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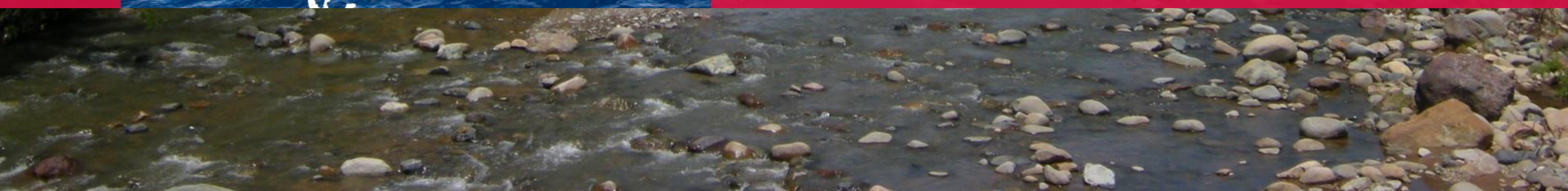
VULNERABILITY AND RESILIENCE TO CLIMATE CHANGE IN SOUTHERN HONDURAS

DECEMBER 2013

ARCC

African and Latin American Resilience to Climate Change Project



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Cover Photo: Looking up the valley of the Río Tiscagua, a tributary of the Río Negro, toward Concepción de Maria and Cerro Guanacaure. Photo by B. Byers, September 2013.

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AFRICAN AND LATIN AMERICAN RESILIENCE TO CLIMATE CHANGE (ARCC)

DECEMBER 2013

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ABBREVIATIONS AND ACRONYMS

ACTRIGOLFO	*Asociación Civil Trinacional del Golfo de Fonseca*
AECID	*Agencia Española de Cooperación Internacional para el Desarrollo*
AFE-COHDEFOR	State Forest Administration-Honduran Forest Development Corporation
ANAFAE	*Asociación Nacional Para el Fomento de la Agricultura Ecológica en Honduras*
ANDAH	Honduran Aquaculture Association
APM	Agricultural Policies and Markets
APROCAFEH	*Asociación de Productores de Café de Honduras*
ARCC	African and Latin American Resilience to Climate Change
ASONOG	*Asociación de Organismos No Gubernamentales de Honduras*
CATIE	*Centro Agronómico Tropical de Investigación y Enseñanza*
CCAD	*Convención Centroamericana de Ambiente y Desarrollo*
CEM	Center for Marine Studies
CIDICCO	*Centro Internacional de Informacion sobre Cultivos de Cobertura*
CODDEFFAGOLF	*Comité para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca*
COMRURAL	*Proyecto de Competitividad Rural*
CONABISAH	Comisión Nacional de Bienes y Servicios Ambientales
CRSP	Collaborative Research Support Program
DGRH	*Dirección General de Recursos Hídricos*
DiBio	*Dirección de Biodiversidad*
DIGEPESCA	*Dirección General de Pesca y Acuicultura*
DOC	U. S. Department of Commerce
EAP	*Escuela Agrícola Panamericana*
ENSO	El Niño-Southern Oscillation
ESRI	Eco-Social Resilience Index
FAO	Food and Agriculture Organization
FAPVS	*Fondo de Áreas Protegidas y Vida Silvestre*
FHIA	*Fundación Hondurena de Investigación Agricola*

GOH	Government of Honduras
HDI	Human Development Index
HIVOS	Humanist Institute for Cooperation
ICF	*Instituto Nacional de Conservación y Desarrollo Forestal, Areas Protegidas y Vida Silvestre*
IDH	*Índice de Desarrollo Humano*
IHCAFE	*Instituto Hondureño del Café*
IPCC	Intergovernmental Panel on Climate Change
JAPOE	*Juntas de Administradora de Agua Potable y Disposición de Excretas*
LUPE	Land Use and Productivity Enhancement
MAFRON	Union of Municipalities of the Boarder
MAREA	Management of Aquatic Resources and Alternative Development
MIRA	*Manejo Integrado de Recursos Ambientales*
MODIS	Moderate Resolution Imaging Spectroradiometer
NASMAR	*Mancomunidad de Municipios del Sur*
NGO	Nongovernmental Organization
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OIMT	*Organización Internacional de las Maderas Tropicales*
OSPESCA	*Organización del Sector Pesquero y Acuícola del Istmo Centroamericano*
PREPCA	Regional Energy & Poverty Program in Central America
PRNM	*Proyecto Manejo Recursos Naturales*
PROARCA	*Programa Ambiental Regional para Centroamérica*
PRONAFOR	*Programa Nacional Forestal*
RCP	Recommended Concentration Pathway
SAG	Ministry of Agriculture and Livestock
SANAA	*Servicio Autónomo Nacional de Acueductos y Alcantarillados*
SEPLAN	*Secretaría Técnica de Planificación y Cooperación Externa*
SERNA	*Secretaría de Recursos Naturales y Ambiente*
SINAPH	*Sistema Nacional de Áreas Protegidas y Vida Silvestre de Honduras*
SMN	*Servicio Meteorológico Nacional*

TNC	The Nature Conservancy
TRMM	Tropical Rainfall Measuring Mission
UNAH	*Universidad Nacional Autónoma de Honduras*
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USD	United States Dollars
USFS	United States Forest Service

EXECUTIVE SUMMARY

OBJECTIVES OF THE ASSESSMENT

The United States Agency for International Development (USAID)/Honduras requested that the African and Latin American Resilience to Climate Change (ARCC) Program conduct a climate change vulnerability assessment for the southern region of Honduras. The objectives of the assessment were to:

- Assess the vulnerability of people and ecosystems in Southern Honduras to the possible effects of climate change.
- Identify actions that could increase resilience and decrease vulnerability in order to provide options for USAID/Honduras programming of Biodiversity and Climate Change Adaptation funds.
- Identify climate-resilient livelihood and employment opportunities that could help reduce poverty.

USAID expects this vulnerability assessment to inform programming that will use two targeted sources of funding – one for climate change adaptation and one for biodiversity conservation.

CONCEPTUAL FRAMEWORK

The vulnerability assessment team applied a conceptual framework that assesses the impact of climate change on ecosystems in Southern Honduras and how these impacts, in turn, affect the socioeconomic well-being of people whose livelihoods depend on these ecosystems. Climate change vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity in line with the Intergovernmental Panel on Climate Change's (IPCC) definition of vulnerability, which has also been adopted by USAID. In this report, the research team provides an evidence-based qualitative assessment of vulnerability and its components.

ASSESSMENT METHODS

The assessment team consisted of four U.S. and five Honduran specialists. The team conducted an extensive literature review and travelled to Honduras on a scoping mission to talk with USAID/Honduras and key stakeholders at the national level and in the southern region. Following the scoping mission, a climate analysis was conducted. This analysis combined findings from recent climate science literature, including new IPCC predictions for the Central American Isthmus region and an in-depth analysis of original climatological records spanning the years 1951–2013, obtained from Honduran government agencies. During the field assessment phase, the team made site visits and held focus group discussions with representatives of 14 communities and with seven mayors and their staff (see Annex E). Two workshops with key stakeholders were organized: one for those from the upper watersheds, and one for those from the coastal-marine zone. The team met with more than 200 individuals from municipalities, communities, government agencies, donors, and the private commercial sector. Following the field assessment, individual specialists on the assessment team prepared written reports on their topic of focus and then met to integrate those findings. This assessment report presents this synthesis of findings and recommendations for climate change adaptation action.

The assessment approach included various methods, some of them innovative:

- A conceptual framework that treats ecosystems and socioeconomic systems as a single unified system in order to assess their linked vulnerabilities and resilience;
- Averaging of daily rather than monthly temperature and precipitation data to give a more detailed picture of current climate and trends;
- Use of the permanent land cover ratio as an indicator of the vulnerability of ecosystem benefits to climate change;
- An eco-hydrological assessment of key ecosystem services in the region;
- Use of pie diagrams of land cover/use as an integrated, visual summary of the ecology and economy in communities representative of different livelihood profiles and locations along major watersheds; and
- Development of a composite indicator of eco-social resilience.

CLIMATE ANALYSIS RESULTS

After a rapid multi-decade increase in temperatures that peaked in 1998, temperatures in Southern Honduras have been nearly stable for 15 years – but at levels warmer than they have been for at least hundreds of years. The El Niño-Southern Oscillation (ENSO) exerts a strong control on temperatures in Southern Honduras at annual and decadal time frames. Models predict increased temperatures of around +2 °C by 2050 due to greenhouse gas forcing.

Precipitation measurements from rain gauges, now validated by satellite observations, show a trend of increasing rainfall over several decades. Multi-model consensus predictions in the current IPCC Assessment Report show a 10–20 percent decrease in precipitation in Southern Honduras by 2050. Because rainfall trends currently show strong and sustained multi-decadal increases in the wet season, the potential for a relatively sudden reversal of the current wet trend to a drier one may catch people by surprise. The potential for a shift to drier conditions makes it more urgent to take advantage of the current wetter-than-average climate to carry out adaptive actions such as reforestation of watersheds.

When taken with the model consensus of close to two degrees of warming for the same time period, climate models suggest that by mid-century, Southern Honduras may be a "hotspot" of magnified climate change stress as compared to other areas of Central America and Mexico. There is the potential for a relatively sudden sea-level rise with the next shift to the ENSO "warm" (El Niño) mode.

POTENTIAL EFFECTS ON ECOSYSTEMS

The IPCC projections for Southern Honduras suggest a warming and drying of the climate by 2050 that would cause almost 50 percent of the current ecological "climate envelope" to be lost, removing habitats currently occupied by certain types of ecosystems and creating other climate combinations that have no equivalents in the current climate. This surprising result suggests that a major ecological shift may occur in the region. Such a shift would decrease the area of cooler and wetter upland forest ecosystems, leading to decreased ability of the affected watersheds to retain water, retard runoff, and recharge the upland infiltration zone. Therefore, this predicted eco-climatic shift has the potential to degrade significantly a critical ecosystem service to the region – stable flows of clean water from the forested areas of upland watersheds.

Key subsistence crops would experience greater climate stress in a warmer, drier climate, perhaps leading to pressure to cultivate them at higher altitudes where the climate is cooler and wetter. This shift could put additional pressure on forest ecosystems in upper watersheds, lead to even more cultivation on steep slopes, and increase the vulnerability of eco-hydrological services from those watersheds.

VULNERABILITY OF ECOSYSTEM BENEFITS TO CLIMATE CHANGE

The natural features of the watersheds of Southern Honduras make them very vulnerable hydrologically, and climate change will only add more uncertainty and exacerbate the problems in those already vulnerable watersheds. The ratio of permanent land cover in a watershed — essentially a measure of the extent to which natural ecosystems have been conserved — is an indicator of its eco-hydrological vulnerability. Permanent types of vegetation, especially forests, are more effective in allowing water infiltration than crop lands or pastures, and therefore more effective in regulating streamflow quantity and quality over time. In forested watersheds, only a fraction of the total streamflow comes from direct runoff – most comes from infiltrated groundwater. Most watersheds in Southern Honduras have a permanent land cover ratio of less than 50 percent, and eco-hydrological processes in these watersheds already have been seriously altered, especially the ratio of baseflow to direct runoff.

The eco-hydrology of the coastal zone is also affected by the ratio of permanent land cover. The coastal zone, including the coastal plain and mangrove zone, depend upon groundwater flows from upland watersheds to push saltwater down and back, maintaining a water table of freshwater that reaches to the inland edge of the mangrove zone. The eco-hydrology of the mangroves and coastal zone in Southern Honduras is extremely complex and has been studied very little; however, mangrove ecosystems themselves function in ways that affect the hydrology of the coastal zone. Predicted climate changes could have a negative effect on at least some of the hydrological factors important to the commercial shrimp industry, such as the quantity and quality of water flowing into the estuaries from upper watersheds during the wet season.

The eco-hydrology of Southern Honduras links upper watersheds to the coastal and marine zone; therefore, an ecosystem-based approach to climate change adaptation is needed in the south of Honduras. Food and livelihood security cannot be achieved without taking an ecosystem-based approach.

Because the 11 protected areas of Southern Honduras conserve significant, critical areas of natural vegetation (i.e., permanent land cover), they contribute significantly to the permanent land cover ratio of the region, both in the upper areas of watersheds and in the coastal mangrove zone. Because the ratio of permanent vegetation to total land area in a watershed is an indicator of its eco-hydrological vulnerability to climate change, these protected areas — if well protected and managed — could be said to anchor the natural climate resilience of the region. (See Annex I for a case study discussing the investments the Tres Valles Sugar Company has made in the watersheds in their growing area.)

SOCIOECONOMIC SENSITIVITY TO THE LOSS OF ECOSYSTEM BENEFITS

The livelihoods of most rural households in Southern Honduras depend on a combination of subsistence production of staple food crops (mainly maize and beans) and livestock in upland, rain-fed zones; artisanal fisheries and some staple crop production on the coastal plain; jobs and income from small and medium agro-enterprises for local or regional markets; and income from employment in large-scale commercial export industries of crops (melons, sugar; see Annexes F and G) and shrimp. All of these agricultural livelihoods and commercial enterprises depend on ecosystem products and services.

Fish and shellfish, harvested from the natural ecosystems of the Gulf of Fonseca, are by far the most important ecosystem products that support livelihoods in Southern Honduras. In the coastal zone, fishing is a major source of food, employment, and income. Fishing is mainly artisanal, employing low-technology techniques and using small craft. Its importance rests more in the number of jobs generated and the food security it provides than the total economic revenue it generates. Wood for both fuel and construction is another ecosystem product that underpins the livelihoods of Southern Honduras; most wood is locally obtained, usually for free or at the cost of labor, from local natural ecosystems.

Water for domestic consumption comes from surface water taken from streams and rivers and groundwater from wells, both of which result from eco-hydrological processes taking place in the watersheds of the region. Growing basic grains, mainly maize and beans, on small-scale subsistence farms is the foundation for food security in the area. Subsistence agriculture depends on ecosystem services to prevent soil erosion, retain groundwater and soil moisture through infiltration, and maintain soil fertility through bacterial nutrient cycling in crop fields and pastures.

Three large commercial agro-industries — sugar, melons, and shrimp — generate a very important fraction of the employment and income that drive the economy of the region. These industries highly depend on sustainable flows of fresh water entering the valleys and the coastal zone, and so have significant incentives to maintain the eco-hydrological health of upper watersheds.

CAPACITY TO ADAPT TO CHANGES IN ECOSYSTEM BENEFITS

Adaptive capacity depends on the ability of individuals, households, communities, and institutions to identify options and take advantage of opportunities to reduce their exposure or sensitivity to climate change. In field work, the research team arrived at the strong general impression that although awareness of the challenges of a changing climate is widespread, the human, financial, and technical capacity of relevant institutions to respond adequately to potential climate changes currently is weak.

