triangle of Central America

Chapter 2 – Highlights

This chapter shows how different agricultural livelihoods and cropping systems, together with sociodemographic factors, shape agricultural resilience and how migration decisions relate to such context. Based on this approach, the following questions were addressed:

a) Does a lack of agricultural resilience to the effects of climate change cause food insecurity and migration?

The data from the field work conducted for this assessment shows there is a link between food security and migration in some livelihood zones in Guatemala and Honduras. Specifically, in Guatemala small and medium-sized staple grain and coffee producers with very low to low food security have high emigration levels. In Honduras coffee producers with high to very high food security have very low to low migration levels. Food insecurity can act as a push factor for migration through different socio-economic factors.

The relationship between food security and migration is channeled through multiple and sometimes indirect pathways. These include factors such as lack of employment opportunities, low wages, violence and conflicts, and climate change events, which are all linked to food security and which consequently, act as push factors for migration. Addressing migration will require understanding the complex constellation of factors that influence migration decisions.

b) Does agricultural resilience to climate change effects reduce food insecurity and the likelihood of migration?

Resilience generally improves food security because families can make on-farm adaptation investments. Certain livelihoods are more resilient to the effects of climate change, and people who depend on those livelihoods will make different migration decisions based on needs, opportunities and the availability of supporting resources. Several factors will affect these migration decisions, including choosing migration as an off-farm adaptation strategy for income diversification.

The literature review and the field work clearly show that climate change does not act as an isolated migration driver. There is no one root cause for migration, and any strategy to face migration must consider the combination of different factors and how they interact in a specific geographic, social and livelihood context. This also means that there is a need for engagement with governments and other key stakeholders who can play an important role in addressing structural issues that contribute to people leaving their places of residence.

2.1 Introduction

Across the NTCA countries, academics and practitioners have identified different types of drivers of migration. The most commonly found are factors of economic nature [19,53–59] such as high levels of poverty and, more pronounced in Honduras, food insecurity. Studies that included large sample sizes [19,56] showed that poverty and unemployment were the main motives for emigration across the three countries. This was exacerbated by the COVID-19 pandemic [60]. Climate change events [19,61–63,84] of both slow (droughts and increasing temperatures, alterations in ecosystems and reduction in agricultural productivity due to reduced rainfall, droughts and pests) and rapid onset (floods, hurricanes, tropical storm, tsunamis) were cited as drivers in all three countries. Other environmental challenges [61,64–66] such as deforestation, land degradation and soil erosion and disasters caused by volcanic eruptions and earthquakes have also pushed Central Americans to leave their home countries. Violence and insecurity [61,62,64,67–73], including gender-based violence and femicide, and structural causes [61,62,64,67,72–74] (e.g., corruption, land tenure insecurity, weak rule of law) also played an important role in people's decisions to migrate.

Migration can be seen as an adaptation strategy, a failure to adapt, or a step toward adaptation (e.g., through sending remittances) [75]. People migrate motivated by socioeconomic factors and other complex reasons, and environmental factors will increasingly influence migration.

> *There is a relationship between the effects of climate change on livelihoods and the internal and external migration that occurs in different areas of the country. (High-level interview, Guatemala)*

As a response to climate-related impacts, migration "may range from mobility as a proactive adaptation strategy to forced displacement in the face of life-threatening risks" [76]. Recent reviews on the impacts of climate change on migration at the global level suggest that there is a distinction between fast and slow-onset climatic events, which can have direct or indirect effects on migration and shape migration responses – temporary or permanent, short or long-distance, voluntary or involuntary, or even result in immobility [75,77]. Fast-onset events have direct effects and result in short-term, involuntary, temporary displacement in proximity to the place of residence [75]. On the other hand, slow, less sudden onsets of climatic events are associated with voluntary mobility, both temporary and permanent, often indirectly affecting migration through economic (e.g., loss or reduction of income) and sociopolitical factors (e.g., the occurrence of conflict) [75]. Slow-onset events are more likely to prompt migration than fast-onset events [77]. Natural disasters such as dry mass movement, earthquakes, extreme temperature, floods, storms, volcanic activity, and wet mass movement, contribute to long-term and gradual migration [19]. The links between the type and frequency of events to migration and the severity of events and their impact on migration are not strong [75]. However, there is a clear signal that this relationship depends on the household's capability and vulnerability [77].

For about 90 percent of the migrants from the Northern Triangle, the preferred destination country is the USA [19,56]. In 2019 around 86 percent of Central American migrants in the USA came from El Salvador (37 percent), Guatemala (29 percent), and Honduras (20 percent). Compared to the 1980s when the total number of Central American immigrants in the US was roughly 350 000, in 2019, this figure exceeded 3.7 million [78].

More people from Honduras and Guatemala migrate from rural areas than from urban areas, while the proportion of migrants of both origins is similar in El Salvador [79]. People who migrate from rural areas of the NTCA countries have more significant vulnerabilities, such as indigenous peoples, smallholders, and subsistence farmers [61], the groups of people for whom the climate change impacts are most pronounced [80]. In 2014 over 50 percent of migrants returned from Mexican border authorities came from rural areas of the three countries and worked in agriculture [19]. The average age of people migrating to the USA is forty years old [78], mostly men [19,55]. In Guatemala, 94 percent of migrants are adults, while the rest are children or adolescents [81]. Many adult migrants have low education levels: 56 percent of Guatemalan migrants and 50 percent of Salvadorans do not have secondary education [78].

2.2 Does a lack of agricultural resilience to the effects of climate change cause food insecurity and migration?

Internal and international migration can exist both independently from each other, but sometimes internal migration occurs as a first step toward the international one [56]. Previous studies in the NTCA showed that people are more inclined to migrate abroad than within a country [56]. The reasons to move domestically appear close to the reasons to emigrate: unemployment and generally poor economic conditions to provide for water access, food security, health and education [56]. However, determining what causes people to migrate is a complex task that requires observing several different factors and their interplay. For instance, environmental factors, such as dry periods and drought, or increased incidence of pest and disease (such as coffee rust), do act as triggers for mobility, but not in isolation. They are tightly related to others, such as economic vulnerability and exposure to conflict and violence [64]. Nevertheless, the findings of this assessment are that under climate change effects such as drought and extended dry periods, floods, and increased crop pest and disease incidence, a lack of agricultural resilience can contribute to food insecurity, and that such insecurity, often in combination with other factors can contribute to migration.

The importance of factors influencing migration decisions varies across studies since they are all conducted at different points in time, and in different geographic and socioeconomic contexts. These discrepancies can be due to differences in survey structures, but also due to the complex nature of human decision-making and the circumstances around it. Nevertheless, the literature does show an understanding of the difficulty in isolating one specific cause of migration. While there is a consistency among studies in which respondents point at economic factors as the main reason to migrate, both internally and internationally, there are also arguments that the underlying reasons for the poor economic situation can come from different phenomena such as violence and insecurity, climate change, and natural disasters.

Food insecurity is becoming an increasingly important driver of migration, even though many people remain "trapped" [75,82] – people who want or need to move but due to various reasons they are unable to. In Guatemala, Honduras and El Salvador food insecurity was found to be linked with greater likelihood for expressing intentions to migrate [83]. While the desire to migrate levels are very similar among individuals who are experiencing severe hunger, moderate hunger and little to no hunger in the NTCA, people who experience severe hunger were the ones who reported most the execution of their migration plans in recent years [56]. In the Dry Corridor, households with at least one member who migrated showed that 47 percent had to do with food insecurity prevalence, and 11 percent with severe food insecurity [19]. A study showed that in Western Guatemala a strong motivation for migration is food insecurity [84]. Particularly the communities whose livelihood activities are highly sensitive to climate variability and face food insecurity, migration is a coping strategy that is often too expensive, too risky, or possible only to a location that faces similar agricultural challenges. Another study conducted in rural Guatemala, suggested that there is a link between the effects of droughts and floods to food insecurity and intention to migrate, and in the future the drivers of migration will be related to worsening food conditions and deteriorated livelihoods in the areas heavily affected by climate change [85].

In 2021, 15, 23, and 35 percent of the population of El Salvador, Guatemala, and Honduras respectively was in need of urgent food assistance [86]. Drivers of food insecurity in the same year were for all three countries compounded by the adverse effects of the COVID-19 pandemic, the rise of the costs of food and the inputs for food production and distribution (fertilizer, fuel, food, and transportation prices), and limited employment opportunities. In El Salvador, violence and insecurity constrain economic opportunities and humanitarian assistance, and in Guatemala and Honduras, the consequences of hurricanes Eta and Iota in 2020 were still felt in 2021. Additionally, Honduras was exposed to dry spells and rainfall deficits, [86] both of which are climate change effects.

Results from the field

During the field workshops we looked at the climate change impacts per cropping system and livelihood zone, and proportion of families with food security throughout a year, and compared with the fraction of families who have at least one close family member (parents or children) who have migrated to the United States (Table 8). This data was collected on the livelihood zone level, in rural areas, with specifying the prevalent cropping or livestock system for that zone. Based on that and on the analysis of adaptive capacity shown in Chapter 1, we identified four distinct groups of livelihood zones and cropping/livestock systems.

The main push factors for migration across the three countries found from this assessment's participatory workshops in the field were lack of employment opportunities, low wages, and increase in agricultural input costs. For staple grains, vegetables and livestock farmers the main reason for migration was lack of employment opportunities (36 percent, 50 percent and 40 percent, respectively). Similarly, for coffee producers, lack of employment (33 percent) and low wages (33 percent) were cited as main reason to migrate. Consistent with the previous studies [19,56], only in El Salvador violence was indicated to be a significant driver for migration, specifically for coffee and vegetable producers in our assessment (17 percent and 25 percent, respectively). Also in El Salvador, an emerging reason for migration to the US was family reunification, significant for livestock, staple grains and vegetable farmers.

Table 8. Climate impacts, food security and migration in prioritized livelihood zones.

Agricultural system	Livelihood zone	Climate change impacts	Food security	Migration
Coffee	SV01, **SV02**	H	VL	VL
	GT10	M	H	NA
	GT06, **GT11**	L	VH	H
	GT07	NA	L	H
	HN05, HN07	M	VH	VL
Staple grains	**SV01**, **SV02**	H	M	L
	GT02	H	VL	H
	GT06, GT11	H	M	M
	GT10	H	M	H
	GT07	NA	VL-L	M-H
	HN05, **HN07**, **HN09**	H	L	M
Livestock	SV01	NA	NA	H
	SV01	H	VH	VH
	GT02	L	VH	NA
	GT10	H	H	VH
	HN07, **HN09**	L-M	H	M
Vegetables	SV01, SV02	H	VL	VL
	SV01	H	L	VL
	GT06, GT11	H	H	M
	HN05, HN07	M-H	L	L

In cases of migration and food security the proportions are qualified as Very Low (0-20 percent), low (20-40 percent), medium (40-60 percent), high (60-80 percent), and very high (80-100 percent). Climate change impacts are qualified as L – low, M – medium, H – high, based on the perception of participants in workshops. NA, no answer. Data from field workshops. All cases are small and/or medium-sized farmers. Livelihood zones in bold if the cropping system is one of the agricultural activities included in the LHZ according to the FEWS NET characterization (See Annex 2).

Group 1 is composed of the livelihood zones where the relationship between food security and migration was identified. Specifically, in Guatemala where we found **very low to low food security and high migration levels,** namely for coffee (GT07) and staple grains (GT02, GT07) producers. In Honduras coffee producers in zones HN05 and HN07 have **high to very high food security and very low to low migration levels.**

For both groups in Guatemala reasons to migrate are of economic nature: search for employment, employment to pay debts and low wages (in case of GT02 reasons not specified). In Honduras, along with low wages, search for a job to pay debts is stated as one of the main reasons to migrate.
As shown in the previous chapter, staple grain producers experience higher impacts of climate variability and gradual climate change due to water deficit (droughts, mid-summer droughts), water excess (extreme rainfalls), yields decrease, and loss of suitable growing areas, all of which contributes to food insecurity. The adaptive capacity for these zones is medium, except for staple grains producers in GT02 where it is very low.
Interventions addressing agricultural resilience and food insecurity could contribute to decreasing migration levels. While the emphasis could be on food security, broader economic aspects need to be included.

Group 2 includes zones with **high to very high food security and high to very high migration,** specifically coffee (GT06, GT11) and livestock farmers (GT10) in Guatemala and livestock in El Salvador (SV01). This indicates that the reasons to migrate stem from causes others than food insecurity. Specifically identified are unemployment (lack of income diversification opportunities combined with low prices of their products) and low wages. As the adaptive capacity analysis showed, while these farmers have generally high adaptive capacity, more specifically, higher access to water, food security, health, education, and personal security, they experience limited conditions in accessing technical assistance and training, agroclimatic information and, specifically in Guatemala, lack of labor and financial capital.
Interventions could focus on improving economic opportunities to potentially decrease migration levels.

Group 3 are areas where there is no strong relationship between food security and migration, which need attention for both food security and economic opportunities.

a) High/very high food security and no data on migration, high adaptive capacity – GT10 (coffee) and GT02 (livestock).
b) Medium food security levels and low, medium and high migration levels, low to medium adaptive capacity – Staple grains:SV01, SV02, GT06, GT10, HN05
c) Low to very low food security and low to very low migration, low adaptive capacity - vegetable farmers (HN05, HN07)
d) High food security and medium migration – Livestock – HN07, HN09, high adaptive capacity; vegetables GT06, GT11, low adaptive capacity.

Similar to the first two groups the main reasons to migrate across the zones were low wages and unemployment, which creates an unfavorable condition for repaying debts (debts due to multiple reasons e.g., cultural or sustaining migration process of other family members).
Interventions focused on building resilience at the farm level and looking for effects in economic outputs over areas which do not show clear relationship between food security and migration (mixed results).

Group 4 includes only livelihood zones in El Salvador. What is distinct about this group is that violence was cited as the main reason to migrate. Our data shows that for coffee growers (SV01, SV02) and vegetable farmers (SV01, SV02) food security and migration levels are very low and very low to low respectively, and generally adaptive capacity is very low.

Violence is one of the greatest drivers of migration in El Salvador. The low levels of migration found in the mentioned livelihood zones could be linked to household finances: poor families with little income cannot afford to cover costs of migrating.

Interventions in these zones will be faced with a challenge of addressing food insecurity and unemployment together with crime and violence in rural areas. The focus could be on building capacities of farmers and community organizations, and on providing opportunities for youth related with agriculture.

While there are many studies that look at geographies, drivers of migration, and socio-economic groups, there is still lack of linkages of different livelihoods and decisions to migrate, which is evident from the difference between our results and the results of previous studies mentioned in this Chapter. To expand on our analysis from the field, we synthesized the information from the Famine Early Warning Systems Network (FEWS NET) which, through individual country Livelihood Profiles Reports, provides a broad characterization of people who share similar means of securing livelihoods and their migration responses. The following brief analysis is based on the profiles for Guatemala, Honduras, and El Salvador [11–13] (see Table 9).

For most livelihood groups (coffee: GT05, SV02; staple grains: GT07, SV01; livestock: HN09; vegetables: GT06), internal migration occurs mainly in very poor or poor households, and it is motivated by the search for employment. Dry periods and drought were among the causes of food insecurity for staple grains and livestock farmers (HN07, SV01). Most of these households share vulnerable conditions such as lack of land tenure (they are predominantly land tenants with small farming plots, the exception is Guatemala where coffee, livestock and vegetable farmers own their land, as the data from workshops showed), large households (various ranges between five to ten members), sale of labor as a main source of income with very little income diversification possibilities, and access to only essential agricultural tools. Internal migration also occurs in some better-off households in livelihoods where coffee is the main economic activity (HN05, GT05). Despite having better conditions than the poorest households, it can be related to a drop in market prices or a loss of yield due to coffee leaf rust. External migration (USA, Mexico, or Belize) can be observed for better-off households of staple grains (SV01), coffee (SV02), and livestock (GT02) livelihoods. Additionally, the members of middle-income and better-off households with coffee and staple grains livelihoods in El Salvador (SV01, SV02) are in a better position to migrate due to the ability to borrow enough money to cover the cost of the trip.