Economic factors play a role in the capacity to adapt to climate changes, of course. Although even the poorest individuals, families, and communities of Southern Honduras are resourceful, for a variety of reasons they often do not have many livelihood options and economic opportunities. This assessment revealed that communities differ in the diversity of their economic options and concluded that communities with more diversity have more capacity to adapt to projected climate challenges.

SOCIOECONOMIC VULNERABILITY

In assessing the vulnerability of people and ecosystems in Southern Honduras to the effects of climate change, three influential factors must be considered:

- exposure of the socioeconomic system, which is equivalent to the ecological vulnerability of the ecosystem products and services upon which the people of the region depend;
- sensitivity to the loss of those benefits, as reflected by dependence on them; and
- adaptive capacity of communities and institutions.

The ratio of a landscape's permanent land cover — in effect a measure of the extent to which natural ecosystems have been conserved — is a good indicator of the vulnerability of ecosystem benefits in a watershed or a municipality to climate change, and therefore of the socioeconomic system's exposure.

The economy and livelihoods of Southern Honduras, from the poorest fishing or farming communities to the large commercial agro-industries, heavily depend on ecosystem products and services that are threatened by climate change. Everyone, in every segment of society, depends on ecosystems even if in different ways. Additionally, the adaptive capacity of relevant institutions at all levels is weak. Communities differ in the diversity of their economic options, and this affects their adaptive capacity.

This study analyzed the eco-social vulnerability of communities in eight municipalities that represent a broad range of climatic, ecological, and socioeconomic conditions in the region. A composite index for measuring eco-social vulnerability was created. This index combines permanent land cover ratio, a ranked score for livelihood diversity, and the Human Development Index (HDI) – a measure of socioeconomic well-being. For the purposes of this study, the assumption is made that people and communities with higher HDI are better able to weather climate shocks, thereby increasing their resilience and adaptive capacity. Using this index, the assessment found that communities in areas with low permanent land cover ratios, low diversity of economic activities, and/or low HDI scores are more vulnerable to climate change and other non-climate stresses than communities with more natural vegetation, more diverse livelihoods, and more human and financial resources.

ADAPTIVE OPTIONS AND RECOMMENDATIONS

An integrated, ecosystem-based approach to climate change adaptation is a necessary component of any effective strategy for food and livelihood security, as well as economic development in general, in Southern Honduras. Sustainable adaptation options must link upper watershed and coastal zone ecosystems and communities because of the ecological and socioeconomic interconnections between them. Adaptation will require watershed-scale responses that link upstream and downstream beneficiaries of ecosystem products and services. As the development hubs of the region, the municipalities of Choluteca, San Lorenzo, and Nacaome must work upstream in their watersheds to break the relationship between poverty and forest loss that has reduced the natural forest cover in upper watersheds, and to regenerate more permanent forest cover there in order to maintain irreplaceable eco-hydrological services.

Donors including USAID have been working with government, nongovernmental organizations (NGOs), and private sector actors in Honduras for decades. In many cases, these donors have carried out or supported activities and projects that address non-climate stressors such as deforestation, soil degradation, and weak governance. In turn, these activities have been effective strategies for addressing climate stressors such as rising temperatures and erratic rainfall. Those projects have seen some success in promoting practices and technologies for agricultural productivity as well as soil and water conservation on hill-slope farms. Future projects should build on those successes; however, given how climate change will exacerbate non-climate stressors and increase the vulnerability of ecosystems and the people who depend on them, it becomes necessary to scale-up these activities. For example, given that some degree of success in conserving soil fertility and moisture has been experienced at the farm level, there is now a compelling reason to complement these activities with projects that strive to achieve larger-scale impacts at landscape and watershed levels.

The commercial agro-industries have a large economic and political influence, and they have a significant impact on the use and management of significant amounts of water and land. Another opportunity for new programs is to work with the commercial agro-industrial sector to improve their ability to invest in and sustain improved land and water use. Adaptive actions will require water users to internalize the costs of water and pay for watershed management improvements upstream (e.g., forest conservation and regeneration) and downstream (e.g., mangrove conservation and regeneration). Commercial agro-industries are aware of how much they depend on eco-hydrological services to provide water of suitable quantity and quality for their enterprises, and they expressed an interest in developing compensation mechanisms that would help protect and restore upper watersheds to maintain those eco-hydrological services.

1.0 INTRODUCTION

1.1 OBJECTIVES

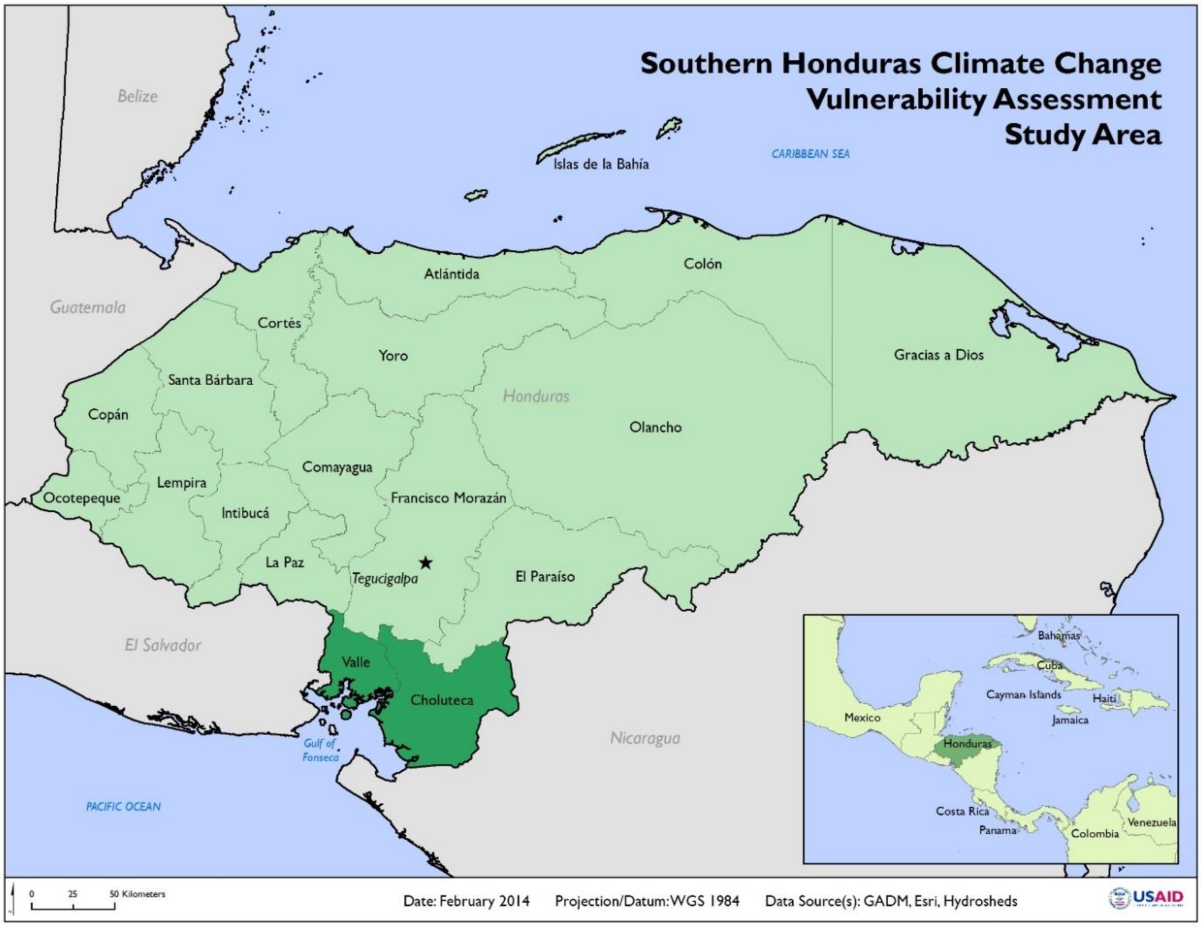
USAID/Honduras requested that the ARCC Program conduct a climate change vulnerability assessment for the southern region of Honduras. The objectives of the assessment were to:

- Assess the vulnerability of people and ecosystems in Southern Honduras to the possible effects of climate change;
- Identify actions that could increase resilience and decrease vulnerability in order to provide options for USAID/Honduras programming of biodiversity and climate change adaptation funds; and
- Identify climate-resilient livelihood and employment opportunities that could help reduce poverty.

USAID/Honduras has specified that this vulnerability assessment should focus on Southern Honduras, in particular the Departments of Valle and Choluteca (Figure 1.1). These departments make up most of Region 13, a development region defined in the Honduran National Development Plan (Plan de Nación).

USAID/Honduras has further specified that they are interested in using this vulnerability assessment to inform programming that will use two targeted sources of funding – one for climate change adaptation and one for biodiversity conservation. The USAID/Honduras Mission also stated that it is interested in improving livelihoods, incomes, and food security for the poorest sector of the population in Southern Honduras. The Mission asked that the assessment particularly focus on vulnerability to climate change at the local level, and on how local institutions (including local and regional offices of national agencies) might respond in ways that would increase their resilience to the negative effects of climate change.

FIGURE 1.1 SOUTHERN HONDURAS CLIMATE CHANGE VULNERABILITY ASSESSMENT STUDY AREA



1.2 BACKGROUND

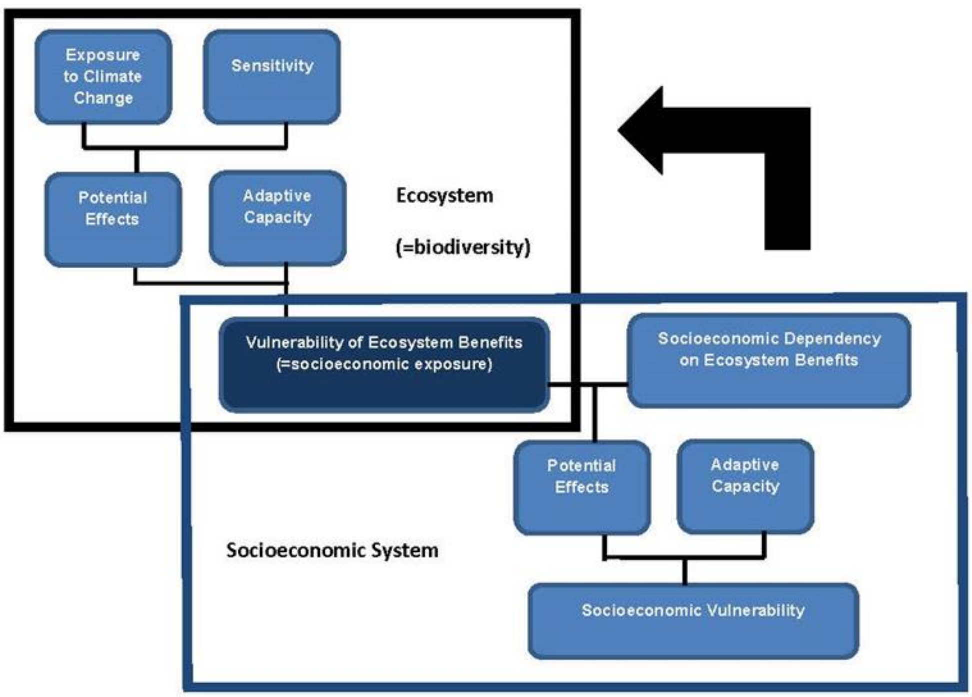
USAID Climate Change Strategy

USAID's Climate Change and Development Strategy 2012–2016 says that "Many years of leadership in biodiversity conservation and natural resources management inform climate sensitive approaches to land use planning and sustainable use of natural resources such as forests and water. Recognizing that this is an emerging field and that adaptation needs will vary considerably with local circumstances, USAID will support…. strengthening of environmental conservation actions that protect natural ecosystems on which human development depends" (USAID, 2012a, pp. 16–17). One of the 10 "guiding principles" listed in the Climate Change and Development Strategy is to "value ecosystem services." This principle provides a strong link between climate change adaptation (and mitigation) and biodiversity conservation, because ecosystem services result from ecological processes that depend on the diversity of species in the ecosystem. Biodiversity is, therefore, the source of ecosystem services (USAID, 2005). The Climate Change Strategy states that: "Although these [ecosystem] services are critical to development, they are often not valued appropriately in the marketplace. For example, forests offer more than just timber for harvest… [they store] carbon; … reduce erosion, improve the quantity and quality of water" (USAID, 2012a, p. 10).

1.3 CONCEPTUAL FRAMEWORK

The concept of "eco-sociological" systems is becoming more widely used in the literature on resilience (Füssel and Klein, 2006; Ostrom, 2009; Smit and Wandel, 2006; Turner et al., 2003; Walker et al., 2004). Figure 1.2 below shows the conceptual framework used to guide the Honduras vulnerability assessment. As the figure shows, the approach taken assesses the impact of climate change on ecosystems in Southern Honduras and how these impacts, in turn, affect the socioeconomic well-being of people whose livelihoods depend on these ecosystems. This integrated approach was adapted from Marshall et al. (2010) and tested by the USAID Management of Aquatic Resources and Alternative Development (MAREA) Project in its vulnerability assessment for the Gulf of Honduras (USAID, 2012b) The conceptual approach is compatible with the Intergovernmental Panel on Climate Change (IPCC) concept of vulnerability, which is also used by USAID and defines vulnerability as a function of ***exposure*** (anticipated climate changes), ***sensitivity*** (how these climate changes affect ecosystems and communities that depend on those ecosystems), and ***adaptive capacity*** (the ability of the affected systems, institutions, and communities to respond and adapt).

FIGURE 1.2 CONCEPTUAL FRAMEWORK FOR THE HONDURAS VULNERABILITY ASSESSMENT



Source: Modified from Marshall et al., 2010, p. 9; and USAID, 2012b, p. 12

1.4 ASSESSMENT METHODOLOGY

Literature Review

The first step in the assessment was to conduct an extensive review of existing literature relevant to the objectives of the assessment. Findings of the literature are available in an ARCC report (USAID-ARCC, 2013).

Scoping Mission

An initial scoping trip took place in Honduras from 11–24 August 2013. Several members of the assessment team met with USAID/Honduras upon arrival and presented an out-briefing before departure. During the scoping mission, meetings were held in Tegucigalpa with key agencies and other stakeholders at the national level, and with key regional stakeholders in Choluteca and Valle Departments. The assessment team visited three marine protected areas (Bahia de Chismuyo, La Berberia, and Estero San Bernardo) and one montane protected area (Cerro Guanacaure). Approximately 30 individuals shared information with the team.

Climate Analysis

The climate analysis conducted for the assessment included:

- Collection and analysis of daily-level weather station data for Southern Honduras obtained by special arrangement from the Servicio Meteorologico Nacional (SMN, four stations); the Dirección General de Recursos Hídricos (DGRH, 14 stations); and the Servicio Autónomo Nacional de Acueductos y Alcantarillados (SANAA, two stations). The earliest records are from 1951 (Amapala) and run through 2011–2013 for most stations. All station records include precipitation measurements, and several also feature other atmospheric parameters such as temperature, relative humidity, wind, and barometric pressure.
- Preparation of climatological assessments for key sites with the longest records (30–60 years), utilizing analysis of daily-level station records. An initial compilation of data included climatological means and extreme values for each day of the year based on all years available for each data series. This compilation provided baseline means for assessing trend behavior and served as the basis for characterizing duration of climatological seasons (early rains, mid-year canícula, late rains, dry season) with high precision.
- Analysis of all available Tropical Rainfall Measuring Mission (TRMM) satellite rainfall data, which cover the period from 1998 to the present. The TRMM measurements closely matched aggregated climate station point measurements and so should serve well as a spatially and temporally consistent data resource for the future.
- Analysis of satellite-based and tidal gauge sea-level data;
- Assessment of tropical cyclone-related risks and hazards; and
- Evaluation of IPCC projections for the Southern Honduras region.

Field Assessment

The field assessment took place from 22 September to 8 October 2013. The team met with USAID upon arrival and presented an out-briefing before departure. The team conducted site visits and focus group discussions with representatives of 14 communities, and with seven municipal mayors and their staff (see Annex E). Discussion guides used in those meetings can be found in Annexes A and B. Two workshops were held with key stakeholders, one for those from upper and middle watersheds, and the other for those from the coastal-marine zone. Agendas for those workshops can be found in Annexes C and D. The purpose of the focus group discussions and workshops was to obtain firsthand information about livelihoods, their dependence on ecosystem products and services, and their vulnerability to climate changes. During the field assessment phase, the team met with more than 200 individuals from municipalities, communities, government agencies, donors, and the private commercial sector.

Synthesis Workshop

After completion of the field assessment research, specialists on the assessment team prepared individual written reports on their topic of focus. The team met in Washington, D.C. from 18–20 November to share their preliminary findings with all team members and to integrate those findings.

Assessment Report

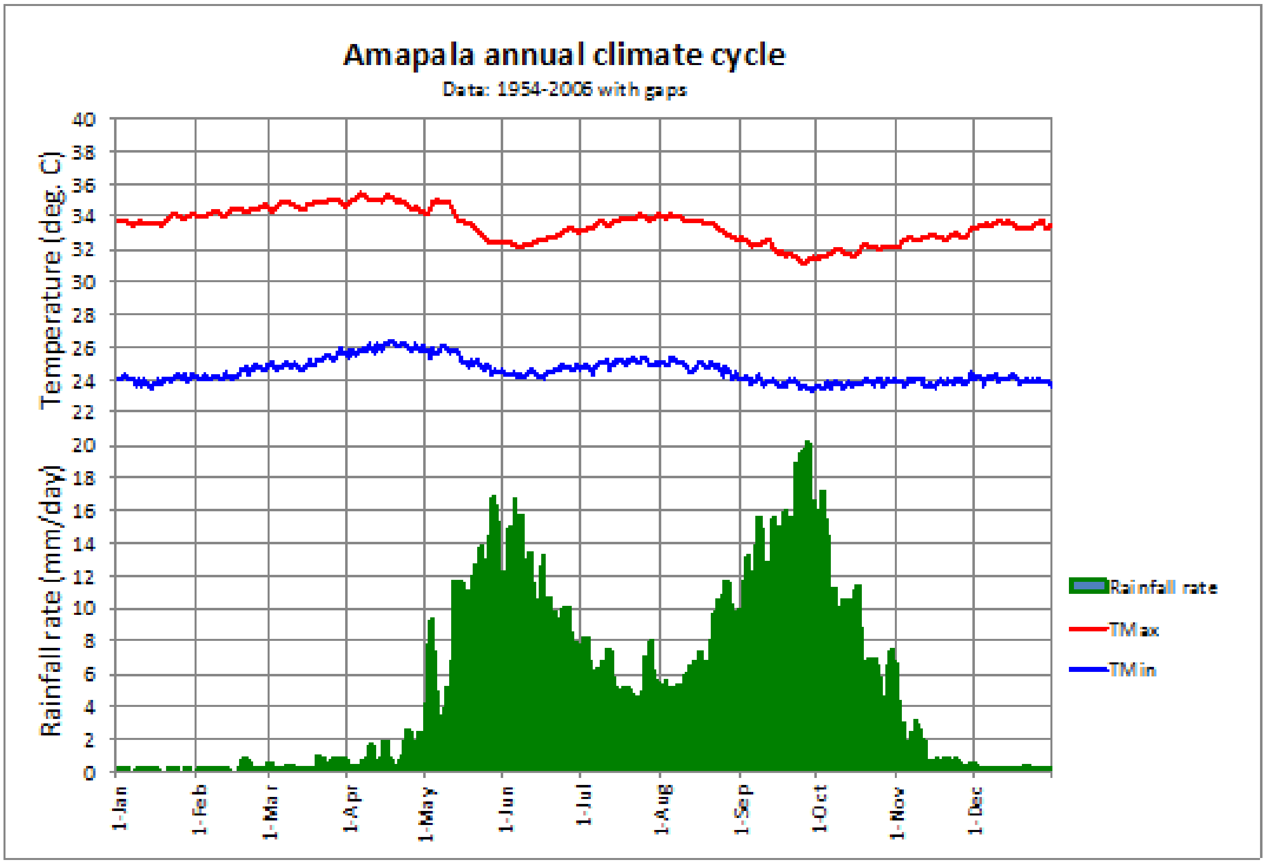
The assessment report was prepared using all of the information gathered throughout the assessment process.

2.0 EXPOSURE TO CLIMATE CHANGE

2.1 GENERAL CLIMATE CHARACTERISTICS OF SOUTHERN HONDURAS

The annual climate cycle throughout the Southern Honduras region features the progression of four clearly identifiable seasonal changes. These are: 1) the dry season (November to April), known colloquially as *verano,* "summer"; 2) a wet season from May to June; 3) a reduction in the rains, called the *canícula*, in July and August; and 4) a second wet season from late August to October (Figure 2.1 shows annual precipitation and temperatures for Amapala, a municipality located in the Valle department of Southern Honduras). The entire wet season from May to October is generally called *invierno*, "winter." The region's ecosystems and socioeconomic systems both have been shaped by this annual climatic cycle. The marked seasonality in rainfall is not accompanied by major changes in temperature. The relative stability of temperatures in Southern Honduras is due to its location well within tropical latitudes, which limits incursions of cool air masses from the north, and to its proximity to warm waters of the eastern tropical Pacific Ocean. The highest temperatures occur in April and May before they fall with the onset of the wet season.

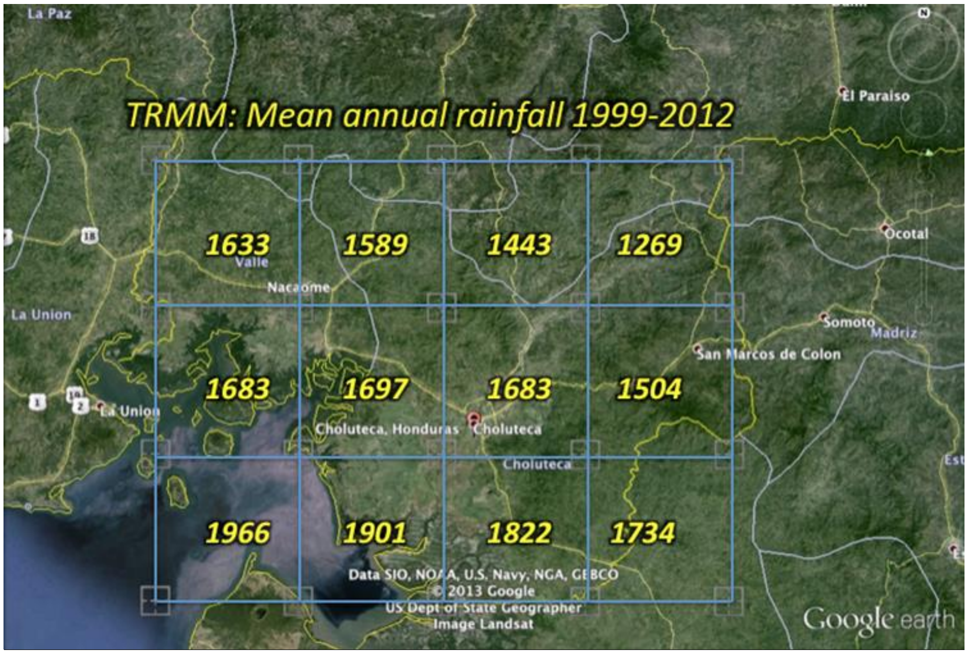
FIGURE 2.1 ANNUAL PRECIPITATION AND TEMPERATURE IN AMAPALA BASED ON DAILY AVERAGES.



Source: A. Seimon, from data provided by Servicio Meteorologico Nacional

Within Southern Honduras, there is a significant rainfall gradient, with approximately 50 percent greater rainfall in the southwest as compared to the northeast (see Figure 2.2 for the research team's analysis of TRMM satellite rainfall data). Annual rainfall peaks can occur at different times depending on location. Temperatures are influenced by elevation and proximity to the coast. The coolest temperatures are found in mountainous areas away from the coast; the hottest temperatures are found in lowlands inland from the coast. Cooler temperatures mean lower rates of evaporation, causing less thermal and hydrological stress to natural ecosystems and crops.

FIGURE 2.2 REGIONAL VARIATION IN MEAN ANNUAL RAINFALL IN SOUTHERN HONDURAS (ANALYSIS BY TEAM CLIMATE SCIENTIST)



Source: A. Seimon, from data recorded by the TRMM

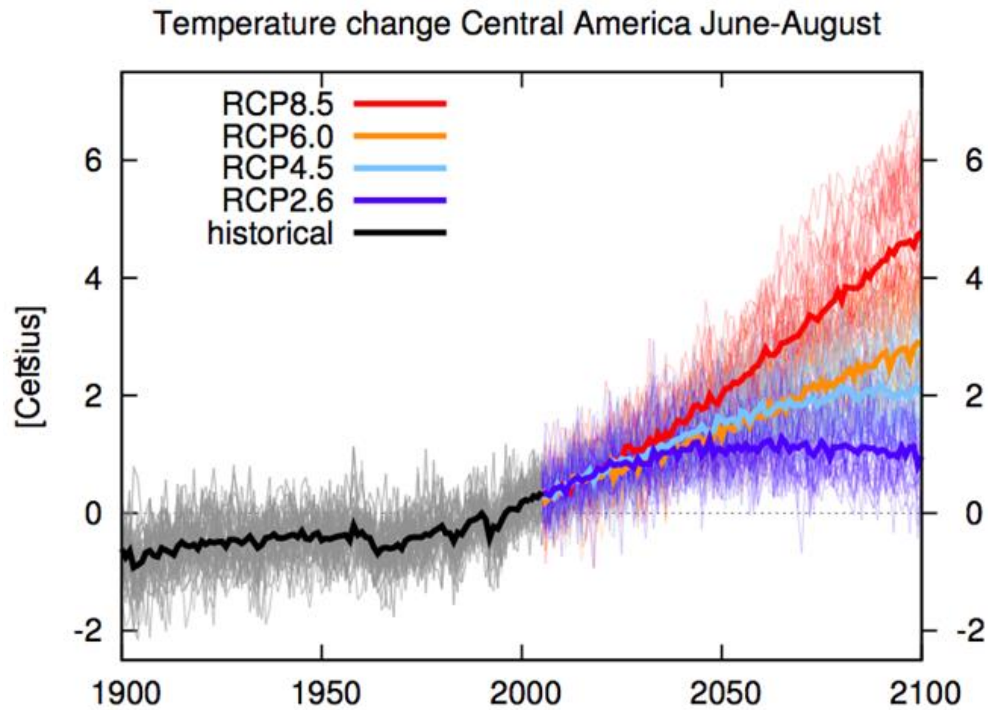
2.2 TEMPERATURE TRENDS AND MODEL PREDICTIONS

After a rapid multi-decade increase in temperature that peaked in 1998, average temperatures across Southern Honduras have been nearly stable for the past 15 years (Berkeley Earth Project, 2013), sustaining high baseline values above any experienced for hundreds, and probably thousands, of years (IPCC, 2013). These patterns closely match trends observed elsewhere in Central America.

Natural variability governs annual to decadal temperature trends through the strong control exerted by the ENSO. The opposing phases of ENSO, El Niño, and La Niña events typically cause monthly temperatures across Southern Honduras to be 0.75–1.0 degrees Celsius above average or below average, respectively. Multi-decadal temperature trends reflect the shifting frequency of El Niño and La Niña events superimposed upon the longer-term global warming signal. A higher frequency of El Niño events relative to La Niña events promotes upward temperature trends. The absence of strong El Niño events since the late 1990s has suppressed the occurrence of exceptionally warm years. There is, therefore, some potential for an upward jump in the mean baseline temperature when an El Niño-dominated pattern of Pacific Ocean sea-surface temperatures occurs.

IPCC model predictions for the region show warming proportional to the degree of prescribed greenhouse gas forcing (Figure 2.3). By mid-century, there appears to be little difference between predictions developed from the four emissions scenarios that were modelled (Recommended Concentration Pathways [RCPs] are the different global emissions trajectories utilized by the IPCC for their Fifth Assessment Report [2013]). Models suggest that by 2050, the hottest temperatures will occur in May, about one month later than at present. The IPCC ascribes high confidence to the likelihood that ENSO will remain the dominant mode of interannual variability throughout the century, so comparable year-to-year temperature variability should continue, superimposed on an overall warming trend driven by greenhouse gas buildup in the global atmosphere.