Table 9. Food security and migration responses in coffee, staple grain and livestock-based livelihoods in El Salvador, Guatemala, and Honduras. Based on the FEWS NET profiles for Guatemala, Honduras, and El Salvador [14–16].

Agricultural system	LHZ	Food security	Migration responses
Coffee	GT05, GT07	ND	National migration; people from poor households migrate to plantation areas or to outside zones for labor.
	SV02	Food insecurity associated with international coffee prices. The poorest, food insecure, sell part of their food reserves and small livestock, or search for employment inside/outside of the zone. They also collect and sale firewood and wild foods.	Poor households: Internal migration (look for work on local farms or in other parts of the country); Better-off households: Migration to the United States (mostly by members of middle-income and better-off households who have or are able to borrow enough money to cover the cost of the trip).
	HN05	ND	HN05 Migration to other zones where wages are higher.
Staple grains	GT02	No food insecurity crises (2011-2016)	GT02 More immigration than emigration of workers (national migration).
	GT05	Local producers able to cover their needs only for 4 months or less in a year.	ND
	GT06	Local producers able to cover their needs only for 4 months or less in a year.	High emigration rate (national migration).
	GT07	ND	Poor households: Internal migration (to plantation areas for labor or outside the zone)
	SV01	Prices rise when grain supplies within the zones are affected by the lack of rain, and during months before the harvest.	Poor households: Internal migration (look for work on local farms or outside the area). Due to food insecurity, the poorest sell firewood, migrate to coffee and sugarcane zones, the sale of their staple grains reserves, and small livestock increases, wild food is collected; Better-off households: Migration to the United States (particularly by members of middle-income and better-off households who have or are able to borrow enough money to cover the cost of the trip).
	HN07	Zone with the greatest risk of food insecurity due to frequent droughts. Poor households use their labor income from agricultural activities to purchase necessities for their 3-month maize and bean production.	Migration to other areas to harvest coffee and/or sugar cane.
	HN09	Poor households affected by low prices at harvest time.	ND
Livestock	GT02	Without food insecurity (2011-2016)	National migration; Poor households: Seasonal migration inside or outside the zone or abroad (Mexico, Belize, US).
	HN09	ND	Poor households: Internal migration (to cities, for labor).
Vegetables	GT06	ND	Poor households: Internal migration (to plantation areas for labor).

ND – no data

The relationship between food security and migration is channeled through multiple and sometimes indirect pathways. As the analysis showed, these include factors such as lack of employment and income generating opportunities, low wages, high input prices, effects of climate change and violence and conflicts, which are linked to food security and which consequently, act as push factors for migration. Therefore, addressing migration will require understanding the complex constellation of factors that influence migration decisions, and agricultural resilience could help with increasing food security which is one of the important aspects.

2.3 Does agricultural resilience to climate change's effects reduce food insecurity and the likelihood of migration?

On- and off-farm climate change adaptation mechanisms influence migration decisions. A global study [75], shows that families who can make on-farm adaptation investments such as new cultivars, crop rotation, improved seeds, or irrigation are less likely to migrate. A study in Guatemala showed that owning a larger farm and growing high-value crops (crops other than maize and beans) is linked to a lower probability of emigrating [87]. These conclusions are, however, based on very few empirical studies and need further investigation. On the other hand, off-farm strategies include migration as an adaptation strategy through wage labor, which provides income diversification.

The results of this report show that specific livelihoods are more resilient to the effects of climate change and that people who depend on those livelihoods will make different migration decisions based on necessities and the availability of supporting resources.

Climate extremes, agricultural production, and migration have complex and non-linear relationships [88]. A review of drivers of migration at a global scale [89] justifies and argues that migration is the result of complex interactions between the drivers of migration and environmental change and that this interaction will increase in the future. Our findings highlight that interrelationship between the drivers of migration, climate change, and food security for the three countries are complex but they still allow for designing four different routes for future interventions that concern food security and migration. Our current understanding can be further improved with additional data on migration and comprehensive approaches to analyzing the mentioned complexity.

Climate change effects do not act as migration drivers in isolation, as there are multiple causes of migration decisions. There is complexity in analyzing the interplay between climate change, food security, livelihoods, and migration. As other studies suggested, there is no one root cause for migration, which indicates that there is no single, uniform way to address migration. There is a need to look at the combination of different factors and how they interact in a specific geographic, social, and livelihood context. This also means that there is a need for engagement with the government and other key stakeholders who can be essential in addressing structural issues that contribute to people leaving their places of residence.

Having agricultural resilience to the effects of climate change could help reduce food insecurity and, consequently, the number of people who move internally or internationally. However, several factors interconnectedly affect migration decisions. This chapter showed how different agricultural livelihoods and cropping and livestock systems, together with sociodemographic factors, shape agricultural resilience and how migration decisions relate to such context.

These results should not be seen as representative but rather as an indication of the potential for further exploration of the relationship between food security, resilience, and migration. Also, the population surveyed for this assessment was exclusively rural, which should be considered when observing the total migrant population (both urban and rural). Limitations to the synthesis of the available literature focusing on the NTCA are found in the dispersed foci and lack of sufficient information on rural agricultural populations. The literature review, therefore, can be seen as complementary to our findings but observed critically since previous studies often involved a broader migrant population, which is not representative of the people participating in this study.

The analysis and the literature review so far have been focused on studies that draw results and conclusions based on field research and other empirical data from the three countries. The results so far are heterogeneous in their understanding of which factors affect migration decisions. Many studies conducted in the NTCA, and this report suggest that economic causes appear to be the most cited reason why people, willingly or unwillingly, migrate within their countries or internationally. Other authors who include broader perspectives on migration suggested that other, more encompassing, and complex factors shape decisions to move, such as corruption and state fragility, poverty, inequality, and lack of social mobility (see [64]). It would be valuable to inspect migration decisions in the NTCA from this perspective and analyze how these drivers intersect with the identified main causes. Nevertheless, the findings of this assessment are that greater agricultural resilience under the effects of climate change can contribute to reducing food insecurity and the likelihood of migration under different pathways. As our results show, food security and migration have different relationships, depending on other drivers, and require that the projects and support programs consider these relationships. Increasing agricultural resilience could be an important step into reducing migration but it needs to be integrated with addressing other drivers.

As observed during the fieldwork and similarly suggested by other studies [19], there is a great need for communication and coordination between local communities, national actors, and international agencies for deeper and more integrated analyses of the climate change-food security-migration nexus.

3 What interventions can increase agricultural resilience to the effects of climate change?

Chapter 3 – Highlights

- To build resilience in the agricultural sector to the effects of climate change, interventions need to address a highly variable context across the region due to heterogeneity in systems (crops, socioeconomic context, and risks to be addressed) and institutional capacities to support the adoption and scaling of practices. Different proposed interventions also target different geographies.

The proposed interventions are:

1. Improve soil management and soil conditions through on-farm erosion control and soil health and conservation practices, and training for agricultural extension workers and farmers
2. Improve water management through water harvesting, spring development, pond development, irrigation system development, and erosion control
3. Develop collaborative efforts for crop breeding and introduction of novel crops with superior nutritional qualities and climate adaptation
4. Strengthen agroforestry systems to improve household benefits
5. Restore and conserve forests
6. Provide training for sanitary and phytosanitary (SPS) / food safety best management practices to improve access to U.S. and other markets
7. Implement workforce development for youth to address food security and migration – building skills and opportunities in partnership with U.S. agricultural trade organizations
8. Implement workforce development through a Youth Conservation Corps (YCC) to address food security and migration
9. Provide crop insurance as a safety net for farmers
10. Provide climate and weather services with actionable information for farmers
11. Scaling of demand-driven agriculture innovations for adaptation and rural business incubators
12. Produce high quality bio-inputs for transforming food systems

3.1 USDA and CATIE technical interventions under the Agricultural Resilience Assessment in the NTCA

USDA and CATIE expert teams have proposed a set of interventions to increase the agricultural resilience of rural livelihoods in El Salvador, Guatemala, and Honduras, considering their strategic planning and institutional experience developed over decades, as well as the results of high-level interviews, literature review, workshops, and direct observation in the field in the NTCA countries from May 16 to July 15, 2022, in a post-COVID scenario.

According to experts' views, intensified and frequent droughts and changes in rainfall patterns have led to significant decrease in cropping and livestock systems of small- and medium sized producers. Scarce access to water for agricultural uses and poor or lack of water and soil management practices appear to have lessened the ability of crops to adapt to various climate conditions and variabilities. Moreover, climate change is threatening the way of life of many Indigenous and other ethnic communities, the majority of whom live in rural areas and depend on subsistence farming and natural resources. The cumulative losses and damages due to the impacts of climate change is significantly affecting young people, who make up much of the population in all three NTCA countries, leaving them with fewer economic opportunities in rural areas. The COVID-19 pandemic has only contributed to this, and climate change is affecting the region adversely, contributing to accumulating vulnerabilities.

Based on on-site experience during this assessment and other knowledge and experience related to agricultural resilience under climate change, USDA has identified the following potential areas of focus for technical interventions: on-farm irrigation and water management; soil management and soil health; crop breeding; sanitary and phytosanitary and food safety training for producers, crop insurance; workforce development in partnership with U.S. agricultural trade organizations and also through a Youth Conservation Corps; and forest conservation and agroforestry.

CATIE's research program responds to concrete problems in the territories and in rural society, while recognizing the need for an inclusive green development model for agriculture committed to a balance between the conditions for economic growth, social inclusion, conservation and use of natural resources, and a greater capacity to adapt to climate change. CATIE's proposals for the NTCA are framed within the following priorities: development of agri-food systems aligned with the conservation of ecosystem services and health, water security, restoration of degraded resources, sustainable agribusiness models, financial tools for green and inclusive development, new technologies, climate action, and gender and social inclusion.

In line with their respective research and intervention priorities, USDA and CATIE proposed on-the-ground and programmatic technical interventions to improve agricultural resilience under the effects of climate change, and in doing so improve food security and the ability of farmers and their families to be successful in their home communities and avoid migrating. **The complete list of proposed interventions is presented in a supplementary document "Action proposals", and the tables below include references to these proposals.**

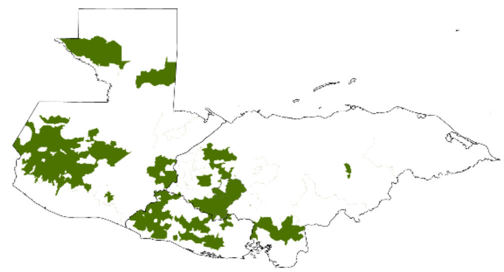
> *The challenge is to innovate with local resources and capital and to maximize local resources. Technologies that require high or medium use of capital are difficult for low-income farming families to adopt. (High-level interview, GT)*

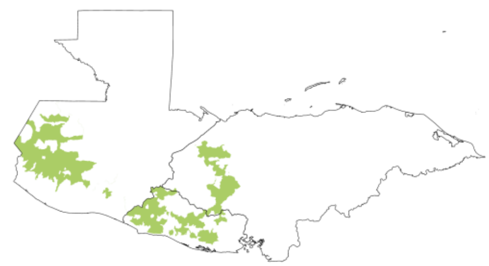
3.1.1 On-the-ground resilience interventions

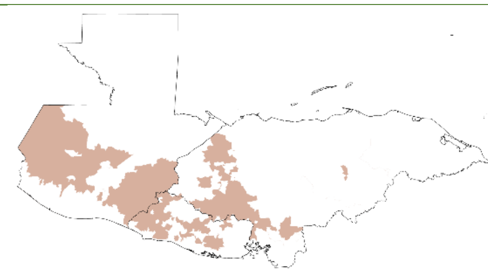
  

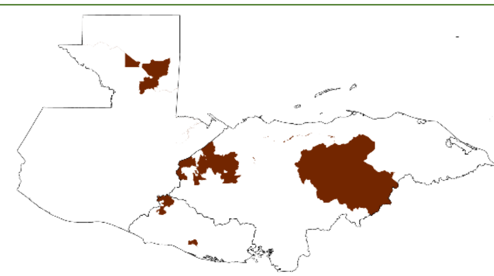
Intervention	Improve soil management and soil conditions through on-farm erosion control and soil health and conservation practices, and training for agricultural extension workers and farmers
Rationale and background	Climate change processes that were consistently identified in this assessment as significantly impacting sustainable agricultural production included: rainfall deficit, abnormally high temperatures, and increased frequency of severe weather events. These factors have a direct impact on soil moisture, increasing evapotranspiration, and affecting plant and fruit development in quality and quantity. These impacts are intensified by soil conditions and topography, where it is necessary to improve practices to maintain healthy and productive soils and increase the farm's resilience under climate changes effects. Many of the management practices applicable to both soil conservation and soil health are also integral to water management interventions because they enhance the water infiltration capacity of the soil necessary for groundwater recharge and storage and surface water accumulation and storage. Soil conservation and stopping soil erosion are paramount.
Actions to support the intervention	• Increase erosion control practices (contour tillage, terraces, reduced tillage, no-till, cover crops, crop residue management, hillside ditch, contour buffer strips) on farm and within local watersheds. • Determine soil suitability for various crops and cultivars and integrate with crop breeding. • Provide training for agricultural extensionists, agronomists, and technical service providers to determine important essential soil characteristics for determining crop suitability and applicable soil management practices at the individual small-producer scale. • Enable farmers and agricultural extensionists access to soil testing for nutrient management. • Utilize digital soil mapping and the Fertility Capability Classification (FCC) to quantify soil health and soil carbon gaps to improve agricultural resilience. • Assist farmer and commodity organizations in adopting soil conservation and soil health practices, including the 4Rs of nutrient management: applying the Right nutrients (fertilizer or other nutrient sources) at the Right rate at the Right time and with the Right placement.
Relevant organizations, programs and/or activities	• National Center for Agricultural and Forestry Technology (CENTA), El Salvador: digital soil map of El Salvador

<table>
<tr><td rowspan="4">Agricultural systems and livelihood zones of focus</td><td>Smallholder farmers (staple grains, vegetables, livestock, and coffee)

Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>Vegetable farming

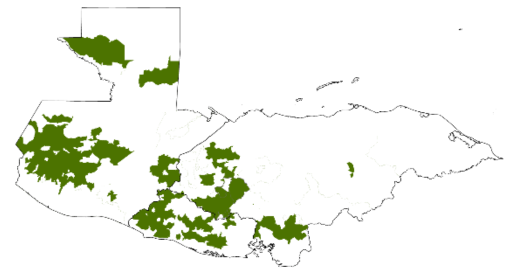
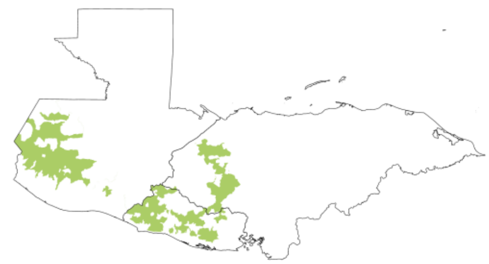
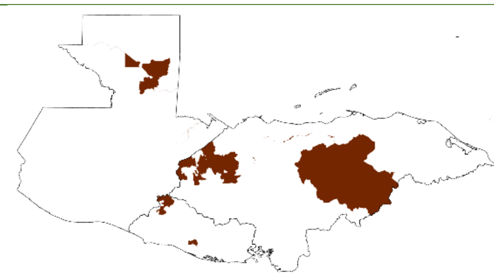
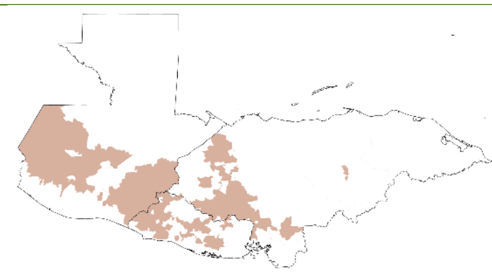
Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>Coffee

Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>Livestock (mainly medium and large farmers)

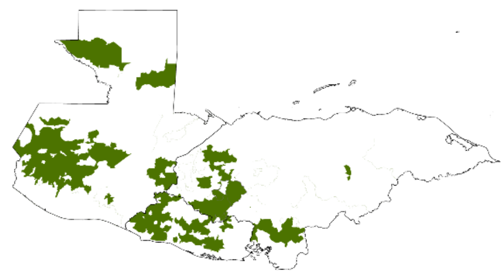
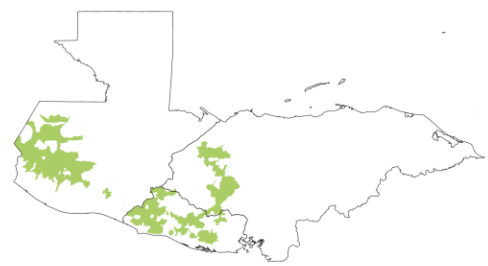
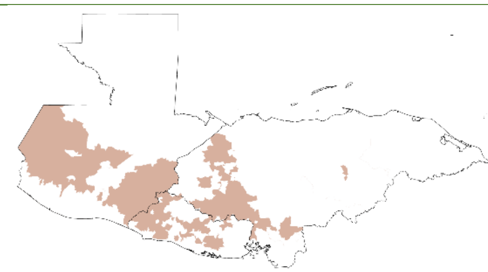
Livelihood zones: GT02, HN05, HN07, HN09, SV01.</td><td></td></tr>
<tr><td>“Action Proposals”</td><td colspan="2">• Soil Health Capacity – Quantifying the Soil Health and Soil Carbon in Northern Triangle of Central America – A follow-on intervention initiated in Honduras (USDA proposal 1)
• Supporting Vulnerable Smallholder Communities during Climate Change through Improving Soil Nutrition for Grain and Coffee Production – A follow-on intervention initiated in Guatemala (USDA proposal 2)</td></tr>
</table>

Intervention	**Improve water management through water harvesting, spring development, pond development, irrigation system development, and erosion control**
Rationale and background	Drought and extended dry spells, and uncertain or changing rain patterns, as well as extreme rain events, are climate change effects that are threatening farmers and their cropping and livestock systems throughout the Northern Triangle countries of Central America (NTCA). There are many areas in NTCA where water resources could be developed to assist in agricultural production and increase the resilience of cropping systems under the effects of climate change. Groundwater could supplement water availability in areas where irrigation could be used to manage crops and livestock. In areas where groundwater may be limited, surface water resources could be developed through the construction of dams and reservoirs. Many rivers occur throughout the Central American region. Larger projects, such as major dams, would require national or international government assistance, but local projects could be developed to provide water resources for farms and ranches. There are many USDA NRCS practices that could be applied to improve water resources while reducing soil erosion throughout the region. There are many favorable conditions that would allow for providing water availability and limiting the impacts of severe events such as drought and heavy rainfall that are related to climate change. Providing technical assistance to producers in the region could help improve agricultural benefits and outcomes.
Actions to support the intervention	• Develop or improve existing water collection systems (spring development, ponds, dams). • Develop on-farm irrigation systems for surface or subsurface that delivers irrigation water by surface means and potential use of renewable energy source. • Increase collection and storage of water through water harvesting systems – use catchment rainwater harvesting to collect and store water from precipitation. • Construct wells for providing water for agriculture. • Implement erosion control practices such as contour buffer strips, hillside ditches, and terraces. • Assist farmer and commodity organizations in adopting improved water management practices on their farms and across their local watersheds.
Relevant organizations, programs and/or activities	• More than 90 USDA approved conservation practices designed to assist producers are related to water.

Agricultural systems and livelihood zones of focus	Smallholder farmers (staple grains, vegetables, livestock, and coffee) Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02.	
	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
	Livestock (mainly medium and large farmers) Livelihood zones: GT02, HN05, HN07, HN09, SV01.	
	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
“Action Proposals”	• Water resources, water excess/deficit, and water use as related to climate change impacts and resilience in Central America **(USDA proposal 3)**	

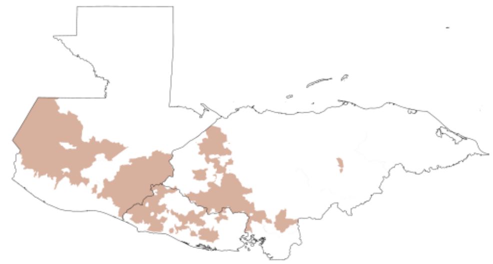
Intervention	**Develop collaborative efforts for crop breeding and introduction of novel crops with superior nutritional qualities and climate adaptation**
Rationale and background	Expanding the number of climate-smart crops and increasing the availability of low and high technologies that give farmers management flexibility and the capacity to continually adapt their cropping systems are critically needed in the region. It means that scientists, educators, extension workers, and farmers in one local/region/country must build collaborative partnerships with scientists, educators, extension workers, and farmers from other localities and countries to learn from each other, to share their knowledge and technologies, and innovate together. Collaborative plant breeding efforts, technologies, and subsequent assessments of staple crops for climate adaptation in Central America are needed to develop varieties with superior nutritional qualities adaptable to extreme swings in water availability and plant water use efficiency. Areas of focus could include matching crops to altered moisture availability patterns, modified cropping systems, and introducing novel crops that are resilient to current climate variability and future climate change, such as roots and tubers for food security. Some collaborative work between scientists of the Northern Triangle countries and U.S. scientists has already occurred or is occurring, but much more is needed. The findings of this assessment point to the need for collaborative research on crop breeding and rapid crop assessment efforts between the USDA Agricultural Research Service (ARS)/Foreign Agricultural Service (FAS) in the United States of America (USA), the Institute of Agricultural Science and Technology (ICTA) in Guatemala, the Directorate of Agricultural Science and Technology (DICTA) in Honduras, the National Center for Agricultural and Forestry Technology (CENTA) in El Salvador, the Tropical Agricultural Research and Higher Education Center (CATIE), and the Zamorano University in Honduras.
Actions to support the intervention	• Assemble data and information from private and public entities regarding potential staple crops and science-based impacts from climate change risks and uncertainties on resources, crops, and people. • Articulate decision criteria to be used to assess crop's climate-smart and sustainability attributes. • Develop a Current and Desired Future Conditions Decision Matrix for all candidate crops, with the potential to implement climate-smart genomic-assisted breeding for crop varieties in conjunction with improved management strategies.

	• Identify and secure resources to support the collaborative research between U.S. institutions or agencies and those of the NTCA on crop breeding that can increase agricultural resilience in the region under climate change.	
Relevant organizations, programs and/or activities	• Guatemala: Instituto de Ciencia y Tecnología Agrícolas (ICTA) • Honduras: DICTA, Zamorano University • El Salvador: CENTA • Orthodox Seed Germplasm Bank, CATIE • USDA Agricultural Research Service	
Agricultural systems and livelihood zones of focus	Smallholder farmers (staple grains, vegetables, and coffee) Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02.	
	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
"Action Proposals"	• Improving climate-smart cropping systems in Central America through capacity building, breeding, and management to develop novel varieties with climate resilience, higher yield, water and nutrient use efficiency, and pest and disease resistance **(USDA proposal 4)**	

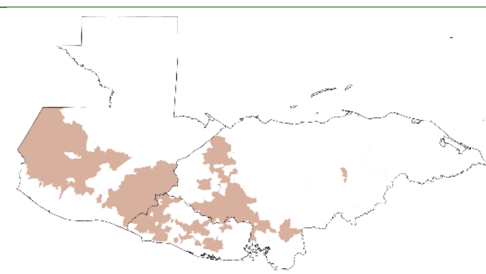
Intervention	Strengthen agroforestry systems to improve household benefits
Rationale and background	Through different actions this intervention aims is to increase adaptive capacity and resilience of rural households through agroforestry strategies that enhance biodiversity, ecosystem provisioning, soil conditions, and biodiversity connectivity at a landscape level. Based on the decades-long trajectory of CATIE through field schools with agroforestry systems (silvo agricultural, silvopastoral and agro silvopastoral) and the experience generated by the institution through the Mesoamerican Agroenvironmental Program (MAP-Norway) in the period 2013 - 2017, it was found that in Trifinio (a region that spans across Guatemala, Honduras and El Salvador) one of the systems that contributed most to food security was the promotion of home gardens and agro silvopastoral systems.
Actions to support the intervention	• Strengthen the capacities of local organizations to propagate plants of superior varieties of coffee and cocoa, and plants of species as shade trees. • Map trees on farms to implement agroforestry planning at the farm level to improve and enhance the presence of trees and other plants in the landscape. • Rehabilitate and re-renovate old and unproductive coffee and cocoa plantations. Old trees need to be replaced gradually with the new varieties, the shade canopy must be re-structured to produce more goods and provide adequate shade for the crops. • Provide irrigation of both annual and perennial crops to increase their resilience under drought by using low energy irrigation systems. • Develop traditional and audiovisual training materials (manuals and videos) and make them available in digital applications and platforms (easy access through smartphones).

Relevant organizations, programs and/or activities	• Latin American agroforestry scientific network
	• Coffee and Cocoa Agroforestry Unit of CATIE, through regional projects in countries of Central America, South America, and the Caribbean, e.g.:
	    o Mesoamerican Agroenvironmental Program (MAP-Norway)
	    o CASCADE Project (with Conservation International and the French Agricultural Research Centre for International Development (CIRAD), funded by the International Climate Initiative (ICI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU)
	    o PROCAGICA project (with the Inter-American Institute for Cooperation on Agriculture (IICA) and CIRAD, supported by European Union)

Agricultural systems and livelihood zones of focus	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
"Action Proposals"	• Small-scale agroecological farms to reshape food systems and climate benefits through circular economy in the Trifinio Region **(CATIE proposal 2)** • Strength agroforestry systems to improve household benefits **(CATIE proposal 3)** • Climate adaptation of livestock systems in the NTCA **(CATIE proposal 4)**	

> *An important enabling condition for practice adoption is recognizing farmers' traditional knowledge. (High-level interview, GT)*



Intervention	Restore and conserve forests
Rationale and Background	The frequency and the intense effects of climate disruptions and disasters, including wildfires, pest and diseases, affect and destroy key forest resources for rural livelihoods. Without employment, formal education, or a social safety net, people affected by extreme weather events in rural areas in the NTCA have few alternative sources of income. In addition, many Indigenous people depend on forests for income, housing, and food. Forests also form a large part of many Indigenous peoples' cultural identity. Forest restoration and conservation, focusing on ecosystem services, can help foster resilience and economic development for communities in and around forests.
Actions to support the intervention	• Provide technical support to Central American country efforts to address regional forest health strategy action items and improve prevention and mitigation efforts on insect outbreaks and the spread of exotic species. • Provide technical support for forest landscape management and high/quality restoration activities. • Support the establishment and longevity of a Forest Health Central America Network and enhance country technical capacity. • Improve existing extension services by providing technical support training and technology transfer from existing research institutions. • Facilitate the creation of extension services for the countries lacking such, by providing direct funding specific to extension services or by prioritization of existing funding. • Provide technical support, landscape management and high-quality restoration activities.
Relevant organizations, programs and/or activities	• USDA Forest Service, International Programs • Central America Youth Conservation Corps • Forests and Biodiversity in Productive Landscapes, Research Unit, CATIE • Forest Seed Bank, CATIE
Agricultural systems and livelihood zones of focus	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02. 
"Action Proposals"	• Central America Youth Conservation Corps **(USDA proposal 5)**

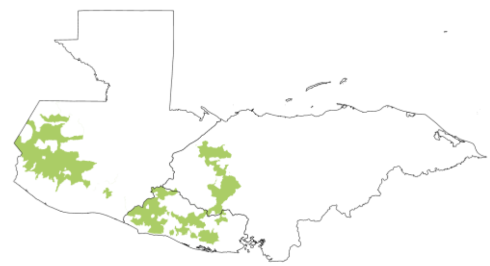
- Enhancing fire management and incident command system capabilities in Central America through train-the-trainer (ToT) and targeted technical support **(USDA proposal 6)**
- Improved Community Resiliency to Climate Change through both Small Grants and Large-Scale Conservation Finance for Natural Infrastructure and Restoration Investments **(USDA proposal 7)**
- Establishment of Regional Forest Health Network **(USDA proposal 8)**
- Improving livelihoods from forests sustainable use and management and long-term conservation **(CATIE proposal 5)**

> *One of the main constraints in climate risk projects implementation is access to financial mechanisms so that farmers can adopt technologies. (High-level interview, GT)*

3.1.2 Programmatic interventions

Intervention	Provide training for sanitary and phytosanitary (SPS) / food safety best management practices to improve access to U.S. and other markets
Rationale and background	Training for local producers in pest and disease management, Good Agricultural Practices, and Integrated Pest Management (IPM) that address sanitary and phytosanitary (SPS) and food safety issues can reduce rejections of produce for export and better enable farmers of the Northern Triangle countries of Central America to be economically successful on their farms. For example, USDA in a project initiated in 2011 in Huehuetenango, Guatemala with support from USAID trained over 2,200 direct beneficiaries on Integrated Pest Management (IPM) in potatoes, snow peas, and French beans as well as on the U.S. Food Safety Modernization Act to which produce exported to the U.S. must comply. Through those 2,200 direct beneficiaries who served as trainers of other farmers ultimately 25,000 farmers were reached by the project. Rejection of exports to the U.S. of agricultural goods from Guatemala dropped from 1,896 containers in 2013 to under 100 in 2016 because of the work done by USDA under agreement with USAID, avoiding serious economic losses to farmers, better enabling them to thrive on their farms rather than migrating. Training of this type could help farmers in all three Northern Triangle countries.
Actions to support the intervention	• Select value chains for the export market and work to integrate small farmers into those value chains; proven examples include potatoes, snow peas, French beans. • Train local producers through a train-the-trainer model that includes simple photo-based field guides to identify crop pests and diseases, provide methods to separate seeds (as in seed potatoes) based on quality, and show simple methods to protect produce in transport from the field, such as plastic baskets used for snow peas. • Introduce practices to improve yields such as proper use of fertilizer, and use of drip irrigation which can improve production and quality. • Work with cooperative associations; expand cooperatives to involve more small farmers, many of whom cannot get into some of the larger cooperatives. • Train cooperative associations on the U.S. Food Safety Modernization Act to build awareness on the requirements for produce and products to gain entry into the U.S. market. • Recognize that climate change is expanding the range of certain pests, as in the example of thrips now being found in Guatemala at higher elevations as temperatures have risen so

	that there is no longer a season cold enough to kill them, so new areas may require new IPM strategies. • Identify and develop opportunities for processing produce into value-added products. Produce which may not be of sufficient quality for sale as fresh may be acceptable for value-added processing. Processing is not only value adding, but also job-creating.
Relevant organizations, programs and/or activities	• USDA Foreign Agricultural Service, Global Programs
Agricultural systems and livelihood zones of focus	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02. 
"Action Proposals"	• Conservation and restoration efforts, to support agricultural resilience facing climate change **(USDA proposal 9)** • Sustainable Agriculture Improvement Project (MAS+): Food Security – Agriculture resilience – Impact on rural migration **(USDA proposal 10)**