FIGURE 2.3 IPCC MULTI-MODEL TEMPERATURE PROJECTIONS FOR CENTRAL



Time series of temperature change relative to the 1986–2005 period averaged over land grid points in Central America for June–August under four different RCP greenhouse gas emission trajectories for the 21st century. Thin lines denote model simulations; thick lines the multi-model mean. Source: Reproduced from Figure AI.25 in IPCC (2013) Working Group 1, Annex 1

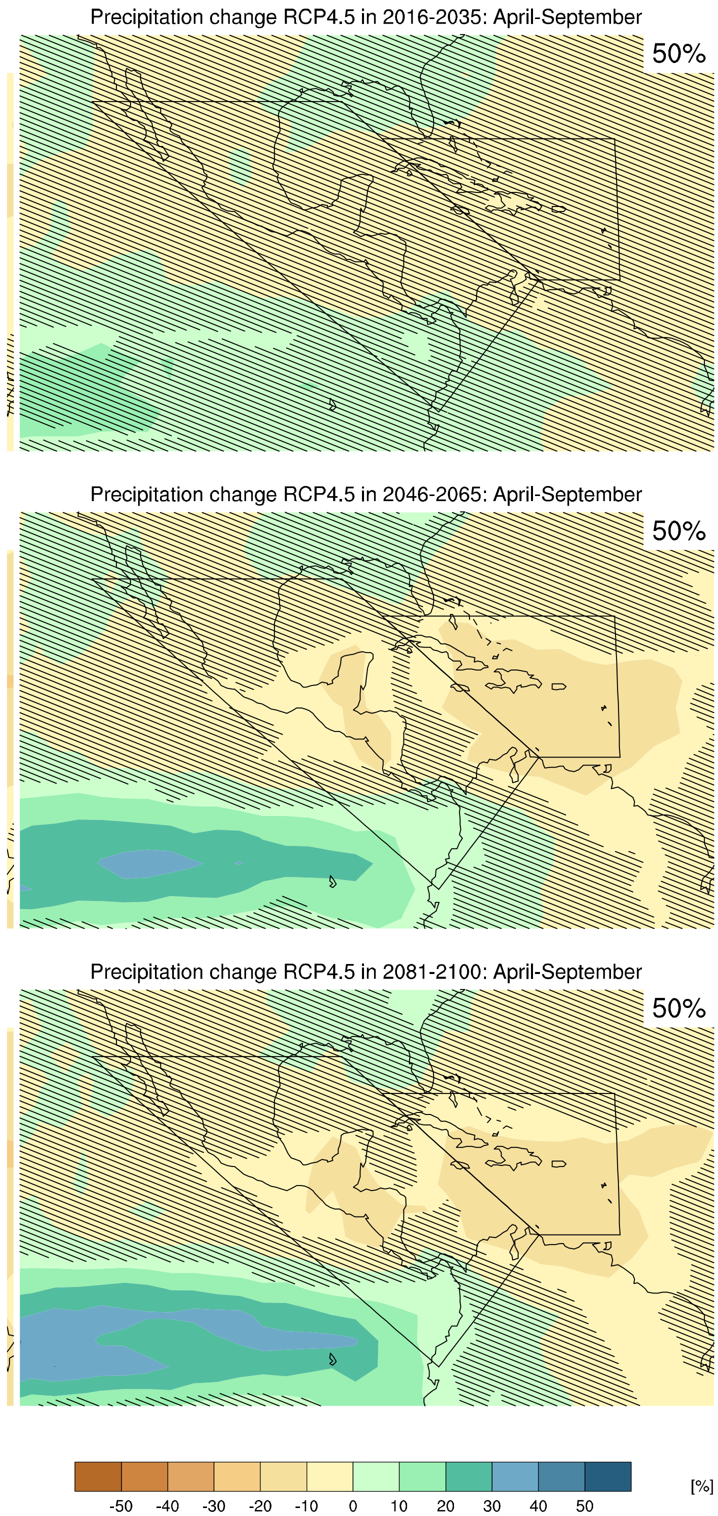
2.3 PRECIPITATION TRENDS AND MODEL PREDICTIONS

An analysis of precipitation trends based on Tropical Rainfall Measuring Mission satellite-based rainfall observations from 1999 to 2013 shows interesting features:

- Significant rainfall events (i.e., one to two days of heavy rainfall) are now common before the onset of the first wet season in mid-May; these events now occur in 50 percent of all years.
- Sub-regional differences are evident in the duration and intensity of the canícula period of reduced precipitation.
- The data suggest a 27-day reduction in the duration of the canícula dry period (from 66 to 39 days) during the past 50 years in the northeastern part of the southern region, with increasing rainfall rates and fewer dry days experienced. The duration is reduced fairly symmetrically at both the beginning and end of the canícula period, representing an encroachment of both wet seasons at the expense of the dry period.
- Observational data identify a strong trend toward wetter conditions in all three seasons characterized by rainfall. Partitioning the trend according to rainfall seasons shows that these increases are experienced across the entire April–November pluvial period.

The recently released findings of the IPCC Fifth Assessment (IPCC, 2013) agree with projections presented in earlier IPCC reports showing long-term drying in Southern Honduras. The maps in Figure 2.4 show modelled precipitation changes for Central America from the IPCC report for 2016–2035 (top), 2046–2065 (middle), and 2081–2100 (bottom) with respect to 1986–2005 in the RCP4.5 emissions scenario. These maps can be taken to represent the consensus of climate predictions under a relatively moderate scenario of anthropogenically-driven climate change. The consensus of all of the individual model simulations, when aggregated together, shows Southern Honduras to be located in the zone of maximum reductions in precipitation in both the mid- and late-century. For example, the map of modelled precipitation given in Figure 2.4 shows that even under a moderate emissions scenario (RCP4.5) a 10–20 percent net decrease in precipitation during the April–September period is predicted by mid-century (2046–2065) for Southern Honduras. This decrease is more severe than predicted for eastern Nicaragua and southern Mexico, or for eastern Honduras. When taken with the model consensus of close to 2 degrees Celsius of warming for the same time period relative to the present, these predictions suggest that by mid-century, Southern Honduras may become a "hotspot" of magnified climate change related stress relative to areas outside the region.

FIGURE 2.4 PREDICTED CHANGES IN PRECIPITATION IN CENTRAL AMERICA TO 2100



Source: Reproduced from Figure A1.27 in IPCC (2013) Working Group 1, Annex 1

2.4 TROPICAL CYCLONES

Tropical cyclones are low-frequency events in Southern Honduras, with only one or two affecting the region per decade. Even so, they can have a major impact on precipitation, bringing up to 50 percent of annual rainfall in a period of only five days. To date, the largest effects have been from Atlantic hurricanes coming ashore in Honduras and Nicaragua, and bringing exceptionally heavy rainfall to Southern Honduras. In the past, cyclones from the Pacific never have been known to hit Southern Honduras as mature systems (at tropical storm or hurricane intensity). There is some evidence for a growing risk from Pacific cyclones, with the only storms known to have approached the Gulf of Fonseca region since observations began in 1949 occurring in 1982, 1988, 1997, and 2005 (Knabb, 2005). Risks may grow due to warming seas and the extension of the hurricane season in time. Detailed climate model predictions of tropical cyclones have not yielded conclusive results, but the warming of sea-surface temperatures off the southern coast will create more favorable conditions for tropical cyclone development than have existed in the past. Rainfall rates in tropical cyclones are expected to increase by approximately 20 percent by late-century as the climate warms, suggesting increasing risks of high-magnitude flood events.

2.5 SEA-LEVEL TRENDS AND PREDICTIONS

Recent trends in sea level in the Gulf of Fonseca region reflect natural variability through the local influence of the ENSO on water temperature and hence sea level. Satellite observations show a slight downward trend in sea level between 1993 and 2012. Tide gauges have recorded an unsteady increase between 2001 and 2010. ENSO variability likely explains these differences between satellite and tide gauge observations, which may perhaps be due to an amplified regional response to El Niño and La Niña events as well as the limited overlap of the time periods in each data set.

An absence of strong El Niño events since the late 1990s has suppressed the temporary occurrence of highly elevated sea levels in the Gulf of Fonseca region. There is therefore some potential for an upward jump in baseline mean sea level with the eventual – and possibly imminent – return to an El Niño-dominated pattern of Pacific Ocean sea-surface temperatures.

The current IPCC assessment asserts that sea-level rise will become dominant over natural variability during the next century, and that major increases are inevitable. Using either the highest or lowest greenhouse gas emission scenarios, the IPCC Fifth Assessment shows very little difference in sea-level increases predicted by 2050. The IPCC projections suggest sea-level increases in the range of 20 centimeters above present levels by mid-century, with natural variability superposed upon that.

2.6 KEY FINDINGS

- After a rapid multi-decade increase in temperatures that peaked in 1998, temperatures in Southern Honduras have been nearly stable for 15 years but are now at levels warmer than any experienced for at least hundreds of years.
- Precipitation measurements from rain gauges, now validated by satellite observations, show a trend of increasing rainfall over several decades.
- The ENSO exerts a strong control on temperature trends in Southern Honduras at annual and decadal time frames.
- IPCC models predict warming by about +2 °C by 2050 due to greenhouse gas forcing.

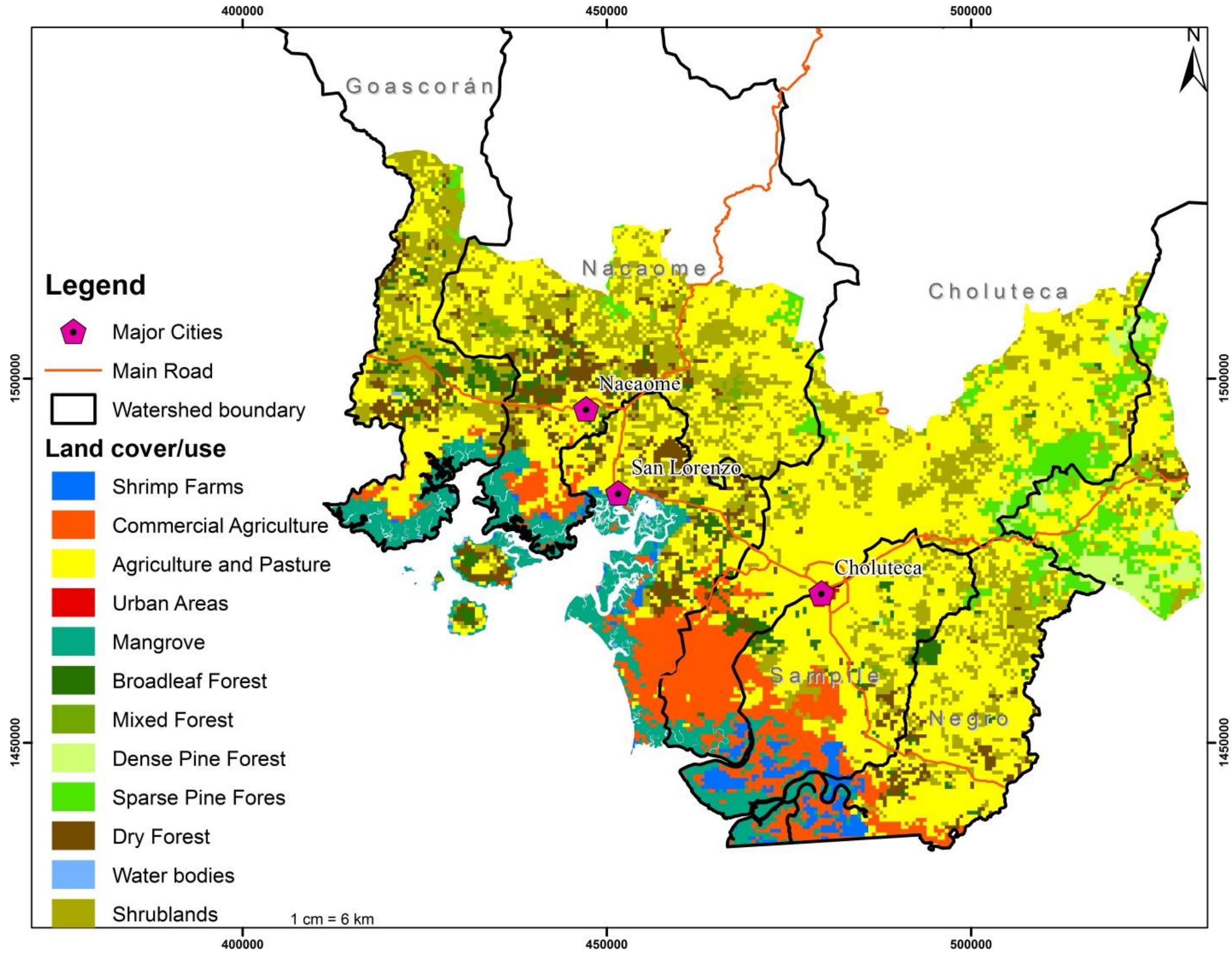
- IPCC multi-model consensus predicts a 10–20 percent decrease in precipitation in Southern Honduras by 2050.
- Temperature and precipitation projections suggest that by mid-century Southern Honduras may be a “hotspot” of magnified climate stress relative to other parts of Central America and Mexico.
- Although temperatures have been relatively stable, and precipitation has been increasing in recent decades, there is potential for a sudden reversal to a warmer, drier climate within a few decades if model projections are correct.
- The potential for a sudden reversal to a drier climate makes it more urgent to take advantage of the current wetter-than-average climate to carry out reforestation of watersheds and other adaptive measures.
- There is potential for a relatively sudden rise in sea level with the next shift to the ENSO “warm” El Niño mode.

3.0 POTENTIAL EFFECTS ON ECOSYSTEMS

3.1 ECOSYSTEM SENSITIVITY TO CLIMATE CHANGE

The spatial distribution of natural ecosystems and human land uses in Southern Honduras are shown in Figure 3.1. This map, based on 2009 Moderate Resolution Imaging Spectroradiometer (MODIS) satellite observations, is the most current land cover and land use map available. The research team has used the seven classes of natural vegetation given on the map as the basis for its analysis of the potential ecological effects of the predicted climate changes discussed in the preceding chapter. These natural ecosystems, shown on the map in different colors, are mangroves, broadleaf forest, mixed forest, dense pine forest, sparse pine forest, dry forest, and shrublands. Shrublands mainly are regenerating dry or mixed forests that previously have been completely or partially cleared and cultivated but have been left fallow, and so represent a transition between agricultural and natural ecosystems. Very small areas of cloud forest ecosystems exist at the highest elevations in the region but are too small to show up on the map. Note that the predominant land cover of the region is not natural ecosystems, but agricultural ecosystems with small-scale crop and pasture lands shown in yellow and large-scale commercial agriculture shown in orange.