Intervention	Implement workforce development for youth to address food security and migration – building skills and opportunities in partnership with U.S. agricultural trade organizations
Rationale and background	In support of the U.S. "Call to Action" to the U.S. private sector to support the U.S. Strategy to Address the Root Causes of Migration in Central America, the U.S. Soybean Export Council (USSEC) proposes to lead members of the USDA Cooperator community in a workforce development program for youth in the Northern Triangle countries of Central America. USDA Cooperators, of which USSEC is one, are non-profit commodity or trade associations that promote U.S. agricultural commodities overseas. Often the work of the Cooperators includes technical capacity-building in countries where they see market potential, and where technical assistance and training to enhance the processing or use of the commodity can help to build demand for the commodity. USSEC proposes to lead a group of USDA Cooperators in implementing training programs in the Northern Triangle Central American countries, targeting end-users of agricultural commodities. These training programs would not only promote a USDA Cooperator's commodity but also increase the professional skills and knowledge of the targeted trainees and help build entrepreneurial opportunities involving the commodity. Training would be organized and delivered to youth (defined as 15 - 29 years old), women and minorities. USSEC has relevant experience in Africa to bring to this effort. Through the training, USSEC with other Cooperators would aim to have: • Regional food and agriculture enterprises increase their capacity to meet growth in demand for their products and utilization of U.S. agriculture products. • U.S. food and agriculture industries increase their exports as well as meet several UN Sustainable Development Goals (SDG) and Corporate Social Responsibility (CSR) goals. • Trainees increase skills and professional development leading to higher earning potential, decent employment, and reduction in the interest to illegally migrate.
Actions to support the intervention	• Identify funds that could be used to support USSEC with other interested USDA Cooperators to organize training and capacity building programs targeting youth, women, and minorities in the Central American markets of Guatemala, Honduras, and El Salvador to align with the U.S. Government's Root Causes Strategy. • USSEC in alliance with other interested members of the USDA Cooperator community identify partner organizations to work with in the region to plan and develop workforce

	training and educational and employment opportunities related to the processing, use, and marketing of selected U.S. agricultural commodities.
Relevant organizations, programs and/or activities	• U.S. Soybean Export Council (USSEC), and other USDA Cooperator organizations USSEC would lead. • USDA Foreign Agricultural Service, Global Programs • Other U.S. Government agencies interested in providing support
Cropping systems of focus	• Other
"Action Proposals"	• Building Protein Value Chain Capacity through Work Force Training and Professional Development in the Americas **(USDA proposal 11)**

> *Young people have participated when they see changes being made and in the adoption of new technologies. (High-level interview, GT)*

> *One of the recognized implementation challenges and bottlenecks is climate-related migration. (High-level interview, HN)*

Intervention	Implement workforce development through a Youth Conservation Corps (YCC) to address food security and migration
Rationale and background	USDA would expand upon its success with the Youth Conservation Corps (YCC) in Honduras through further work in Honduras and the addition of Guatemala and El Salvador. The USDA Forest Service, with support from USAID/Honduras and working with partners helped to start YCC Honduras in 2017 to teach natural resource management skills and provide opportunities for at-risk youth in western Honduras. The YCC is a program for young men and women to work and learn by doing conservation activities such as forest protection, and eventually linking them to employment and higher education opportunities in the sector, including work in the national parks. Like the YCC implemented in the United States by USDA Forest Service, participants of YCC Honduras (in Spanish Jóvenes para la Conservación - JPC) gain technical skills to manage forests, protect watersheds, and conserve nature. They learn to build trails, apply first aid, construct fire lines, manage nurseries, and gain a wide set of practical experiences as part of their training. As of 2022 almost 300 Honduran youth have graduated from the program, earning national accreditation from Honduras National Institute for Vocational Training (Instituto Nacional de Formación Profesional de Honduras, INFOP) as Environmental Promoters. YCC graduates are twice as likely to attend university, compared to the national average of high school graduates. Currently, approximately 90% of YCC graduates are either working or attending university. The YCC Honduras program has a 100% graduation rate. This program could be intensified and expanded within the Northern Triangle region. The YCC training also has a personal and community development focus that empowers students to be agents of change in their communities. Through leadership opportunities in the various democratically elected committees within the YCC Program, they learn the value of teamwork, leadership, and the power of democratic spaces to respond to the needs and interests of their community. In fact, one of the YCC Honduras graduates was inspired to become a candidate for Vice-Mayor in her hometown. A 2019 graduate noted that the YCC Honduras program helped him to become an agent of change in his community. He stopped thinking about migrating to the United States and instead started a successful family business with his brother.

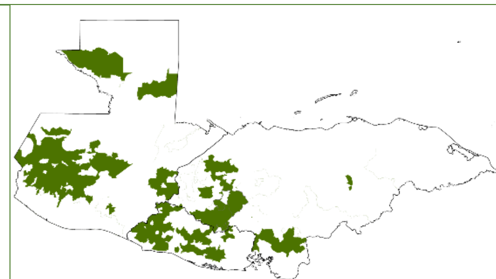
<table>
<tr><td>Actions to support the intervention</td><td colspan="2">

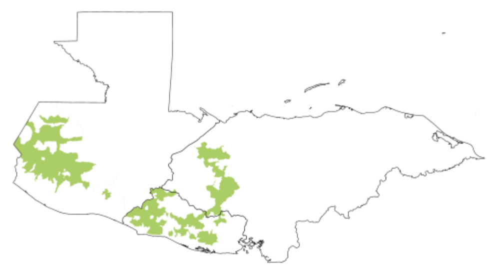
Involve the public and private sector in the development of YCC training processes that are competency based and help youth attain employment in the environment sector.
Increase resilience to climate change by implementing youth-led YCC environment community projects.
Through the YCC implement a comprehensive nationally certified training programs in each of the Northern Triangle countries that provide opportunities for employment, higher education, and entrepreneurship initiatives in their communities, reducing youth migration and empowering young people Honduras, Guatemala, and El Salvador.

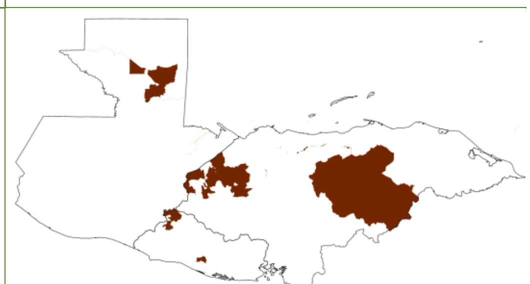
</td></tr>
<tr><td>Relevant organizations, programs and/or activities</td><td colspan="2">

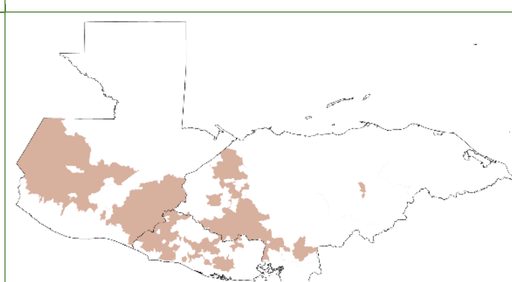
Youth Conservation Corps (YCC) in Honduras
USDA Forest Service, International Programs

</td></tr>
<tr><td rowspan="4">Agricultural systems and livelihood zones of focus</td><td>Smallholder farmers (staple grains, vegetables, livestock, and coffee)

Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>Vegetable farming

Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>Livestock (small, medium and large)

Livelihood zones: GT02, HN05, HN07, HN09, SV01.</td><td></td></tr>
<tr><td>Coffee

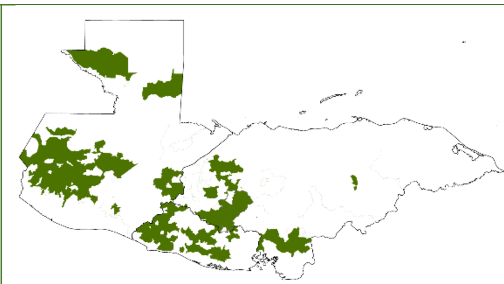
Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.</td><td></td></tr>
<tr><td>“Action Proposals”</td><td colspan="2">

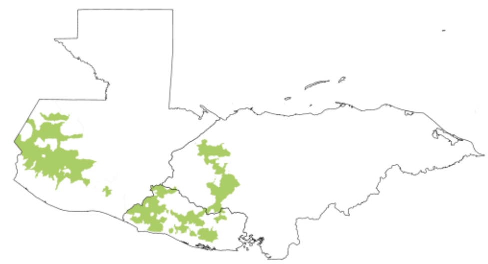
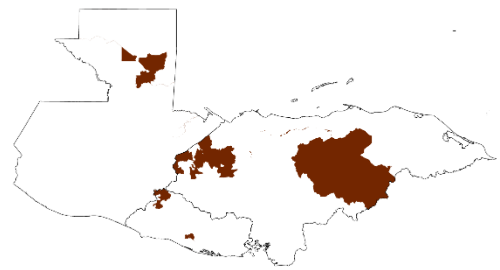
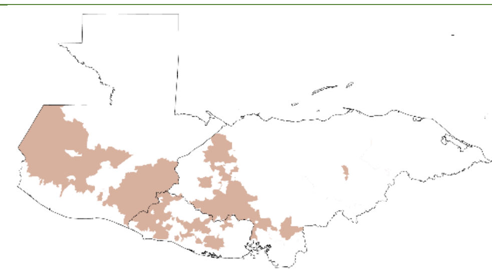
Central America Youth Conservation Corps (USDA Proposal 5)

</td></tr>
</table>

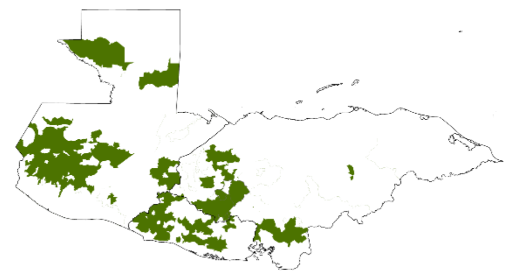
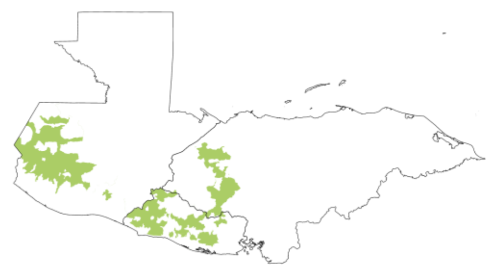
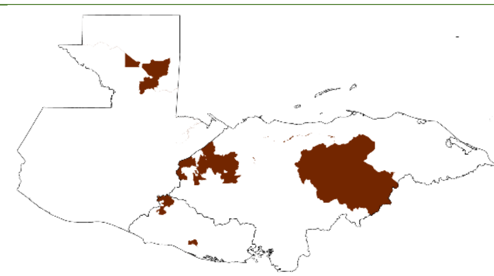
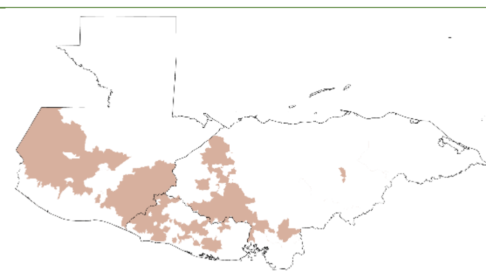
Intervention	Provide crop insurance as a safety net for farmers
Rationale and background	Crop insurance is insurance that farmers and ranchers can purchase to protect against either the loss of their crops due to natural disasters, such as drought or flood, and other natural perils like fire, disease, and pests, or the loss of revenue due to declines in the prices of agricultural commodities. Insurance typically is purchased for a growing season and before the crop is planted. It is usually specific to a particular crop or commodity. Crop insurance can be an important safety net for farmers facing the uncertainties of climate changes and threat of food insecurity. For crop insurance to be a viable enterprise it has to be a "fair bet", meaning that the farmer and the insurer enter into an insurance contract early in the crop season, before it is apparent whether or not there will be losses. If a particular disaster or peril was absolutely certain no one would insure a farmer or rancher for it. Conversely, if it was apparent that there will be a good crop with a high yield, then the farmer would not want to buy insurance. If there is a fair bet, then even with climate change, no one can say with certainty that in some year there will be a drought and how severe that drought will be, even if drought is trending to be more frequent or severe. However, insurers would use that trend data in determining what the insurance premiums should be. In addition, for crop insurance to be a viable enterprise there needs to be sufficient financial resources (government or private reinsurance) to cover widespread crop correlated or simultaneous losses that may affect most farmers or ranchers in a country. There also needs to be a cost-effective and efficient way to determine if there has been some event covered by the insurance (loss adjustment), its location, which insured farmers or ranchers have a claim, and how much should be paid, and there needs to be timely and efficient way to make payment. In the United States, the USDA Risk Management Agency oversees Federal crop insurance. It is complex, and USDA subsidizes the program to make the purchase of insurance coverage more affordable to U.S. farmers and ranchers. However, Federal crop insurance has been shown to be an effective risk management tool helping to strengthen the economic stability of agricultural producers and rural communities. In the NTCA, the economic impact on a farm of successive years of drought, as well as hurricane-caused flooding, are believed to be among the reasons people may have to abandon their lands and potentially migrate. For these farmers, potentially insurance that could help them survive a

	climate change induced disaster or peril, might enable them to recover from a bad year and not have to leave their farms. As crop insurance has been a tool in the U.S. to foster resilience and stability for agricultural producers and their rural communities, perhaps it could be developed and applied to be such a tool in the Northern Triangle countries of Central America. In meeting with a representative of the Climate Change Unit of the Ministry of Agriculture, Livestock and Food (MAGA) of Guatemala, the USDA-CATIE team learned that MAGA has an "Agricultural insurance for climate risk management" program that is in the pilot phase, starting with 6,000 producers with a goal of 40,000 producers, and provides coverage for heavy rains and extended drought. The financial mechanism is carried out through a bank. Further exploration of this program, and other crop insurance approaches (such as index insurance) being applied in other countries could be useful to the NTCA country governments, international development agencies and international financial institutions, or other actors who have interest in determining if crop insurance could be a viable tool in strengthening rural communities' agricultural resilience under climate change and possibly helping to stem migration.
Actions	• Identify what crop insurance programs, such as that of MAGA Guatemala are operating, and see what their experience has been so far. What have been their costs, and how do farmers like the insurance? • Identify which commodities might be most viable for crop insurance for the NTCA. • Determine which governments, development agencies, national or international financial institutions might have interest in crop insurance. • Convene technical experts in agriculture, climate change, and crop insurance, along with government officials and insurance company representatives, and national and international financial institutions to explore whether a crop insurance program for Central America is desirable, attainable, and potentially useful in strengthening the agricultural resilience of rural communities and helping to stem migration.
Relevant organizations, programs and/or activities	• MAGA Climate Risks Agricultural Insurance for Family Agriculture • USDA Risk Management Agency, Federal Crop Insurance Program
Agricultural systems and livelihood zones of focus	Smallholder farmers (staple grains, vegetables, livestock, and coffee) Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02. 

Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
Livestock (mainly medium and large farmers) Livelihood zones: GT02, HN05, HN07, HN09, SV01.	
Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	

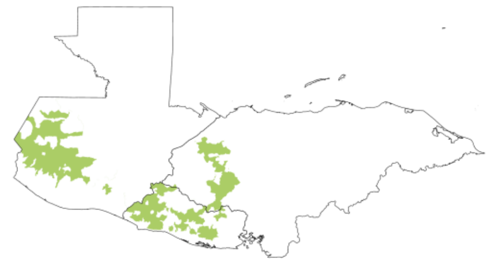
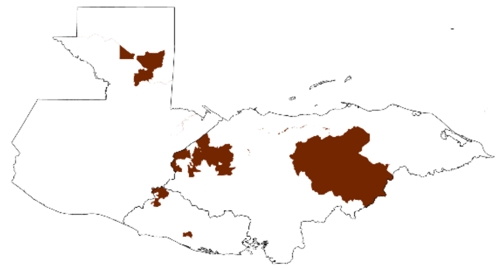
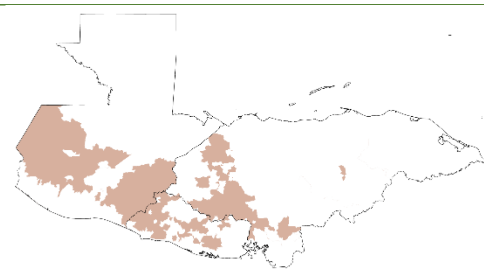
  

Intervention	Provide climate and weather services with actionable information for farmers
Rationale and Background	Across the NTCA region staple grains and coffee cultivation have experienced low yields and frequent crop damage and losses due to droughts, other climate extremes and climate change-fostered pest and disease. Farmers are often uninformed and unprepared to plan for or respond to the climate change-induced changes, uncertainties, and extremes in weather patterns and weather events. Providing climate and weather bulletins, and advisory notifications to help farmers in their decisions on when to plant, when to harvest and when to irrigate their crops is needed to increase farmers' resilience under climate change. Climate and weather services (CWS), through text messaging, internet, radio, printed bulletins, newspapers, and in-person outreach can inform farmers if drought is predicted, or rains are expected. It would be important that these services are specific in various localities, because of differences in weather due to the climate and the landscape across the NTCA. Progress has been made in terms of the provision of climate and weather services (CWS) in the NTCA, a transformative approach for agriculture adaptation that enables field level responses to climate variability and change improving well-being of rural livelihoods. Agroclimatic Technical Roundtables (MTAs) are being promoted across the region aiming at developing locally tailored agricultural advisories based on weather and seasonal forecasts. However, work is needed to add value to current efforts by strengthening i) the process of tailoring information to local needs (i.e. content, format, language, timing), ii) develop mechanisms for dissemination at the last mile for information to reach farmers through an integrated dissemination strategy, iii) improve usability of the advisories at local scale with complementary approaches bringing technical capacities, inputs, credits and others, and iv) designing, piloting and scaling business models for CWS, including public-private partnerships, for job generation, sustained delivery of services and scaling. CWS-enabled resilience responses at the farm level include use of weather information for improved use of agrichemicals and crop protection measures and use of seasonal and sub-seasonal forecasts for planning of the crop growing season (i.e., irrigation planning, planting dates, variety selection among others).
Actions to support the intervention	• Further develop technical capabilities of Ministries of Agriculture, universities, and other public and private institutions to provide CWS. • Develop partnerships with farmer associations and commodity organizations with for the dissemination and uptake of CWS. • Strengthen the process of tailoring information to local needs. • Develop mechanisms for dissemination at the "last mile" for information to reach farmers.