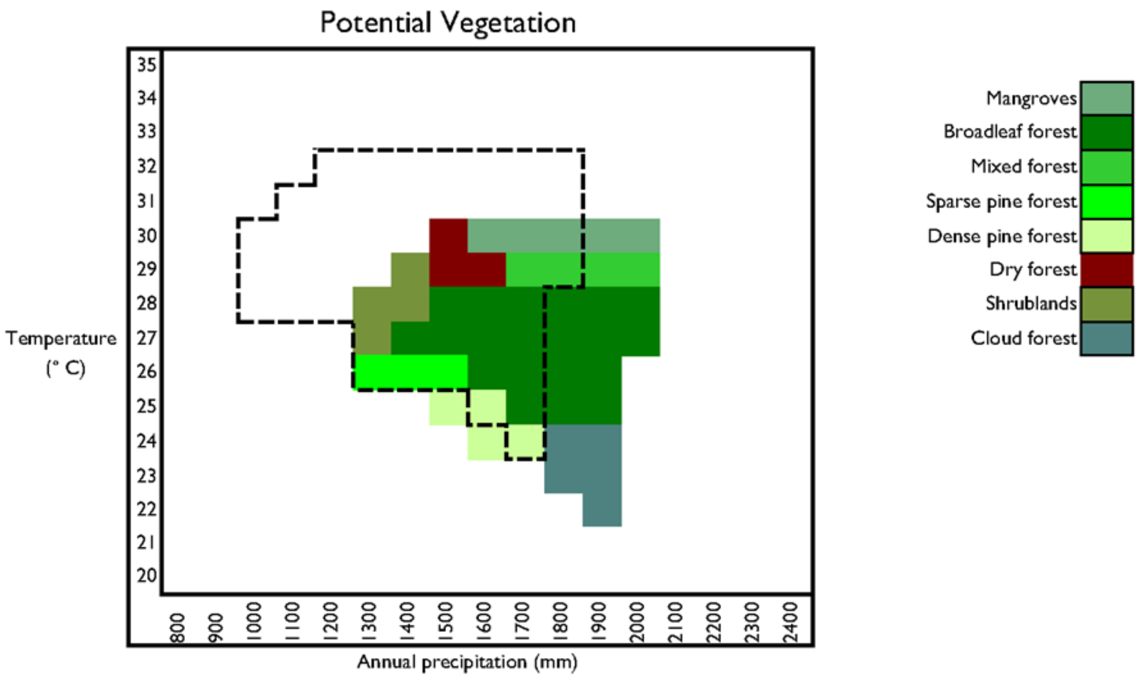
FIGURE 3.1 LAND COVER AND LAND USE MAP BASED ON 2009 MODIS DATA



Source: Rivera et al., 2011

Ecologists often use temperature and precipitation to characterize "climate envelopes" for species and ecosystems (Whittaker, 1975). These "envelopes" outline the combinations of temperature and precipitation within which a species or ecosystem is found. The climate envelope diagram in Figure 3.2 shows how the natural ecosystems of Southern Honduras are distributed with respect to current temperature and precipitation levels. The dotted outline in the diagram shows how the ecological climate envelope would shift by 2050 if the predictions from the IPCC Fifth Assessment Report for a high-emissions scenario were to occur (a temperature increase of +2 °C and a precipitation decrease of –15 percent, about 200 mm less than at present). The IPCC temperature predictions based on different emissions scenarios (see Figure 2.3) show very little difference until about 2040, when the high-emissions scenario curve (RCP8.5) starts to diverge upward from the others. There is little doubt that a 2 °C temperature increase will be reached in Southern Honduras; the only question is when. Given current rates of increase in greenhouse gas emissions, 2050 appears to be the most likely time frame for reaching the +2 °C warming level.

FIGURE 3.2 CURRENT CLIMATE ENVELOPE FOR ECOSYSTEMS IN SOUTHERN HONDURAS AND SHIFT BASED ON IPCC 2050 CLIMATE SCENARIO[1]



Source: Assessment team, 2013

The climate conditions outside of the dotted outline on the right side of the diagram — that is, those areas with precipitation above 1,800 mm/year in the current climate — would probably disappear from the region. The white area inside the dotted outline (above and to the left of the current climate envelope) show new temperature-precipitation combinations that currently are not found in the region but would be added; that is, the white area will be drier and warmer than any climates now found in Southern Honduras. Out of a total of 48 grid cells covered by the current climate envelope, 22 cells of currently existing area would be lost from the cooler and wetter side of the diagram, and an equal number would be gained on the hotter and drier side. This change amounts to 46 percent of the current temperature-precipitation climate envelope in Southern Honduras – a startling result.

This shift would be a significant ecological change that could affect ecosystem benefits. Areas suitable for cooler, moister forest types – broadleaf forests, mixed forests, and pine forests – would decrease, and areas suitable for cloud forests would completely disappear. Areas with climates suitable for shrublands

[1] Annual precipitation values in this matrix are based on satellite-observed rainfall (TRMM) validated by point-source measurements from regional climate stations. Temperatures are inferred from the standard reduction in temperature as a function of height in the tropics (a reduction of ~0.5 °C per 100 m increase in elevation) with long-term means at regional weather stations operated by the Servicio Meteorologico Nacional providing reference baselines. Land use data is drawn from Rivera, Lowry, Hernández, Ramzy, Lezama, and Velázquez, 2011.

and dry forests would increase. The predicted changes would affect ecological functioning and therefore the products and services that these ecosystems provide (Grimm et al., 2013; Nelson et al., 2013).

Effects on Forests

Currently cloud forests exist only in small patches at the highest elevations in La Botija and probably at the top of Cerro Guanacaure. Increased temperatures could reduce the amount of time during which clouds cover the forest, leading to loss of epiphytes such as bromeleiads and associated fauna. This drying would reduce infiltration, soil moisture, and groundwater flow from cloud forest watersheds in the upper Rio Negro drainage. Drying could also make cloud forest susceptible to fires and to replacement by pines, which are fire tolerant.

Cloud-forest bromeliad, La Tigra National Park. Photo by B. Byers

Dense pine forest with pasture, La Botija Multiple-Use Area. Photo by B. Byers, September 2013

Broadleaf forest is found on Cerro Guanacaure and on many small hills within the coastal plain of Valle and Choluteca Departments. Some broadleaf forest is also found in the La Botija protected area. A warmer, drier climate would cause some species to be lost from these forests and shift them toward lower-density mixed forest ecosystems. In a similar effect to that of the loss or degradation of cloud forest, the loss of these montane forests could reduce groundwater infiltration and affect aquifers in the coastal zone unless counteracted by forest regeneration in upland areas.

Broadleaf forest on Cerro Guanacaure. Photo by B. Byers, August 2013

Mixed forests combine elements of broadleaf forests and dry forests. They are found in areas with combinations of precipitation and temperature between those that are ideal for those forest types. Very little mixed forest is identified on the land cover map of Figure 3.1.

Dry forests are found in the warmer parts of Southern Honduras, generally in areas that receive between 1,600 mm and 1,800 mm of precipitation annually. Because of the strongly seasonal distribution of precipitation, dry forests are composed of mostly dry-season deciduous trees, which shed their leaves during the dry season. Dry forests are some of the most converted ecosystems of Honduras, with poor representation in the protected area system of the country (House and Rivas, 2008).

Shrublands — *barbecho* or *guamil* in Spanish — are dry or mixed forests in early stages of succession and regeneration following clearing for crops or pastures. These fallowed areas may be left uncultivated for several years, during which time native species begin to sprout and recolonize the area. A hotter, drier climate likely would slow natural regeneration on these lands. That kind of climate would also favor drought-tolerant species over those with greater moisture requirements. A warmer, drier climate could increase fire frequency in all ecosytems.

Effects on Seasonal Freshwater Lagoons

A hotter, drier climate would decrease the period during which ephemeral/seasonal freshwater lagoons – *lagunas de invierno* – are present. This kind of climate would potentially decrease habitat for migratory waterbirds in coastal wetlands areas, which are now a Ramsar site, of international importance.

Effects on Mangroves

A hotter, drier climate could potentially threaten mangroves in some areas with excess salinity unless counteracted by reforestation in upper watershed zones, which would maintain more stable groundwater flows. Increased salinity could threaten some sensitive shellfish species in the mangroves. If sea-level rise (an indirect effect of climate warming) occurs, then coastal areas now used for sugarcane or shrimp ponds could flood, and areas where mangroves grow could potentially increase.

Effects on the Gulf of Fonseca

From an oceanographic point of view, the Gulf of Fonseca is unique for several reasons. It is shallow, averaging less than 10 m deep; therefore, it maintains warm water conditions throughout the year. Circulation in the Gulf differs between the dry and wet seasons. From May to October, typical estuarine conditions are established, with surface circulation formed by a flow of low salinity and high-temperature water discharged from the rivers entering the gulf. This water is less dense than oceanic water, so this surface current flows out to the Pacific, while oceanic water of higher density (with higher salinity and lower temperature) enters along the bottom of the Gulf from the Pacific and flows toward the coast. During the dry season, evaporation and lower flow of freshwater from rivers cause surface waters in the Gulf to become more saline but warmer. Mixing is reduced, thus reducing nutrient levels and ecological productivity. A hotter climate with less precipitation could cause such conditions to last longer, and some fish species may move deeper, farther from the coast or out of the Gulf completely as they seek cooler and less saline water.

Indirect Effects of Climate Change

In addition to the direct effects of climate change, its indirect effects — and often its synergistic effects in combination with other threats — are likely to threaten some species and ecosystems:

- Sea-level rise caused by climate change could be a significant threat to some coastal species and ecosystems that could not shift their distributions quickly enough.
- Ocean acidification is a threat to some marine organisms, especially those with shells made of calcium carbonate, such as mollusks.
- Increases in the frequency of wild fires are likely to threaten some terrestrial species and forest ecosystems.
- Changes in the distributions of pests and pathogens may threaten some species.

3.2 ADAPTIVE CAPACITY OF SPECIES AND ECOSYSTEMS

- Species and ecosystems have some natural biological capacity to adapt to climate changes of all kinds, as exemplified in the list below:
- Species can move and/or shift ranges altitudinally, for example by moving up to find cooler temperatures as the climate warms.
- Mobile animals can move relatively quickly if the appropriate habitat exists.
- Plants, trees, and ecosystems can only shift their distributions very gradually, through reproducing and colonizing new habitats.
- Species can evolve genetically to tolerate higher temperatures, less rainfall, or other environmental changes. This evolution takes many generations.
- The natural adaptive capacity of species and ecosystems can be increased by specific management actions. For example, creating biological corridors that connect fragments of natural habitat can allow species to move and shift their ranges. Additionally, conserving large-enough areas of a given ecosystem and large-enough populations of a given species will help to conserve the full range of genetic variation within populations and species that allows them to adapt genetically to a changing climate.

3.3 POTENTIAL EFFECTS ON CROP SPECIES AND AGRICULTURAL ECOSYSTEMS

The most important crop species grown in Southern Honduras are generally well-adapted to the hot and seasonally wet climate, including maize, the main staple crop grown by small-scale farmers, as well as sugarcane and melons, the main commercial crops (see Annexes F and G). These crops can tolerate high temperatures during the growing season if enough water is available. The warmer and drier climate predicted by IPCC models would be expected to lead to more frequent water stress for these and other crops.

Studies comparing optimal temperature and precipitation for maize, beans, and coffee throughout Honduras under present and future conditions over the course of the century suggest that a warming and drying climate will become increasingly problematic for agricultural production (Ordaz et al., 2010; Eitzinger et al., 2012). While major declines in yield are projected for the latter half of the century, coming decades will become increasingly variable, with individual years of low yields occurring much more frequently by 2050 than at present (Ordaz et al., 2010). In the southern region all three crops grow in conditions that are warmer than their respective thermal optima, so increased warming will be a factor that increasingly limits yields. For maize cultivation a growing season mean temperature close to 22 degrees is most favorable (Ordaz et al., 2010), whereas in the southern region the current climate along the heavily cultivated coastal plain averages around 29 °C between May and October. For beans, conditions along the coastal plain are already highly unfavorable, and less so as a function of increasing elevation; however, in coming decades conditions supportive of bean cultivation will shift ever higher and further inland (Eitzinger et al., 2012). Areas with a climate suitable for coffee, which are already limited to cooler and wetter upland areas, would decrease.

Maintaining a favorable relationship between crop yield and thermal conditions would therefore require cultivation at higher elevations with cooler temperatures and more moisture, or increased use of irrigation at lower elevations. Shifting cultivation into mountainous areas could exacerbate the loss of permanent, natural vegetation and create additional soil erosion because of steep slopes.

3.4 KEY FINDINGS

- IPCC climate projections of warming and drying for Southern Honduras suggest that by 2050, almost 50 percent of current climate types, as determined by the existing combinations of mean annual temperature and precipitation, would disappear from Southern Honduras and be replaced by temperature-rainfall combinations not found within the region at present.
- Areas suitable for cooler, moister forest types — broadleaf forests, mixed forests, and pine forests — would decrease; areas suitable for cloud forests would disappear completely; and areas suitable for shrublands and dry forests would increase.
- This ecological change would be a significant and would certainly affect the composition and functioning of ecosystems; therefore, it would affect the ecosystem products and services available to people in the region.
- Species and ecosystems have some natural biological capacity to adapt to climate changes of all kinds, and this natural adaptive capacity can be increased through specific management actions such as the creation of biological corridors that allow mobile species to move.
- Key crop species would experience greater water stress in a warmer, drier climate, perhaps leading to pressure to cultivate them at higher altitudes or increase irrigation at lower altitudes.

4.0 VULNERABILITY OF ECOSYSTEM BENEFITS TO CLIMATE CHANGE

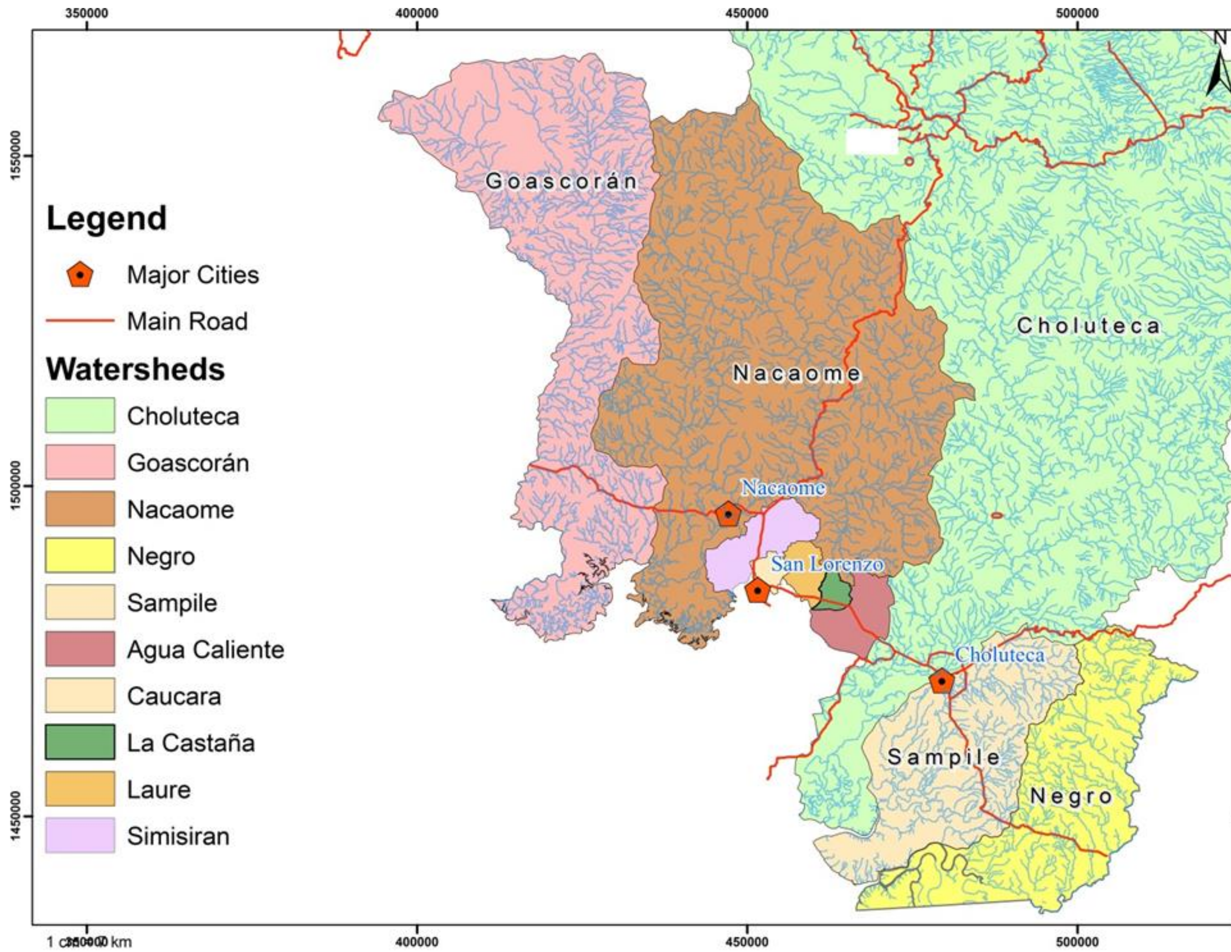
The vulnerability of ecosystem benefits is a factor of their exposure to climate changes, their sensitivity, and their adaptive capacity. Having discussed those issues in Chapters 2 and 3 above, this report will now assess the vulnerability of ecosystem benefits. In the research team's conceptual model, this is the point of overlap and linkage between the ecosystem and the socioeconomic system (see Figure 1.2). For the socioeconomic system, the vulnerability of ecosystem benefits to climate change creates socioeconomic ***exposure*** to the loss of those natural products and services.