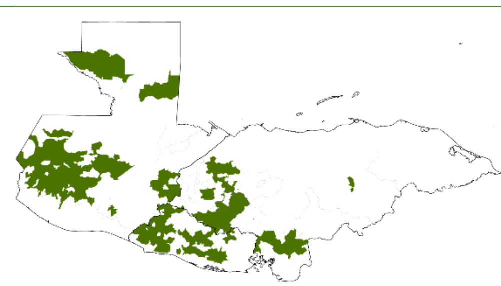
	• Improve usability of CWS advisories at local scale. • Design and pilot and scale out business models for CWS, including public-private sector partnerships for job creation, especially for young people, in providing CWS.	
Relevant organizations, programs and/or activities	• Assessment of CWS for agriculture and food security • National capacities: o Guatemala: Agrometeorological bulletins, drought monitoring, soil humidity, climatic projections, Crop monitoring systems o El Salvador: Agrometeorological and ENSO bulletins o Honduras: Seasonal forecasts, Agrometeorological bulletins	
Agricultural systems and livelihood zones of focus	Smallholder farmers (staple grains, vegetables, livestock, and agro-forestry Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02.	
	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
	Livestock (mainly medium and large farmers) Livelihood zones: GT02, HN05, HN07, HN09, SV01.	
	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
“Action Proposals”	• Actionable climate and weather services **(CATIE proposal 7)**	

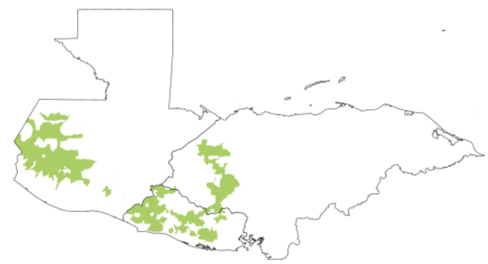
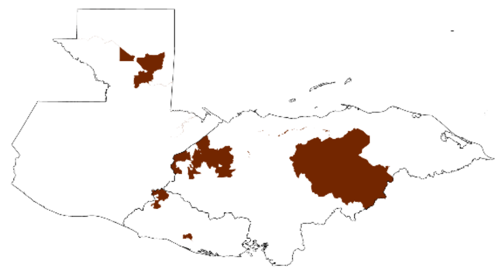
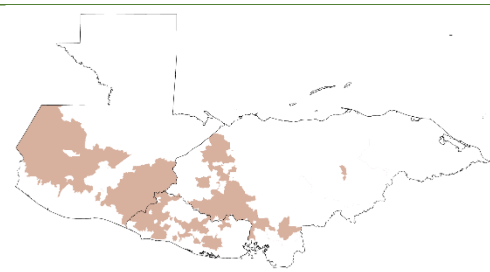
  

Intervention	Scaling of demand-driven agriculture innovations for adaptation and rural business incubators
Rationale and Background	Young people under 24 years of age coming from rural areas constitute the greater part of emigration from northern Central America. They have the potential to integrate into productive activities, many of them linked to agriculture, but who, due to gaps in labor access, local services, and infrastructure, access to resources, and training, are unable to do so. On the other hand, young people prefer attractive or immediate alternatives with fewer risks (market, climate change), and with greater social recognition. This reality makes young people the most vulnerable to migrating (rural-urban or to other countries) in search of opportunities and to cover their needs. This generates social problems (e.g., the thickening of poverty rings), productive problems (aging of the countryside), and competitiveness problems (low innovation). The objective of this proposal is to integrate business incubators and scaling of demand-driven agricultural innovations for adaptation by existing financing instruments, financial governance spaces and insurance, and investment funds to accelerate the business incubators and the scaling of innovations in the Dry Corridor of the NTCA.
Actions to support the intervention	• Identify potential farmers association groups and/or agribusiness. • Identify workspaces, mentorship opportunities network of mentors and coaches geared toward business innovation, and access to investors for start-ups in the business opportunities identified. • Implementing rural business incubators and screening processes, including innovation design, business model development, marketing strategy, and financial viability. • Leverage additional financial resources from the public and private sectors, as well as impact investors. • Address needs and remove barriers that limit access to risk mitigation instruments such as insurance and guarantees. • Identify and systematize lessons learned and establish monitoring and evaluation systems of financial and market mechanisms to monitor progress.
Relevant organizations, programs and/or activities	• Environmental Economics and Sustainable Agribusinesses Unit (UEAAS/EfD) – CATIE

Agricultural systems and livelihood zones of focus	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
	Livestock (mainly medium and large farmers) Livelihood zones: GT02, HN05, HN07, HN09, SV01.	
	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
"Action Proposals"	• Generational integration in the sustainable agri-food value chains as a strategy to reduce youth migration in rural areas of the NTCA **(CATIE proposal 6)**	

Intervention	Produce high quality bio-inputs for transforming food systems
Rationale and Background	The challenges of climate change and the increasing pressure of emerging pests and diseases on agricultural production systems require a redesign of these systems to reduce their vulnerability and dependency on external chemical inputs. Key to the successful evolution of bio-inputs is the efficient transformation of biological materials (including the recycling of agricultural by-products, food wastes, manures, etc.) into high-quality fertilizers, as well as the screening and reproduction of beneficial microorganisms for improving soil fertility and suppressiveness, as well as for preventing or controlling pests and diseases.
Actions to support the intervention	• Quantify and document the benefits of using bio-inputs for adaptation, mitigation, and employment generation. • Support mechanisms for developing small and medium-sized enterprises and employment opportunities by producing high-quality bio-inputs, particularly for youth, women, and ethnic groups. • Raise awareness regarding the increasing need for developing, testing, and promoting high-quality bio-inputs. • Support regulatory frameworks to favor developing and using high-quality bio-inputs, including quality requirements based on scientific evidence for national and international markets in the target countries.
Relevant organizations, programs and/or activities	• CATIE's collections of orthodox seeds, fruits and tubers, all of public domain (ITPGRFA) • Agrobiodiversity and food security Unit - CATIE • Agroecological intensification and diversification of production systems • Agrobiodiversity (including marginalized or underutilized crops) • Bioinputs (biofertilizers, biocontrol agents) • Regenerative Food Business Consortium (NAR) with the support of The International Development Research Centre (IDRC) and FAO – Crop Trust.
Agricultural systems and livelihood zones of focus	Smallholder farmers (staple grains, vegetables, livestock, and coffee) Livelihood zones: GT02, GT05, GT06, GT07, GT10, GT11, HN05, HN07, SV01, SV02. 

	Vegetable farming Livelihood zones: GT06, GT11, HN05, HN07, SV01, SV02.	
	Livestock (mainly medium and large farmers) Livelihood zones: GT02, HN05, HN07, HN09, SV01.	
	Coffee Livelihood zones: GT06, GT07, GT10, GT11, HN03, HN05, HN07, SV01, SV02.	
"Action Proposals"	• Bio-inputs for transforming food systems **(CATIE proposal 1)**	

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Annex 1. Drought history and crop suitability

Recent drought history

A 31-year chart analysis (Figure A1-2) and 6-year map series (Figure A1-3) developed by the USDA FAS show the recent drought history in the Central American Dry Corridor (CADC or "Dry Corridor'). The bar charts display drought and wet conditions annually from 1990 to 2021 during the main wet season months of June through November in major cropland areas throughout El Salvador, Guatemala, and Honduras. In El Salvador, the more significant drought years in major agricultural lands included 1991, 1994, 2000, 2001, 2015, 2018, and 2019. In Guatemala, the more significant drought years in major agricultural lands included 1991, 1994, 2004, 2009, 2015, 2018, and 2019. In Honduras, the more significant drought years in major agricultural lands included 1994, 2000, 2004, 2009, 2015, and 2019.

The recent 6-year map series displays various drought severities from June through August during the years 2015 to 2020, with the main Dry Corridor area boundary highlighted in El Salvador, Guatemala, and Honduras. During the summers of 2016, 2017, and 2020, drought conditions were limited throughout many of the Dry Corridor areas in the three countries. However, during the summers of 2015, 2018, and 2019, severe, extreme, and exceptional drought conditions could be found in many parts of the Dry Corridor in the three countries.

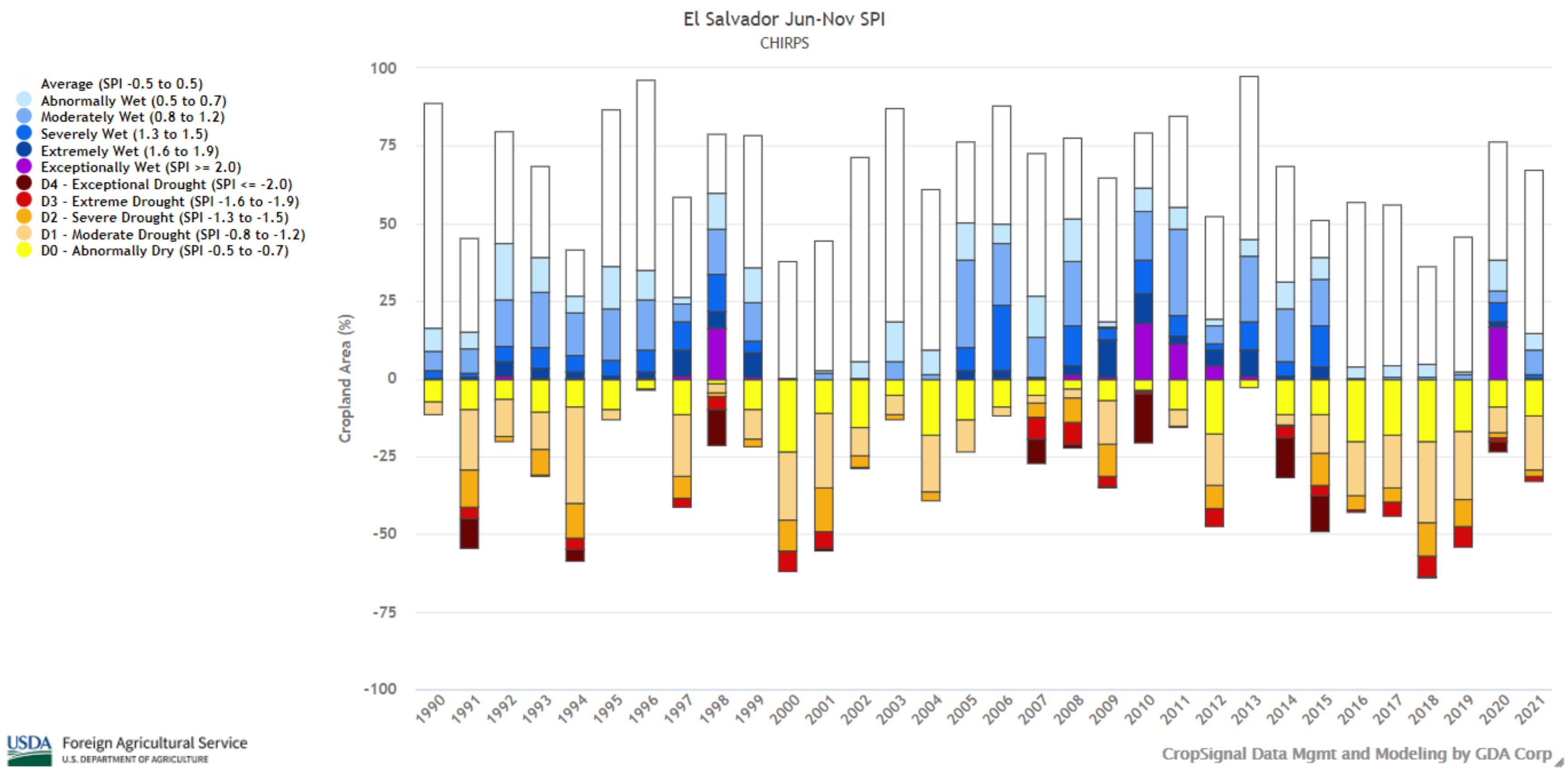


Figure A1-2 (a) Proportion of cropland area affected by different drought intensity between June and November in El Salvador. Source: USDA Foreign Agricultural Service, Global Market Analysis, International Production Assessment Division (USDA/FAS/GMA/IPAD).

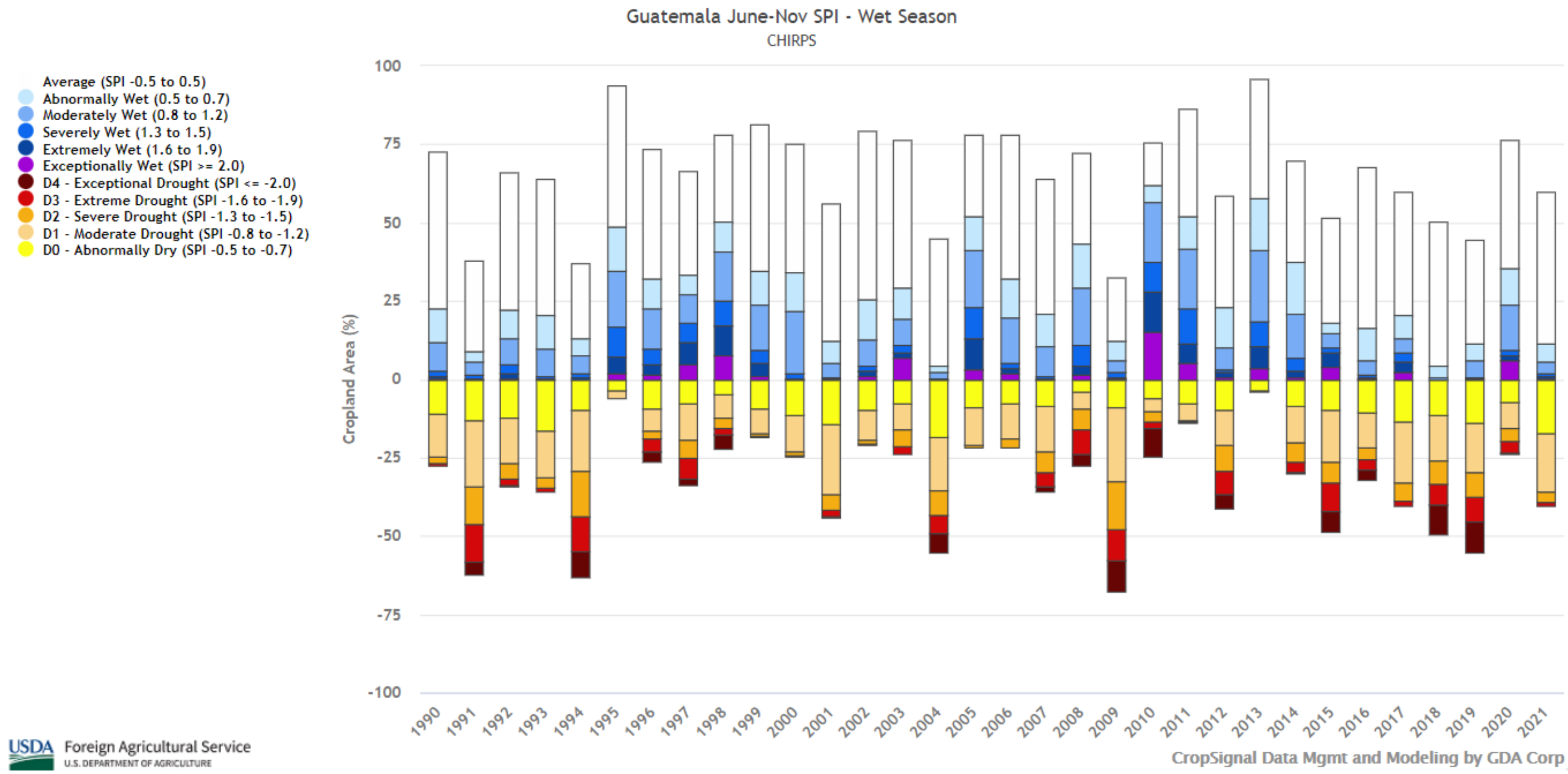


Figure A1-2 (b) Proportion of cropland area affected by different drought intensity between June and November in Guatemala. Source: USDA Foreign Agricultural Service, Global Market Analysis, International Production Assessment Division (USDA/FAS/GMA/IPAD).

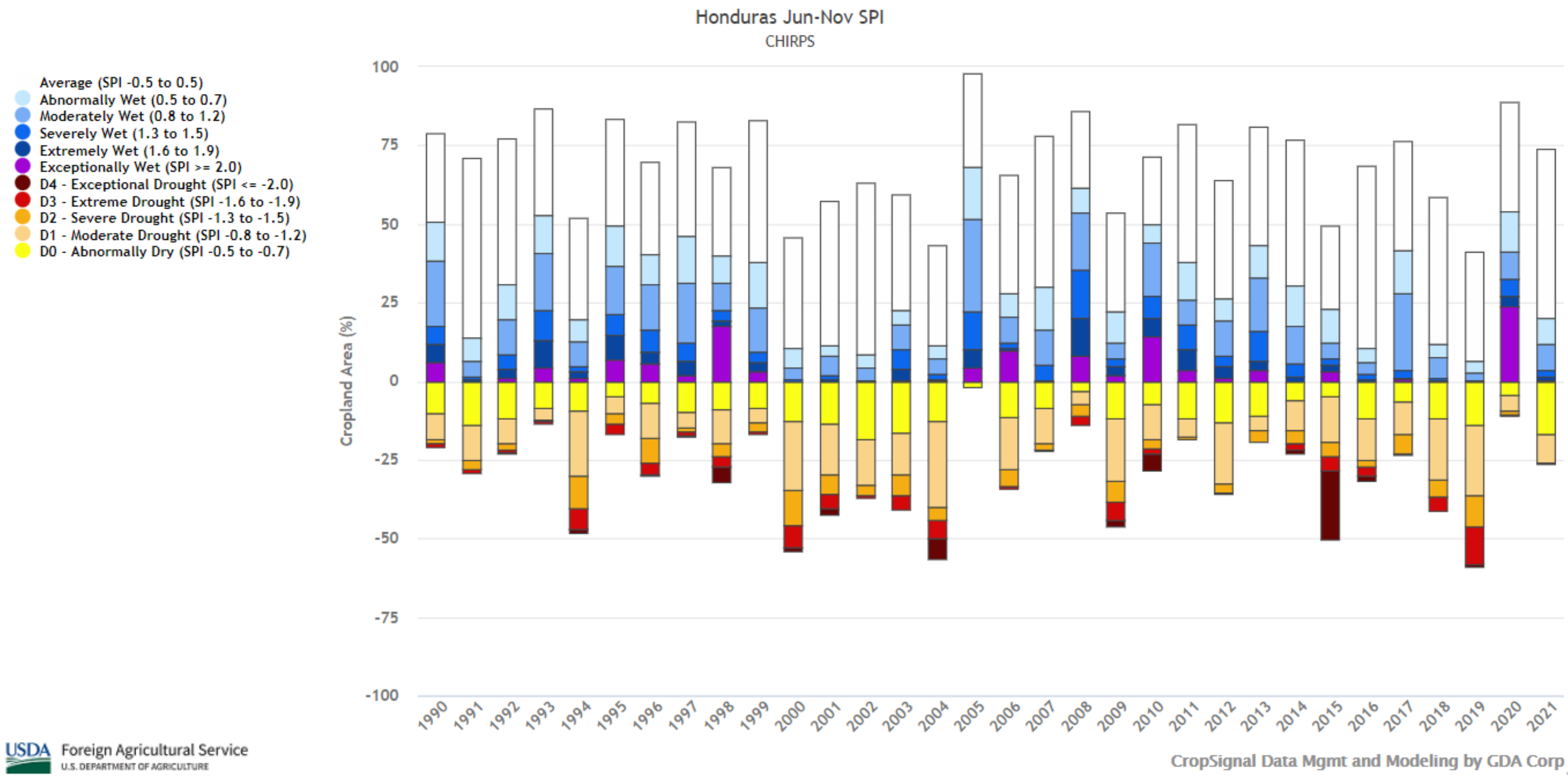


Figure A1-2 (c) Proportion of cropland area affected by different drought intensity between June and November in Honduras. Source: USDA Foreign Agricultural Service, Global Market Analysis, International Production Assessment Division (USDA/FAS/GMA/IPAD).

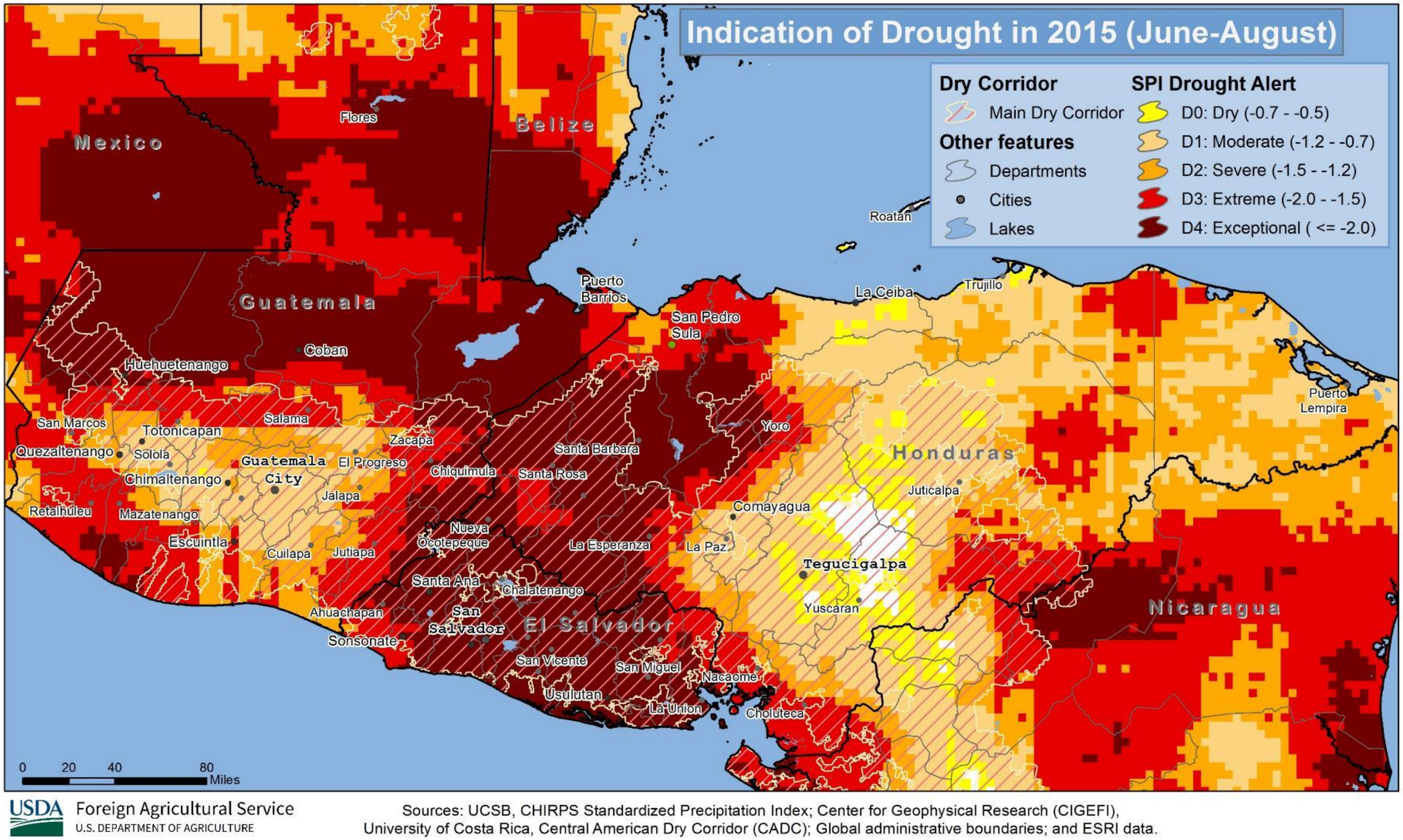


Figure A1-3 (a) Indication of drought in June-August 2015 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

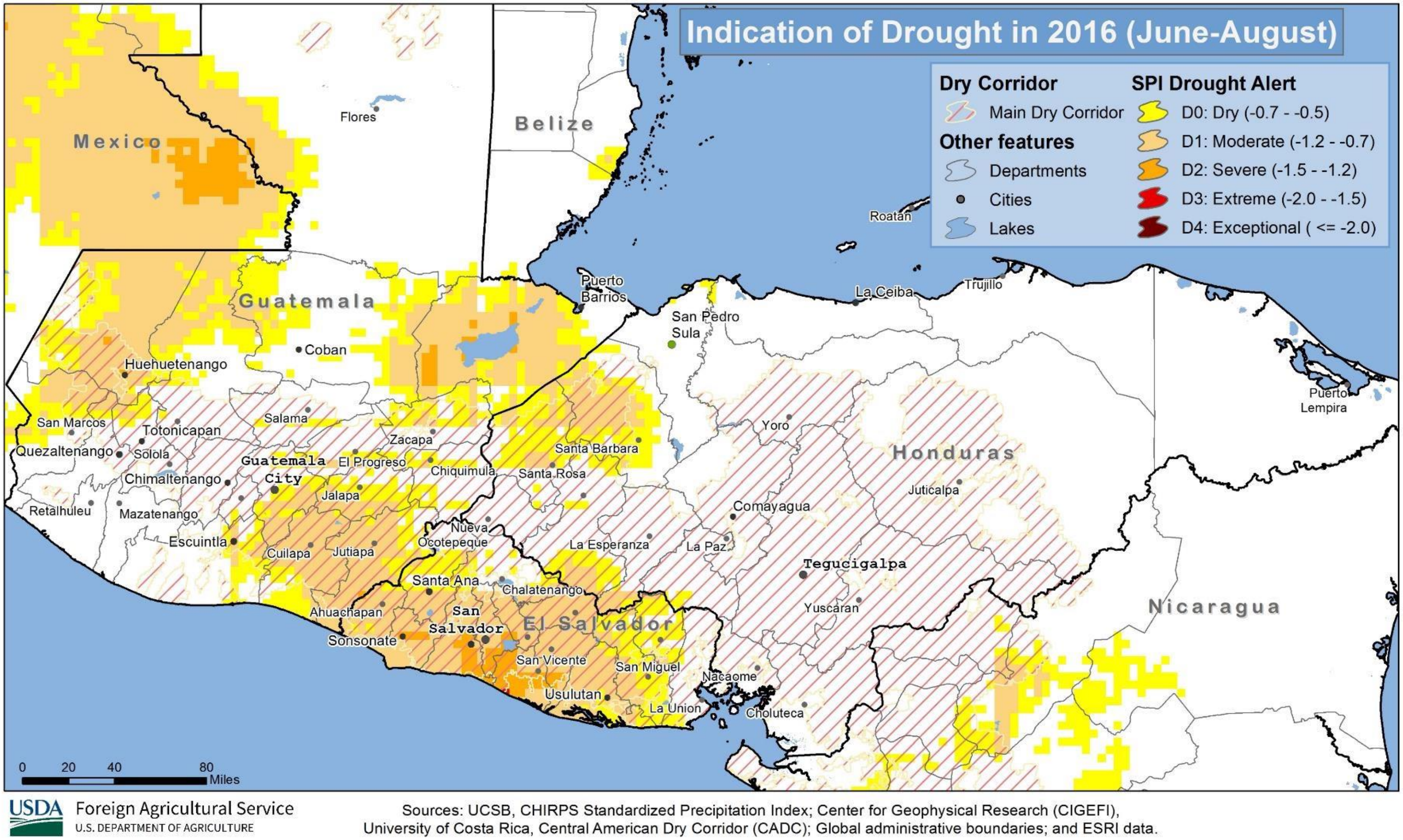


Figure A1-3 (b) Indication of drought in June-August 2016 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

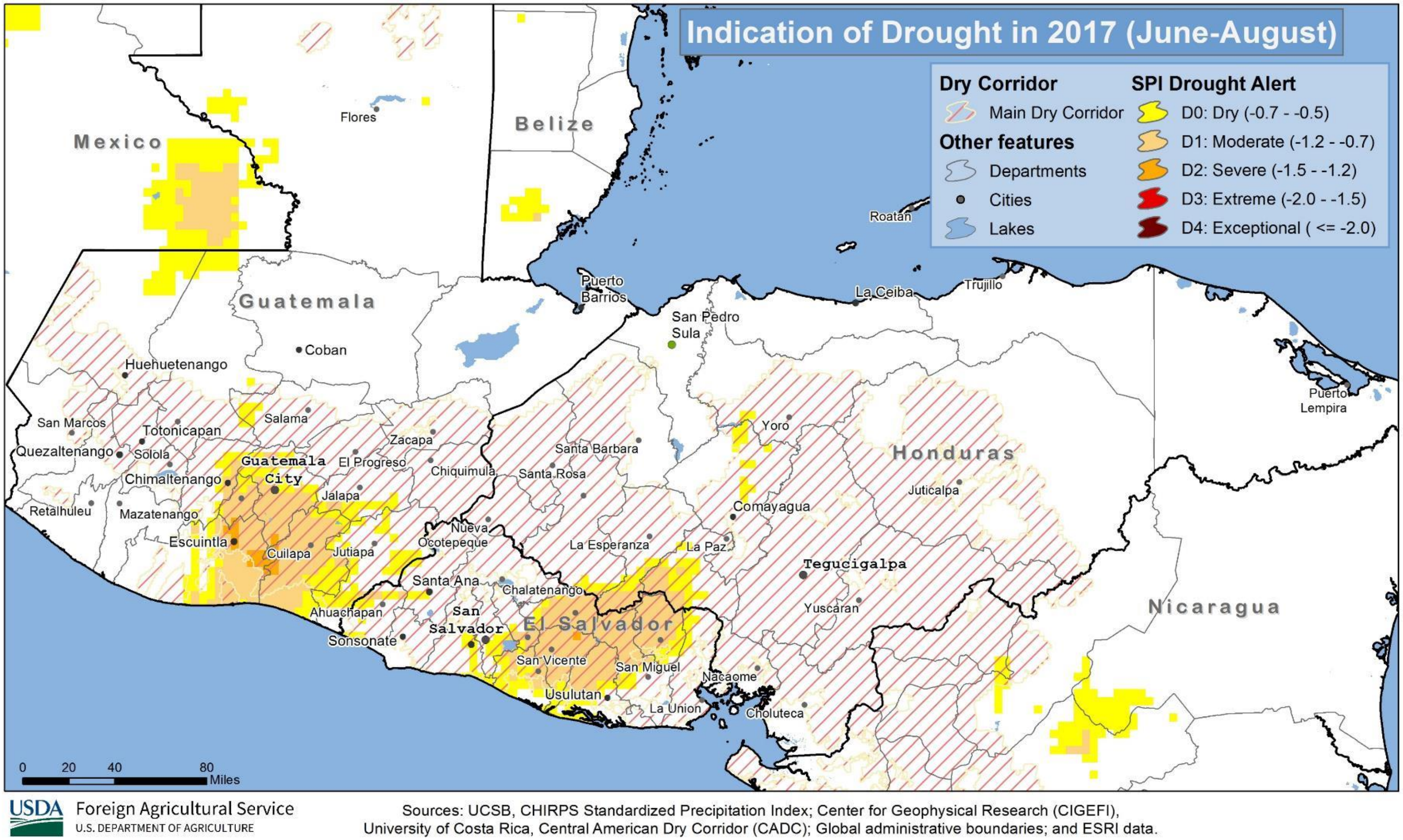


Figure A1-3 (c) Indication of drought in June-August 2017 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