In the previous chapter, the reader learned that if the IPCC's latest model predictions for Southern Honduras are correct, there could be a very significant shift in the ecological climate envelope of the region. Such a shift would certainly affect ecosystems and their functioning, and therefore affect the ecosystem products and services they generate. The most serious implication of such a climate shift relates to the eco-hydrological services of upland forest ecosystems that provide clean, stable flows of water to lower watersheds. The impact on water has additional important implications for the eco-hydrology of aquifers on the coastal plain, for mangroves, and for the fisheries that depend on them.

4.1 ECO-HYDROLOGY OF UPPER WATERSHEDS

Figure 4.1 shows a map of the watersheds draining into the Gulf of Fonseca. Five main rivers flow into the Gulf. Five small catchments on the coastal plain between Choluteca and Nacaome are also shown on the map because those small watersheds play an important role in the hydrology of the coastal zone. The natural features of the watersheds of Southern Honduras make them very hydrologically vulnerable. Climate change will only add more uncertainty and exacerbate problems in these already vulnerable watersheds, as the research team explains in this chapter.

FIGURE 4.1 WATERSHEDS OF SOUTHERN HONDURAS



Hydrologists describe watersheds in terms of their natural features: geomorphology, geology, soils, climate, and land cover. Together these features affect the quantity, quality, and timing of the flow of water from the watershed and give an indication of its hydrological fragility. If available, hydrologists also analyze data on stream flow and precipitation in order to infer catchment runoff patterns and flow paths. Stream flow, one of the main outputs of a watershed, is an integrated signal of the interaction among all the natural features of the watershed (Caballero et al., 2012; Caballero et al., 2013).

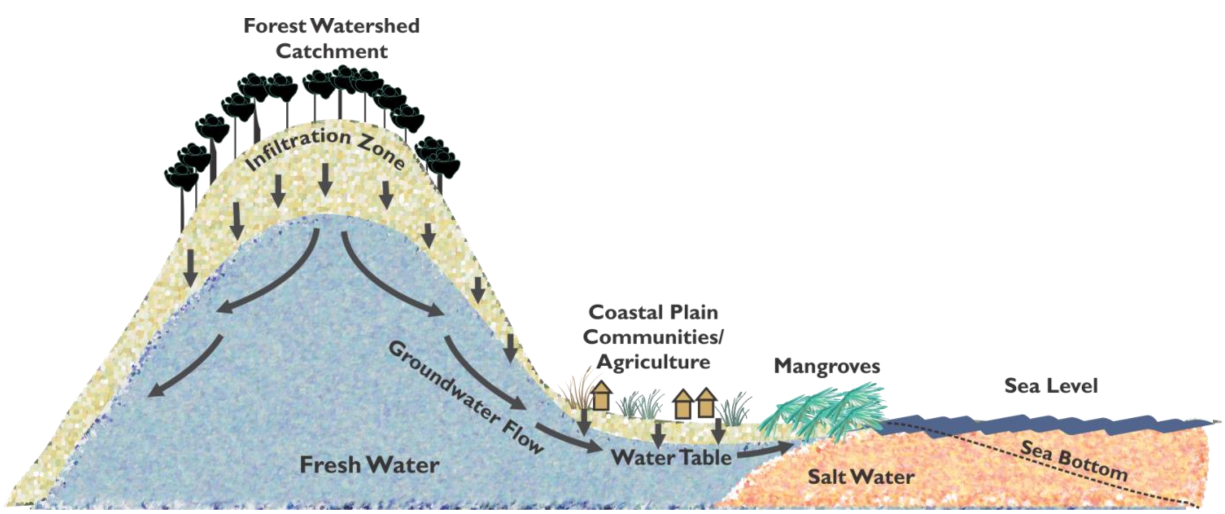
Geomorphological features determine how concentrated and rapid the flows could be during and immediately after a rainfall event. Gulf of Fonseca watersheds are generally steep, with an average slope of about 17 percent (Table 4.1). These slope values indicate that these watersheds are prone to a very rapid flow of both surface and subsurface runoff. With such steep slopes, water can flow from the upper parts of the catchment to the Gulf of Fonseca very rapidly. During Hurricane Mitch, an extremely high-precipitation event, for example, it took only about 36 hours for precipitation from the headwaters of the Choluteca River to reach the Gulf of Fonseca (Smith et al., 2002). Even during normal flow conditions, headwater flows might reach the Gulf in 12 days.

TABLE 4.1 PACIFIC BASIN WATERSHEDS

River/Watershed	Watershed area (km2)	% share of Pacific Basin by area	Average slope (%)
Choluteca	7109.20	53.33	22
Nacaome	2707.00	20.31	22
Negro	801.50	6.01	13
Sampile	738.10	5.54	8
Goascoran	1666.00	12.50	21
Simirisan	114.40	0.86	--
Agua Caliente	101.70	0.76	--
Laure	45.00	0.34	--
La Castana	24.40	0.18	--
Caucara	23.90	0.18	--
Total	**13,331.20**	**100.00**	**17**

The type of vegetation in a watershed, i.e., the land cover, is the most important factor affecting watershed hydrology because of its effect on the rate at which precipitation either infiltrates into the ground or runs off the surface. Permanent vegetation, such as that of natural forest ecosystems, is much more effective in allowing infiltration than are crop fields, pastures, and shrublands (see Figure 3.1). When forested, landscapes capture water and feed it into ground water flows. In forested watersheds, only a fraction (4 to 8 percent) of the total stream flow comes from direct runoff; most comes from infiltrated groundwater, which eventually produces a base flow of subsurface water that reaches the streams (Caballero et al., 2012; Caballero et al., 2013; see Figure 4.2). Infiltration stabilizes stream flows, minimizes soil erosion, improves water quality, and recharges underground aquifers. Watersheds with a low percentage of permanent land cover are subject to higher surface runoff, lower infiltration rates, more soil erosion, and lower base flows following precipitation events. Lower base flows persist into the dry season in these watersheds.

FIGURE 4.2 ECO-HYDROLOGY OF SOUTHERN HONDURAS



Source: Assessment team, 2013

Hanson et al. (2004) found that in the Talgua River watershed of Honduras, infiltration rates decreased by 100-fold when land cover changed from primary forest (infiltration rate: >840 mm/hr) to coffee plantation (89–109 mm/hr) to heavily-grazed pasture (8–11 mm/hr). Recent studies of two experimental watersheds with different permanent land cover ratios — in this case in areas with pine forests, shade-grown coffee, and crop agriculture — suggest that in areas with similar soils and climates, the permanent land cover ratio directly affects the ratio of infiltration to direct runoff. In the Zapotillo watershed, with a permanent land cover ratio of 59 percent, the runoff rate was 31 percent; meanwhile, the adjacent Capiro watershed, with a permanent land cover ratio of 39 percent, had a runoff rate of 39 percent (Bonilla Portillo and Garay, 2013). Thus, conversion from forest to other land uses leads to a shift from primarily infiltration to primarily surface runoff (causing more rapid and higher peak flows following rainfall events), and to a reduction in dry season base flows (Grupta et al., 1974; Grupta et al., 1975; Bruijnzeel, 1989; Bruijnzeel, 2002).

Broadleaf forest cleared for pasture near Cerro Guanacaure.
Photo by B. Byers, August 2013

Truck stuck in the flooding Río Sampile below El Corpus during a heavy rain. Photo by B. Byers, September 2013

A recent study of four micro-watersheds in La Tigra National Park, Honduras, found that watershed discharge on a per-area basis was four times greater from the cloud forest than from the other watersheds, despite relatively minor differences in annual rainfall. "These results highlight the importance of biological factors (cloud forests in this case) for sustained provision of clean, potable water, and the need to protect the cloud forest areas from destruction, particularly in the populated areas of Central America." (Caballero et al., 2013). This finding can be generalized to point out the importance of ecological factors in hydrological systems in general. For this reason the authors use the term "eco-hydrology" in this report.

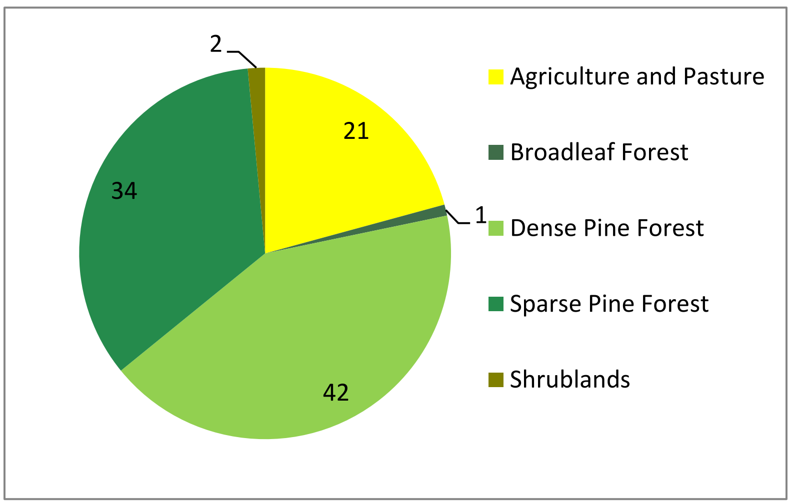
The ratio of permanent land cover to total area in a watershed — essentially a measure of the extent to which natural ecosystems have been conserved in an area — is an indicator of its eco-hydrological vulnerability and/or resilience. Most watersheds in Southern Honduras have a permanent land cover ratio of less than 50 percent, indicating that the majority of the landscape has been cleared of natural vegetation and converted to croplands or pastures (Table 4.3). There is no doubt that eco-hydrological processes in these watersheds already have been seriously altered, especially the ratio of baseflow to direct runoff. Erosion and soil loss in these watersheds is high, and rivers carry and deposit high-sediment loads. Some major rivers (e.g., the Choluteca, Sampile, and Negro) may become dry in their lower stretches during the late dry season because of high levels of sedimentation of the riverbed, even though water may be flowing underground in the channel.

If the permanent land cover ratio is used as an indicator, the Río Sampile watershed is the most eco-hydrologically vulnerable in Southern Honduras, followed by the Río Negro watershed, and then by the Río Nacaome watershed (see Table 4.3).

TABLE 4.2 PERMANENT LAND COVER RATIO FOR MAJOR WATERSHEDS OF THE GULF OF FONSECA

River/Watershed	Area (km^2)	Permanent Land Cover (km^2)	Permanent Land Cover Ratio
Choluteca	7109	2546	0.36
Goascoran	1666	465	0.28
Nacaome	2707	581	0.21
Negro	802	77	0.10
Sampile	738	52	0.07

FIGURE 4.3 LAND COVER CONTRASTS (%) IN SAN JUAN DE DUYUSUPO AND EL JOCOTE COMMUNITIES, MUNICIPALITY OF SAN MARCOS DE COLON



Two of the communities that the research team visited provide a striking contrast in land cover and land use in their immediate vicinities; they also illustrate the significance of the permanent land cover ratio. To characterize the differences, the research team calculated the area under each type of land cover or use (see Figure 3.1) within a radius of 4 km from the community, a total area of about 50 km^2, and plotted them in pie charts to provide a land use "snapshot." These pie diagrams show the percentage of the area surrounding the community covered by natural ecosystems of various types (i.e., permanent land cover) or agricultural land uses of various types (i.e., non-permanent land cover). Because human land uses reflect local economic activity, these pie charts give an integrated, visual summary of both the local ecology and local economy.

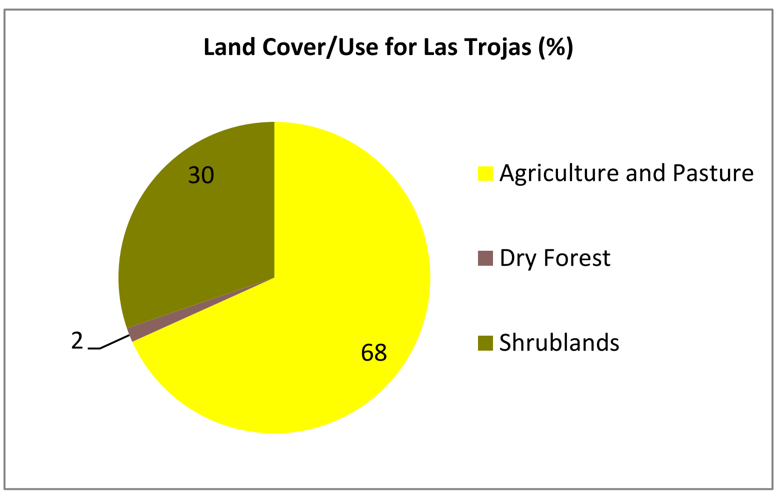
San Juan de Duyusupo and neighboring El Jocote are small rural communities in the municipality of San Marcos de Colon, located about 20 km south of the municipal capital within the Montaña La Botija multiple-use protected area. Natural ecosystems here are mainly pine and mixed pine-oak forests, which cover about three-quarters of the landscape. A small area of cloud forest is found here at the highest elevation. The mountains of La Botija form the upper watersheds of the Río Coco, flowing north to the Atlantic, and the Río Negro, flowing into the Gulf of Fonseca.