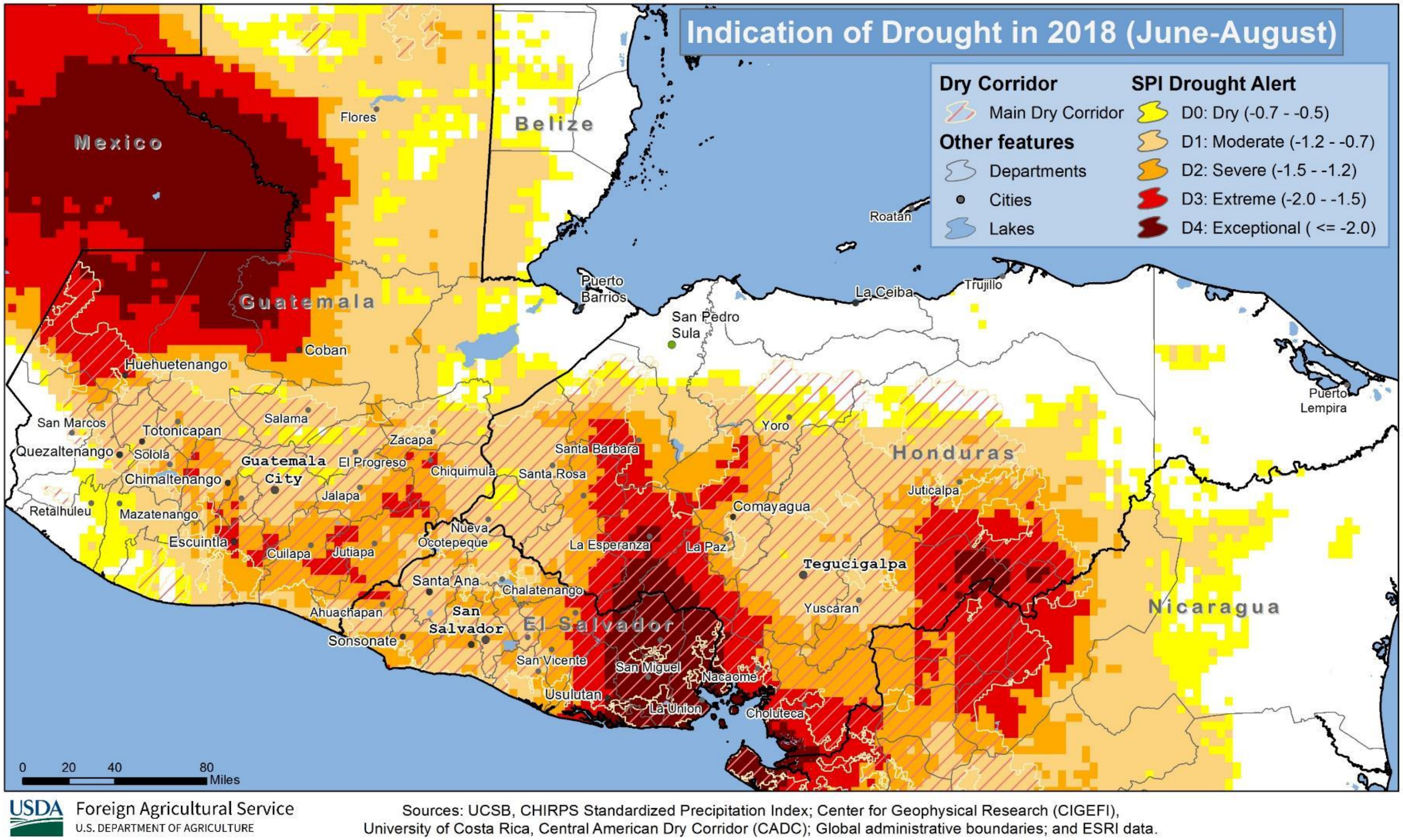


Figure A1-3 (d) Indication of drought in June-August 2018 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

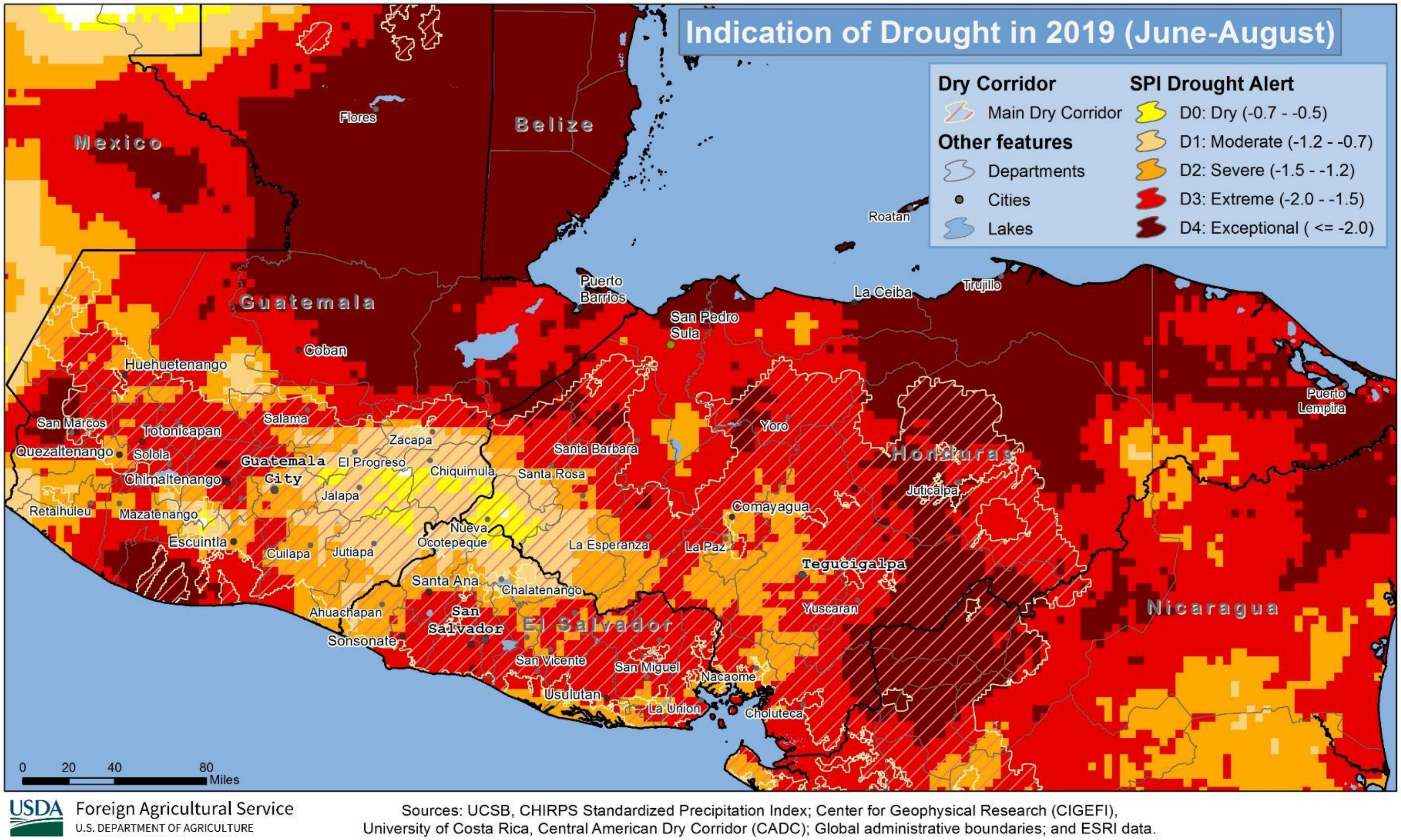


Figure A1-3 (e) Indication of drought in June-August 2019 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

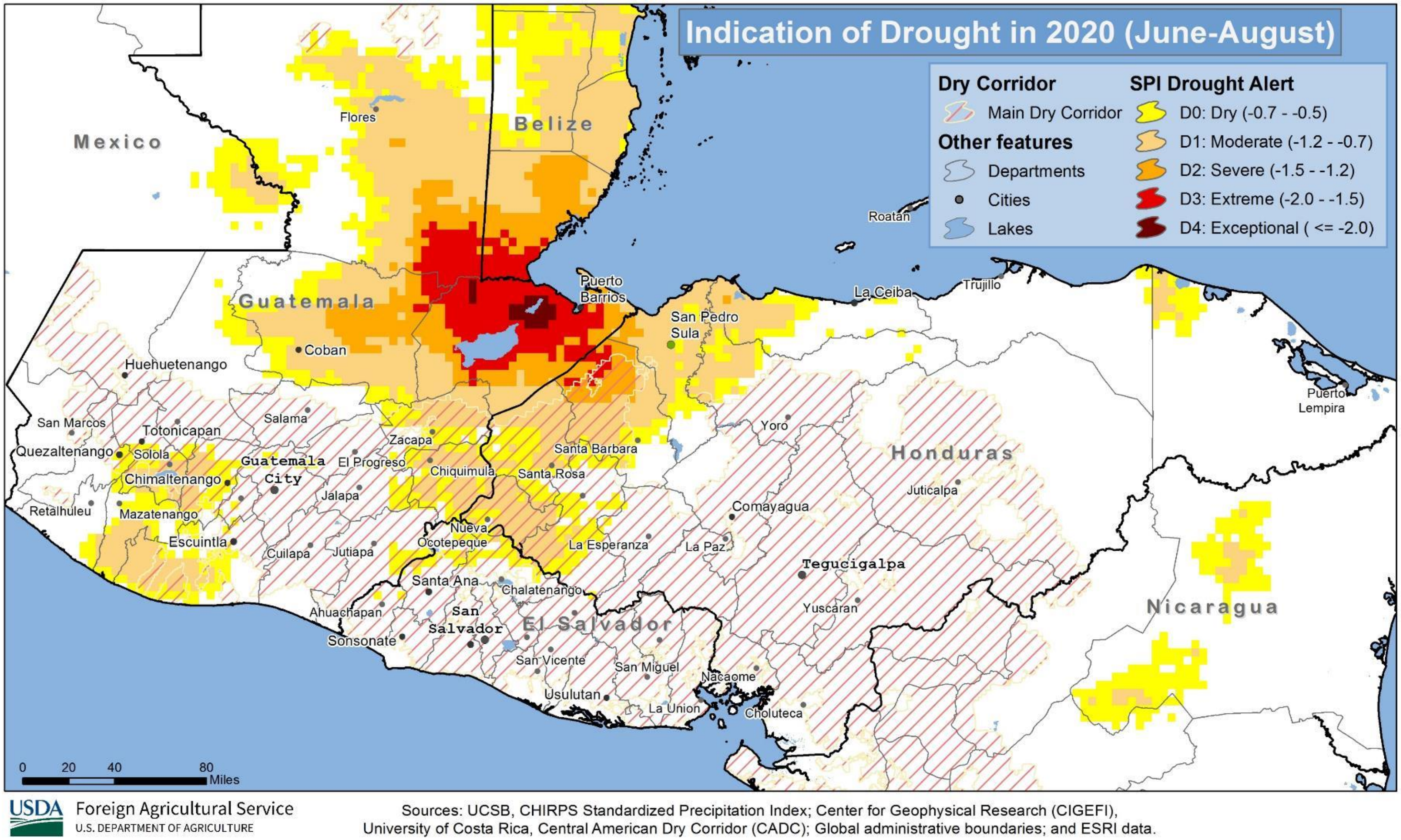
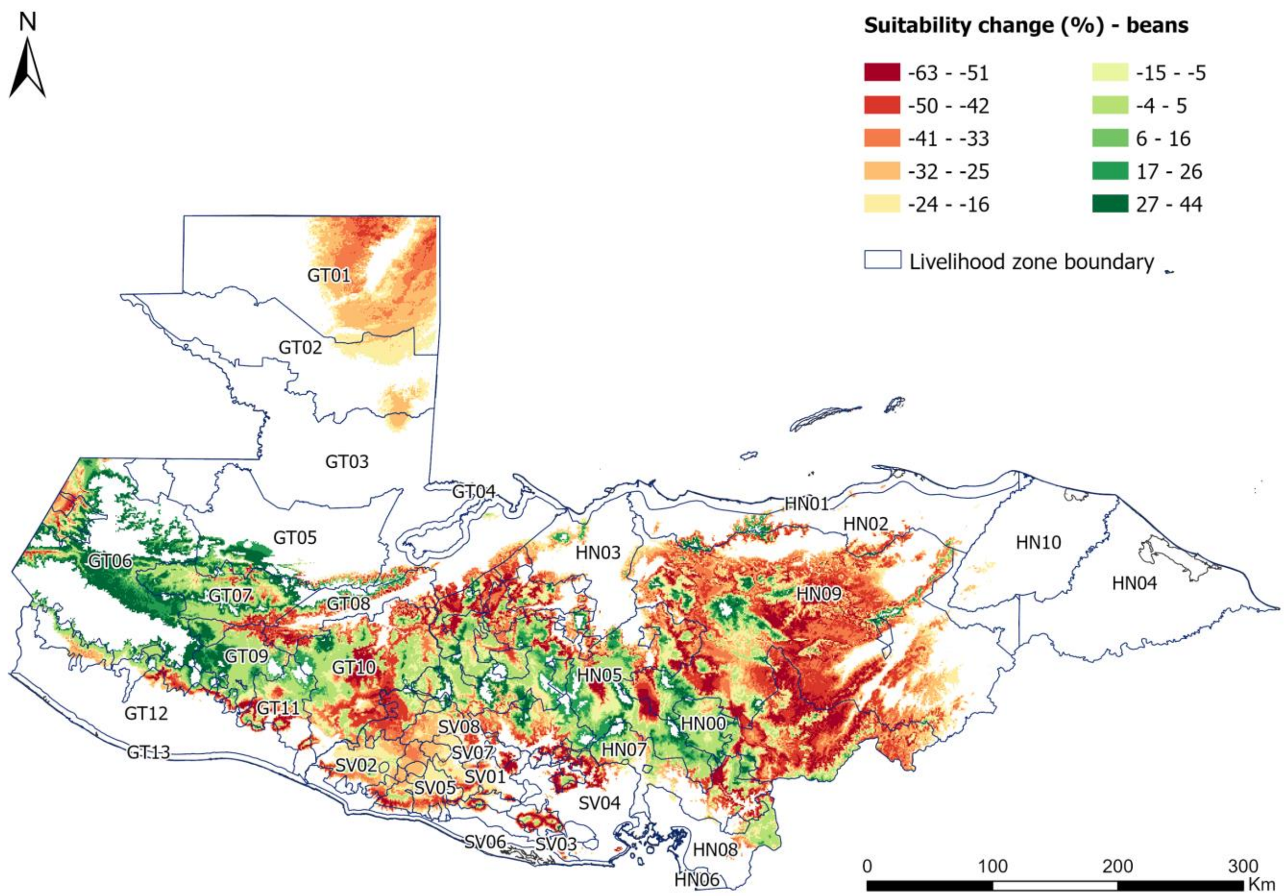


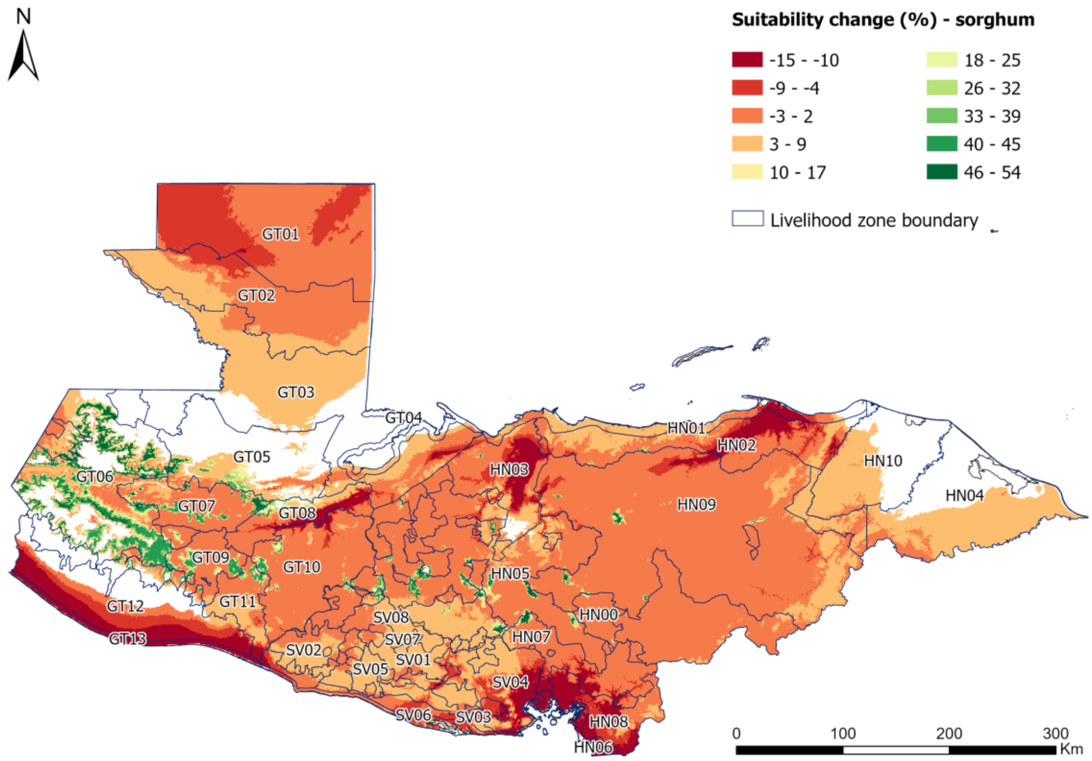
Figure A1-3 (f) Indication of drought in June-August-2020 in the three countries of the NTCA. Source: USDA/FAS/GMA/IPAD.

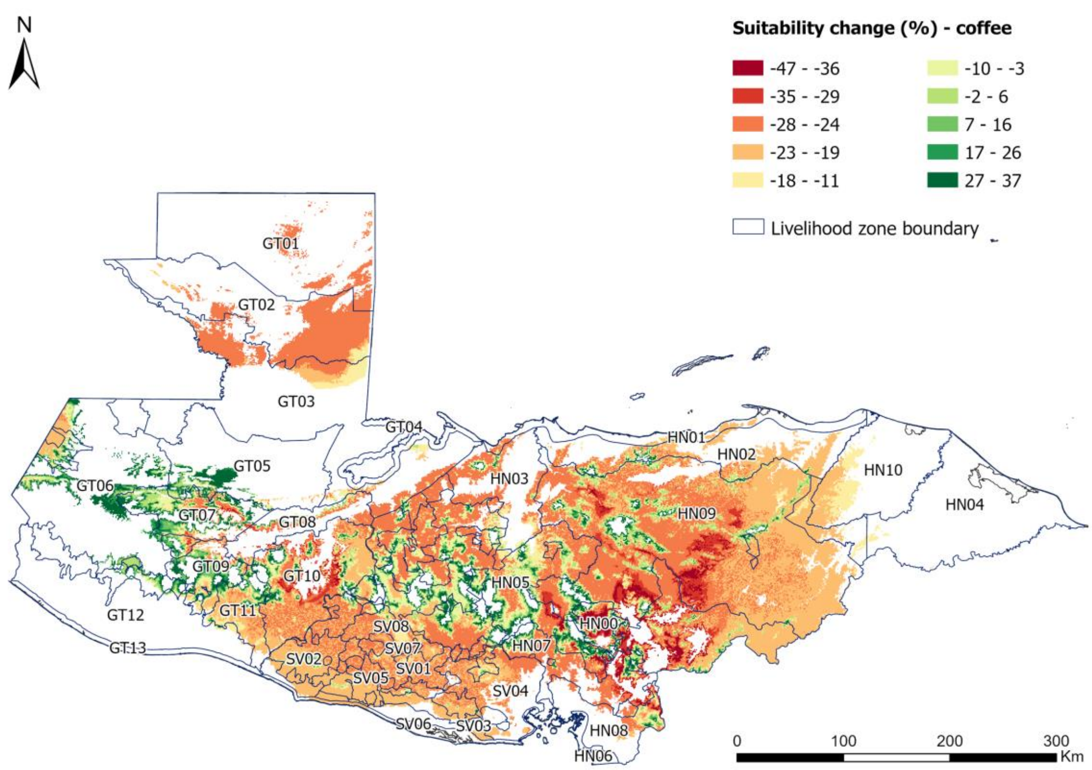
Crop suitability

The following figures show projected climatic suitability changes for beans, sorghum and coffee cultivation between the 1960-2000 and the 2020-2049 (2030) periods under the A1B emission scenario (rapid economic growth, low population growth, efficient technologies, and a balance on energy sources).

The figures were adapted by CATIE from Bouroncle et al. 2017. Mapping climate change adaptive capacity and vulnerability of smallholder agricultural livelihoods in Central America: ranking and descriptive approaches to support adaptation strategies. Climatic Change 141, 123–137. https://doi.org/10.1007/s10584-016-1792-0 Supplementary material 7. distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/). Only suitability changes of Guatemala, El Salvador, and Honduras were included. Suitability change thresholds and colors were changed. The agricultural land proportion of each crop was not included.



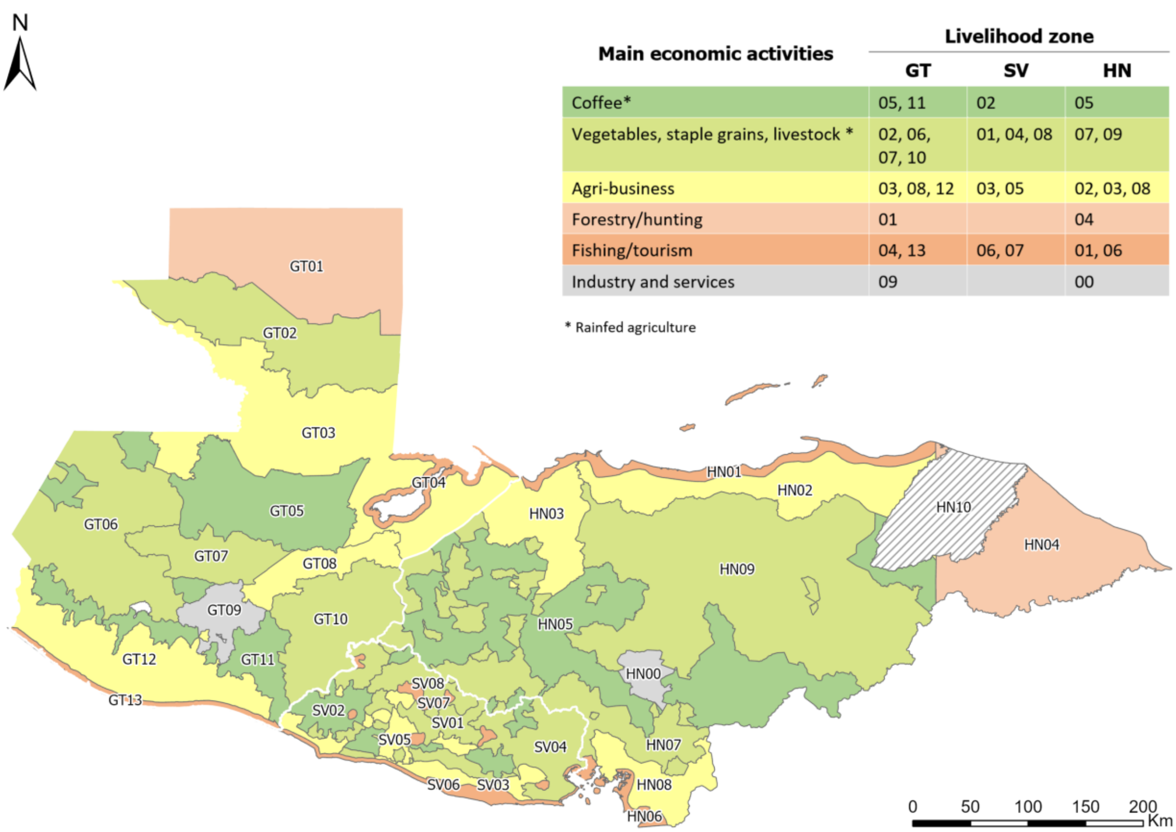

N
Suitability change (%) - sorghum
-15 - -10
-9 - -4
-3 - 2
3 - 9
10 - 17
18 - 25
26 - 32
33 - 39
40 - 45
46 - 54
Livelihood zone boundary
GT01
GT02
GT03
GT04
GT05
GT06
GT07
GT08
GT09
GT10
GT11
GT12
GT13
SV01
SV02
SV03
SV04
SV05
SV06
SV07
SV08
HN00
HN01
HN02
HN03
HN04
HN05
HN06
HN07
HN08
HN09
HN10
0
100
200
300
Km


N
Suitability change (%) - coffee
-47 - -36
-35 - -29
-28 - -24
-23 - -19
-18 - -11
-10 - -3
-2 - 6
7 - 16
17 - 26
27 - 37
Livelihood zone boundary
GT01
GT02
GT03
GT04
GT05
GT06
GT07
GT08
GT09
GT10
GT11
GT12
GT13
SV01
SV02
SV03
SV04
SV05
SV06
SV07
SV08
HN00
HN01
HN02
HN03
HN04
HN05
HN06
HN07
HN08
HN09
HN10
0
100
200
300
Km

Annex 2. El Salvador, Guatemala, and Honduras livelihood zones and their main agricultural systems

Livelihood zones (LHZs) used in this report are a subdivision of the NTCA countries based on research by the Famine Early Warning Systems Network (FEWS NET), a provider of early warning and analysis on acute food insecurity worldwide created by USAID in 1985.

FEWS NET Livelihood Profiles Reports for each country of the NTCA provide a broad characterization of people who share similar means of securing livelihoods, combining agricultural production and labor (wages). Those reports [11–13] define 21 LHZs in these countries. Of them, 13 are centered in rainfed cropping systems based on coffee production, distributed across medium and high-altitude areas, and staple grains and livestock distributed in lowlands of the Pacific and Caribbean slopes. The sale of agricultural labor, although present in both groups, is more important in the second, while the cultivation of vegetables is complementary in both. Other LHZs are based on agro-industrial crops or coastal resources. See Figure A2-1 and Table A2-1.



Main economic activities	Livelihood zone		
	GT	SV	HN
Coffee*	05, 11	02	05
Vegetables, staple grains, livestock *	02, 06, 07, 10	01, 04, 08	07, 09
Agri-business	03, 08, 12	03, 05	02, 03, 08
Forestry/hunting	01		04
Fishing/tourism	04, 13	06, 07	01, 06
Industry and services	09		00

* Rainfed agriculture

Figure A2-1. Map of livelihood zones in the NTCA. Prepared with the FEWS NET livelihood zone spatial data [14–16].

Livelihood zone code and name		Main agricultural system
SV02	Coffee, staple grain, labor, and tourism	coffee
GT05	Coffee, cardamom, forestry, and vegetable production	
GT11	Coffee production	
HN05	Mountainous coffee and vegetables	
SV01	Staple grain and labor	staple grains / staple grains and livestock
SV04	Eastern staple grain and livestock	
SV08	Northern staple grain and livestock	
GT02	Central Petén staple foods and cattle farming labor	
GT06	Western highlands labor, staple crops, vegetables, trade, and remittances	
GT07	Baja Verapaz and Quiché staple food and agricultural labor	
GT10	Eastern subsistence food crops and agricultural labor (coffee, fruit, and vegetables)	
HN07	Subsistence grains and remittances	
HN09	Grains and livestock	
SV03	Sugarcane, staple grain, and labor	agro-industrial crops
SV05	Agro-industry and commerce labor	
GT03	South Petén, Northern Transversal Strip (FTN) and Izabal agro-industry and food crops	
GT08	Motagua valley, fruit agribusiness labor and mining labor	
GT12	Southern agricultural industry labor and food crops	
HN02	Atlantic littoral palm oil production	
HN03	Labor income from maquilas, banana, and sugarcane	
HN08	Labor income from melons and shrimp	
SV06	Coastal fishing, aquaculture, and tourism	forestry, hunting, fishing, and tourism
SV07	Inland fishing, aquaculture, and tourism	
GT01	North Petén forestry and eco-tourism	
GT04	Caribbean artisanal fishing and tourism	
GT13	Pacific Ocean artisanal fishing, trade, and services	
HN01	Garifuna littoral and Bay Islands tourism	
HN04	Mosquitia hunting and fishing	
HN06	Gulf of Fonseca fishing and salt	
GT09	Industrial, agribusiness labor, commerce, and services of central area	Industry and services
HN00	Urban center	

Table A2-1. Livelihood zones in Guatemala, Honduras and El Salvador. Prepared with the FEWS NET livelihood zone descriptions [11–13].

Annex 3. How were the extrapolation maps developed?

The extrapolation maps were created by combining two datasets: the data collected in the field and national censuses of each country [20–22]. The process was done for each country separately due to differences in data sources and their format, and the available analysis level. The maps show the combined outputs of both processed data sets, with the field data given priority over the census data. For Guatemala and El Salvador, the level of detail is shown on the municipality scale, while for Honduras on the department scale due to census data availability. The final output shows aggregated results (municipality level or department) according to livelihood zones for each country. Additionally, the results are overlaid with land use and land cover layers [90,91] to show for which municipalities the cropping or livestock system in question is dominant based on spatial analysis. In other words, it shows the areas for which each cropping or livestock system occupies the municipality's largest and second largest area.

The main framework for extrapolating the field data were livelihood zones. Census data is shown for municipalities or departments for which the data was not collected in the field, and which belong to the same livelihood zones as municipalities/departments for which the data was collected. This implies that the livelihood zones which are marked as N/A are the ones in which there were no data collected in the field. In the case of livestock in Guatemala, the unit of collected data in the field did not correspond to the unit of the census data and it was, therefore, not feasible to extrapolate. Since not all municipalities and departments fall strictly within one livelihood zone, their belonging to a livelihood zone was determined based on either the largest proportion of the municipality/department area overlapping with a livelihood zone, or in cases when it was not possible to determine in this way, based on the knowledge from the field about dominant livelihoods in that specific municipality/department. The farm sizes shown in the figure are based on the data collected in the field. Ranges for each farm size differed per country and they were expressed in different units (*manzanas, tareas, cabezas*). Similarly, the data in national censuses are also expressed in different units (*manzanas*, hectares). All the data was standardized by converting the values into hectares. The data for farm sizes collected in the field was used to determine farm size ranges from the census data. Dominant farm size for each cropping or livestock system, as shown on the map, represents the results from the field, or in the case of census data, the largest proportion of farmers in each municipality or department who own a farm of a size that corresponds to the classification collected in the field.

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