Approximately 10,000 people live in about 2,000 rural households in this area. The main livelihoods are raising livestock; production of basic grains (e.g., maize, beans, sorghum); and coffee production. Livestock production is the basis of the local economy, with 40 percent of households having from a few to up to 30 cattle. There is a surplus of production, which is sold to local markets. Cattle graze in the natural pine and pine-oak savanna habitats, so this system is silvipastoral. Production of basic grains is for household consumption only, and about 40 percent of the population grows these subsistence crops. Coffee production is possible at the elevations found here, and over 600 hectares of coffee are now being grown under shade in native pine-oak forests. According to community informants, this economic sector is very important now; approximately 20 percent of the population depends on income from coffee, and production is expanding. While providing income, coffee farms also conserve the natural permanent land cover.

Looking toward the core of the La Botija protected area from a cattle farm near San Juan de Duyusupo.
Photo by B. Byers, September 2013

Coffee planted under the shade of a natural pine-oak forest near San Juan de Duyusupo.
Photo by B. Byers, September 2013

FIGURE 4.4 LAND COVER/USE FOR LAS TROJAS



Las Trojas is a community in the municipality of Concepción de Maria. It presents a dramatic contrast to San Juan de Duyusupo, which is only a short distance away. Las Trojas lies in the watershed of the Río Tiscagua, one of the tributaries of the Río Negro. The river starts on Cerro Guanacaure, a multiple-use protected area that is within the Municipality of El Corpus. About 20,000 people live in about 3,500 households in the valley. The landscape is dominated by crop fields and pastures, which cover 68 percent of the surface; approximately one-third of the land is shrubland, generally regenerating dry or mixed forest that had been cleared for crops in the past but that is currently fallow. Only about 2 percent of the area is natural dry forest.

About 90 percent of the families here grow basic grains – about 60 percent of which is eaten directly, and 40 percent of which is sold in local and regional markets. Basic grain crops are often planted on steep slopes, and soil erosion is a problem. When soils erode, they lose their fertility, and production goes down. Keeping livestock is the other major livelihood activity here, and the valley has approximately 1,400 hectares of pastures, which were cleared from forest originally, and many of which are burned to keep them from reverting to forest. About a quarter of the pastures belong to small producers, but the majority belong to large producers. Ten percent of the families here engage in livestock keeping both for food and for sale, and around 40 percent of household incomes come from livestock sales – the same percentage as for sales of basic grains. Some fruits (e.g., avocado, mango, mandarins, oranges, lemons) and vegetables (e.g., tomatoes, chile, squash) are grown for consumption and sale in regional markets (El Triunfo, Choluteca). Community members estimated that about 60 percent of adults from the area take seasonal work in commercial agroindustries in the coastal areas below or are involved in artisanal mining. About 5 percent of families here receive remittances that help support them.

This community seems to illustrate what has been called the "forest-hydrology-poverty nexus," in which a lack of local economic opportunities provides incentives for clearing forests in order to grow subsistence crops, which in turn has negative effects on the hydrology of the entire downstream watershed (Nelson and Chomitz, 2004).

Beans, maize, pastures, and shrublands above Concepción de Maria. Photo by B. Byers, September 2013

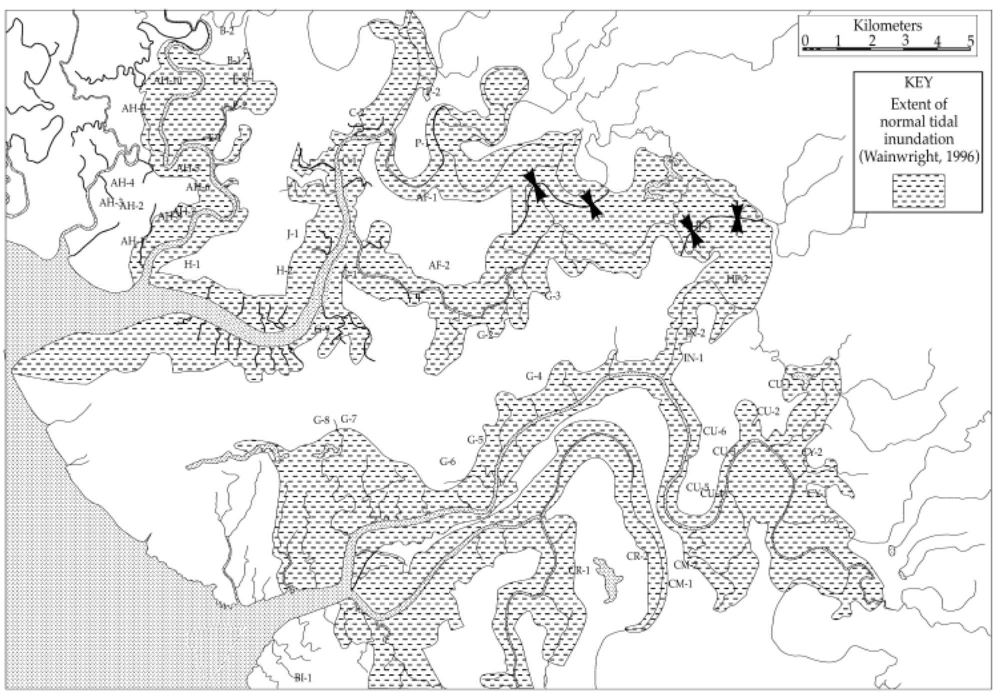
Maize planted on a steep slope above the Río Tiscagua near Las Trojas community.
Photo by B. Byers, September 2013

4.2 ECO-HYDROLOGY OF THE COASTAL ZONE

The eco-hydrology of the coastal zone is also affected by the permanent land cover ratio in two main ways. First, the coastal zone, including the coastal plain and mangrove zone, depends on groundwater flows from the upland watersheds to push saltwater down and back, maintaining a water table of freshwater that reaches to the inland edge of the mangrove zone. Second, mangrove ecosystems themselves function in ways that affect the hydrology of the coastal zone.

Mangrove ecosystems are coastal, intertidal forest ecosystems dominated by a few species of salt-tolerant trees. Mangroves generally are most prolific in river deltas where fresh water and saltwater mix, and some sediment is deposited. The five main rivers that discharge into the Gulf of Fonseca form extensive, braided estuaries that create ideal conditions for mangroves. Figure 4.5 shows the tidal range in the El Predragal and San Bernardo estuaries; the stippled intertidal zone indicates the extensive area of potential habitat for mangroves. The coastal zone of the Gulf of Fonseca now has 37 percent of the total area of mangrove forests in Honduras (ICF, 2011), with approximately 24,000 hectares of mangroves in Choluteca Department and an equal area in Valle. Mangroves were once more extensive here before the advent of large-scale commercial shrimp aquaculture that began in the 1980s.

FIGURE 4.5 INTERTIDAL AREAS OF POTENTIAL MANGROVE HABITAT, ESTERO EL PREDREGAL AND ESTERO SAN BERNARDO



Source: Wainwright, 1996

Six mangrove species are found in the Gulf of Fonseca: *Rhizophora mangle, Rhizophora racemosa*, *Aviccennia germinans*, *Aviccennia curumo*, *Laguncularia racemosa*, and *Conocarpus erectus* (AFE-COHDEFOR, 2002). Because they grow in areas of soft, depositing sediments, many mangrove species have extensive systems of propping roots. These roots create a complex physical structure and substrate that provides shelter and habitats for many marine species.

Red mangroves in Bahia de Chismuyo Habitat/Species Management Area.
Photo by B. Byers, August 2013

Mangrove root systems trap sediments and nutrients, and build coastlines seaward. They protect the coast from erosion from waves, tides, and storms. Mangroves can retard the flow of freshwater from land to sea, acting like a living "dam" or barrier, and thereby helping to prevent saltwater intrusion into coastal aquifers (see Figure 4.2). Some species have the physiological ability to remove salt from seawater and to excrete it on their leaves, which also adds to their ability to prevent saltwater intrusion. Mangroves serve as important bio-filters to remove nutrients and contaminants coming from the inland watersheds, protecting the waters of the Gulf of Fonseca from land-based pollution. Mangroves sequester carbon from the atmosphere in the physical structure of the tree, roots, and leaves, as well as in the organic matter deposited in the mud on which they grow.

Because they grow in water in the intertidal zone, the climate envelope suitable for mangroves is not expected to shift as dramatically as that of upland ecosystems under predicted changes in precipitation and temperature (see Figure 3.2). Reductions in freshwater flows from rivers that would occur in a warmer and drier climate could affect mangroves by changing salinity levels and sedimentation rates. Sea-level rise could remove mangrove habitat at the coastal margin but could also create potentially suitable habitat farther inland. Due to their ability to trap sediments and build coasts seaward, mangroves are a natural buffer to potential sea-level rise.

The 18,500 hectares of commercial shrimp ponds that exist today around the Gulf of Fonseca were originally constructed in areas of mangroves or in areas of extensive mangrove-fringed tidal flats and lagoons that filled with brackish water during the wet season, called *lagunas de invierno*. Satellite images document the dramatic expansion of shrimp ponds that has occurred since the 1980s (Figure 4.6). In the 1973 image, mangroves appeared to cover most of the zone of potential intertidal habitat shown in Figure 4.5.

The eco-hydrology of the mangroves and coastal zone is extremely complex and has been studied very little. The best studies conducted to date focused on the areas of extensive shrimp pond development in the San Bernardo and El Predregal estuaries near the Nicaraguan border (Ward, 1995; 2000). USAID supported studies through the Aquaculture and Pond Dynamics Collaborative Research Support Program (CRSP). The studies were carried out because of concern that shrimp pond levees might diminish tidal flushing and lead to degraded water quality in the estuaries (Ward, 1995). When shrimp are concentrated and fed in ponds, the nitrogenous wastes that are produced must be flushed out by pumping cleaner water into the ponds, or else oxygen levels could drop so low that the shrimp would die. "In effect, these shrimp farms could eliminate the tidal flats, hydraulically isolating these areas by enclosure within levees to create their shrimp ponds." (Ward, 2000:14) Most shrimp ponds were constructed on tidal flats inside the mangrove fringe approximately following the extent of normal tidal inundation, so the reduction of the tidal volume is limited. Shrimp farms in the upstream sections of the estuaries do reduce tidal flushing, but there the more important control on water quality is the volume and quality of freshwater inflows from upstream watersheds. (Ward, 2000)

For the river-channel estuaries in the Gulf of Fonseca where shrimp farming is being practiced, hydrographic variables such as tidal range, freshwater throughflow, tidal currents, and salinity levels control the effect of shrimp ponds on their water quality. Above a certain level of shrimp pond development, water quality in the estuary can become so degraded as to prohibit economical aquaculture. In other words, the estuaries of the Gulf of Fonseca have a certain "carrying capacity" for shrimp cultivation due to their eco-hydrology. The studies by Ward lead to the important conclusion that freshwater flows in the wet season are very important for maintaining water quality suitable for shrimp farming. Because climate change could diminish these flows through its effects on the eco-hydrology of the upper watersheds, it could thereby threaten shrimp production, at least in the upper sections of the estuaries.

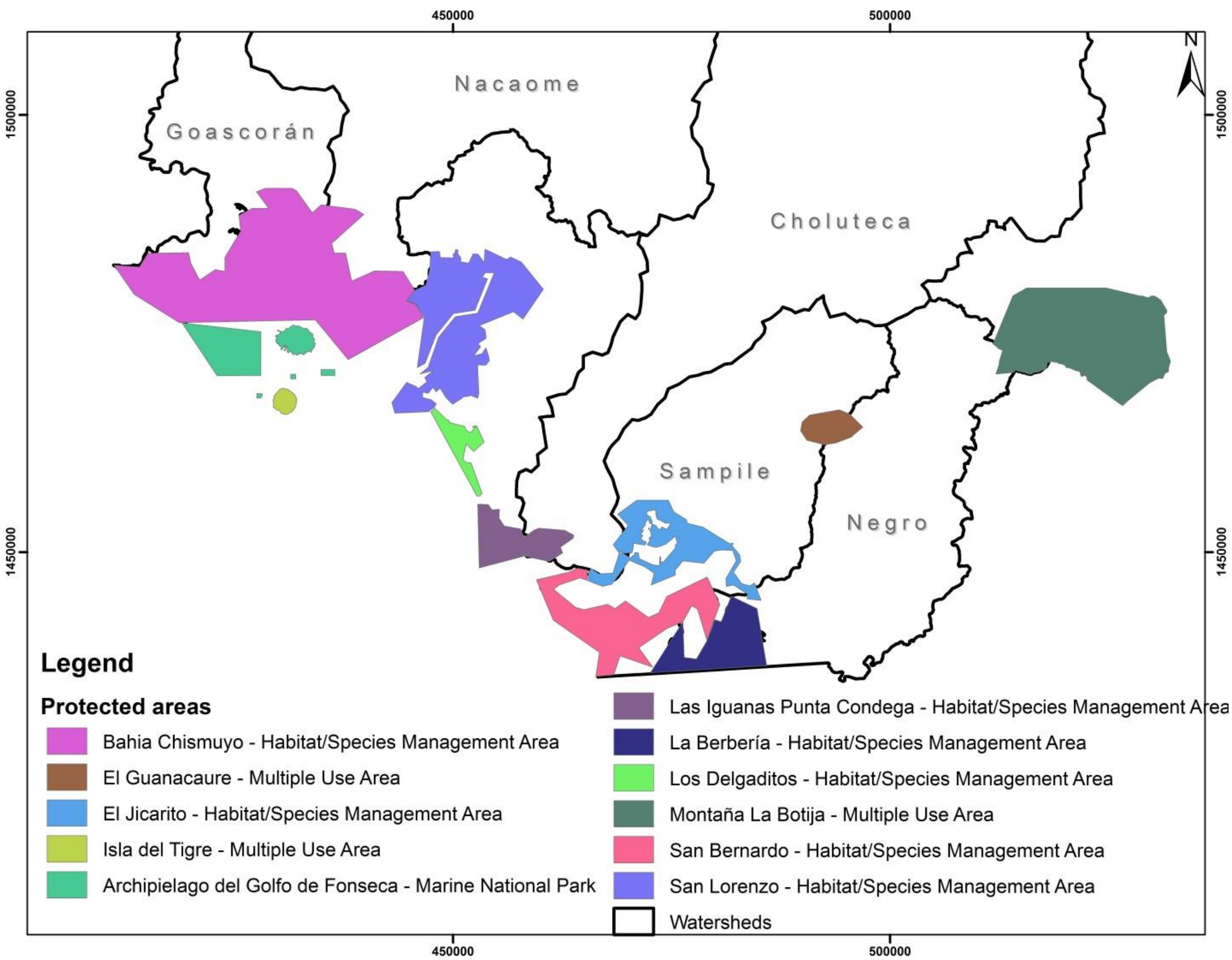
FIGURE 4.6 LANDSAT THEMATIC MAPPER SATELLITE IMAGERY OF THE EL PREDREGAL AND SAN BERNARDO ESTUARIES DURING THE DRY SEASON; UPPER IMAGE FROM JANUARY 1973; LOWER IMAGE FROM APRIL 2006

Source: UNEP, CATHALAC, and USAID, 2005

4.3 PROTECTED AREAS AND ECOSYSTEM BENEFITS

Because the 11 protected areas of Southern Honduras conserve significant, critical areas of natural vegetation (i.e., permanent land cover) in the region, they contribute significantly to the permanent land cover ratio, both in the upper areas of watersheds and in the coastal mangrove zone. This effect can be visualized by comparing the distribution of natural ecosystems on the land cover map in Figure 3.1 with the map of protected areas in Figure 4.7. Because the ratio of permanent vegetation to total land area in a watershed is an indicator of its eco-hydrological vulnerability to climate change, these protected areas could be said to anchor the natural climate resilience of the region.

FIGURE 4.7 PROTECTED AREAS OF THE GULF OF FONSECA



4.4 KEY FINDINGS

- The natural features of the watersheds of Southern Honduras, especially their steepness, make them hydrologically very vulnerable to rapid flows of both surface and subsurface runoff after rainfall events.
- Permanent types of vegetation, especially forests, are more effective at allowing infiltration than are non-forested areas, and also therefore at regulating stream flow quantity and quality over time. In forested watersheds, only a fraction of the total stream flow comes from direct runoff; most comes from infiltrated groundwater.

- The ratio of permanent land cover to total area in a watershed — essentially a measure of how much natural forest is left — is an indicator of its eco-hydrological vulnerability.
- Most watersheds in Southern Honduras have a permanent land cover ratio of less than 50 percent, and there is no doubt that eco-hydrological processes in these watersheds already have been seriously altered, especially the ratio of infiltration to direct runoff.
- The ecological effects of the predicted climate changes described in Chapters 2 and 3 would potentially decrease the area of cooler-wetter upland forest ecosystems, leading to decreased ability of the affected watersheds to retain water, retard runoff, and recharge the upland infiltration zone. These changes would significantly decrease the key ecosystem benefit to the region – stable flows of clean water from the upland forest areas of watersheds.
- In addition to the five main rivers that flow into the Gulf of Fonseca, five small catchments on the coastal plain between Choluteca and Nacaome play an important role in the hydrology of the coastal zone. These small catchments are key in maintaining water tables up for shallow aquifers that are water sources for Choluteca, San Lorenzo, Nacaome, and many other small communities in the coastal zone.
- The eco-hydrology of the coastal zone is also affected by the permanent land cover ratio. The coastal zone, including the coastal plain and mangrove zone, depend upon groundwater flows from the upland watersheds of the region to push saltwater down and back, maintaining a water table of freshwater that reaches the inland edge of the mangrove zone.
- Mangrove ecosystems affect the eco-hydrology of the coastal zone in complex ways. Few studies of mangrove eco-hydrology have been conducted.
- Freshwater flows in the wet season are very important for maintaining water quality suitable for commercial shrimp farming. Predicted climate changes could reduce the amount and quality of water entering the estuaries from upper watersheds, and thereby reduce the potential yields and economic viability of shrimp aquaculture.
- Because the 11 protected areas of Southern Honduras conserve significant areas of natural vegetation (i.e., permanent land cover), they significantly contribute to the permanent land cover ratio, both in the upper areas of watersheds and in the coastal mangrove zone. As the ratio of permanent vegetation in a watershed is an indicator of its eco-hydrological vulnerability to climate change, these protected areas could be said to anchor the natural climate resilience of the region.
- Due to the fact that the eco-hydrology of Southern Honduras links upper watersheds to the coastal and marine zone, an ecosystem-based approach to climate change adaptation is needed in the region.

5.0 SOCIOECONOMIC SENSITIVITY TO THE LOSS OF ECOSYSTEM BENEFITS

According to the conceptual model used in this assessment, the ***sensitivity*** of people and their livelihoods to ecosystem benefits losses that could be caused by climate change is a reflection of their dependence on those benefits (see Figure 1.2). This chapter describes the dependence of communities and livelihoods in Southern Honduras — and indeed the economy of the entire region — on ecosystem products and services that may be threatened by climate change. According to the IPCC, sensitivity and adaptive capacity are independent terms that factor together to affect vulnerability. Adaptive capacity will be discussed in the next chapter.

The livelihoods of most rural households in Southern Honduras depend on a combination of subsistence production of staple food crops (mainly maize and beans) and livestock in upland, rain-fed zones; artisanal fisheries and some staple crop production on the coastal plain; jobs and income from small and medium agro-enterprises for local or regional markets; and income from employment in large-scale commercial export industries of crops (melons, sugar; see Annexes F and G) and shrimp. All of these agricultural livelihoods and commercial enterprises depend on ecosystem products and services.

5.1 DEPENDENCE ON ECOSYSTEM PRODUCTS

Ecosystem products are material benefits such as food, building materials, fuel, fibers, and medicines that are obtained from wild species harvested from natural ecosystems. Ecosystem services are material benefits that result from the ecological processes and functions in ecosystems, such as stable flows of water from forested watersheds, nutrient cycling in soils, pollination, and oxygen and carbon cycling through photosynthesis (USAID, 2005). Domesticated crop and livestock species are not considered ecosystem products because they are not wild species harvested from natural ecosystems; however, all such agricultural products indirectly depend on ecosystem services such as water from watersheds, pollination from wild pollinators, and nutrient cycling from soil microorganisms for soil fertility.

Fish and Shellfish

Fish and shellfish harvested from the natural ecosystems of the Gulf of Fonseca are by far the most important ecosystem products that support livelihoods in Southern Honduras. In the coastal zone, fishing is a major source of food, employment, and income. Fishing is mainly artisanal, employing low-technology fishing techniques and using small craft. Its importance lies more in the number of jobs generated and the food security it provides than in the total generated economic revenue.

Mangrove ecosystems are the ecological "factory" for the production of fish and shellfish. Many studies have shown a correlation between the production of fish and shellfish and mangrove area, especially for shrimp; however, the ecological relationships are complicated and still not well understood. (Aburto-Oropeza et al., 2008; Manson et al., 2005)

According to an assessment of fishing activity by the Fisheries and Aquaculture Development Project for the Gulf of Fonseca (AECID, 2012), from 2008 to 2009 there were approximately 2,000 active fishermen in the Gulf, fishing from about 1,000 boats and traveling from 35 embarkation points. Between 2004 and 2005, the average number of persons fishing per day was estimated to be around 1,000; between 2008 and 2009, the average number of persons fishing per day had decreased to about 800. This decrease in fishing effort is attributed to overfishing of stocks and to marine territorial conflicts between Honduras and its neighbors, Nicaragua and El Salvador. (AECID, 2012)

Artisanal and small-scale fisheries in this region comprise mixed-species confined to shallow waters and mangrove estuaries. Fishermen exploit a range of fish using nets and lines, and shrimp are captured using a variety of gear. Four types of fish — grunts, marine catfish, corvina, and stingrays — account for more than half of the weight of the total catch of the region. The remainder of the catch weight is made up of at least 60 other species of fish, crustaceans, and mollusks.

One type of fishery, known locally as *pesca a pie*, involves harvesting the mangrove bivalve *Anadara tuberculosa*, known locally as "*curil*," by wading in the mangroves at low tide and collecting *curiles* by hand. C*uriles* are found mainly in areas with red mangroves, one of the five species of mangroves found around the Golfo de Fonseca. *Curileros* usually are from poor families with little education, low literacy, many children, and few alternatives to generate income. Many *curileros* are women and children (Box, 2012). The average income of a *curil* collector is $6.00 per day, which puts them in the lowest income group for all artisanal fisheries of the Gulf and makes them an especially vulnerable sector of the fishing community.

The fisheries study cited above (AECID, 2012) found the following economic values for the main products produced by the ecosystems of the Gulf of Fonseca between 2008 and 2009 (Table 5.1).

TABLE 5.1 ECONOMIC VALUES OF PRODUCTS FROM MANGROVE ECOSYSTEMS

Ecosystem Product	Amount	Value (US$)
Fish	7.6 million pounds	$3,759,000
Artisanal Shrimp	1.2 million pounds	$1,583,000
Mangrove Crabs	1.1 million crabs	$117,000
Curiles	5.1 million *curiles*	$172,000

Source: AECID, 2012

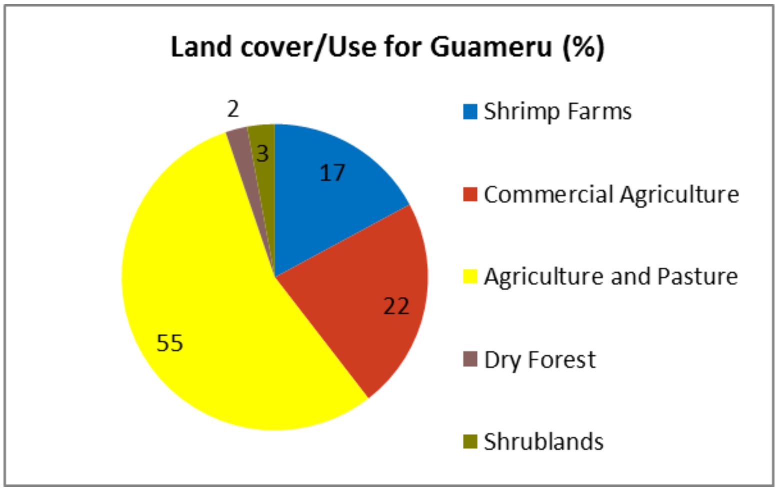
Fish in San Lorenzo market. Photo by B. Byers, September 2013.

Besides direct employment in fishing, it is important to mention the indirect employment generated by this sector, including in the marketing of fish and shellfish, building of boats and docks, manufacturing of fishing gear, and repairing of outboard motors.

A warmer, drier climate, as predicted by IPCC models, could reduce catches and/or require longer travel distances and greater costs for fishermen when some fish species move farther from the coast or out of the Gulf as they seek cooler and less saline water. Populations of *curiles* and mangrove crabs could be negatively affected by longer, hotter dry periods, which would reduce the harvest of these species.

Two of the coastal communities visited during this assessment provide a striking contrast in land cover and land use in their immediate vicinities, and illustrate the challenges of heavy dependence on ecosystem products and services from mangroves and other coastal ecosystems. The below pie chart shows the land cover and land use in the immediate vicinity of these communities and provides an integrated, visual "snapshot" of the diversity of both the local ecology and local economy.

FIGURE 5.1 LAND COVER/USE IN GUAMERU AND COSTA AZUL COMMUNITIES IN THE MUNICIPALITY OF NAMASIGUE



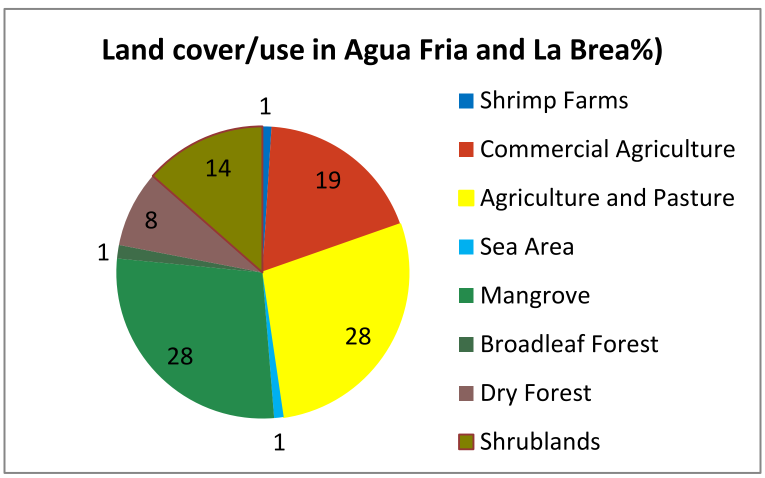
The small fishing communities of Guameru and Costa Azul are about 25 km from Choluteca, near three of the coastal protected areas that are co-managed by CODDEFFAGOLF and ICF: El Jicarito, La Berberia, and Estero San Bernardo.

About 365 people in 100 families live in these two communities. Fishing is the main economic activity, with about 75 percent of adults involved in that activity. Marine products are basic to subsistence here, and fishermen have access to a seasonal lagoon (*laguna de invierno*) with an area of about 400 hectares where they catch shrimp and fish. The lagoon is productive only in the wet season; in the dry season it dries out. Shrimp are sold to Granjas Marinas for export; fish are also sold and consumed. Neither Gameru nor Costa Azul communities have access to or depend on mangroves. An association of women from the communities has an 18-hectare shrimp pond. Commercial shrimp ponds occupy approximately 1,800 hectares in the area. Community members reported that if fishing collapses here, then they will have to move elsewhere.

About 10 percent of community members work as laborers in the commercial shrimp, melon, and sugar industries – mostly young people. About 10 percent are farmers, producing mainly maize and cowpeas (*frijol alacín*) on land rented from large landowners. About 5 percent of the community members keep livestock. The average family has about 0.33 to 1.75 hectares of land and grows yuca, camote, and sometimes fruits (e.g., nance, mango, cashews, oranges, lemons). Wood for cooking and building has to be obtained from the mountains. Remittances are not important here.

Boy fishing in the outflow channel of a commercial shrimp pond near Guameru. Photo by B. Byers, August 2013

FIGURE 5.2 LAND COVER/USE IN AGUA FRIA AND LA BREA COMMUNITIES, MUNICIPALITY OF NACAOME, DEPARTMENT OF VALLE



Agua Fria and its neighboring community La Brea are approximately 10 km west of Nacaome in the Department of Valle. La Brea is within the Bahia de Chismuyo Habitat/Species Management Area, a multiple-use protected area co-managed by CODDEFFAGOLF and ICF.

About 7,000 people in around 1,200 households live in these communities. The economy here depends on a mixture of fishing and agriculture. Fishing generates most employment. Most individuals fish from boats and/or collect crabs, *curiles*, and *casco de burro* on foot in the mangroves. Middlemen (*coyotes*) buy fish directly from the fishermen to sell in the regional market, and in the case of *casco de burro* to export to El Salvador. In some cases women from fishing families directly sell fish in neighboring communities. When fishing is not good, some fishermen work as laborers in commercial agriculture (melon, sugarcane). Some fishermen also grow maize here. In November some people harvest wild honey in the mangroves. About 40 percent of the families in Agua Fria grow maize, and about 10 percent have livestock. From October to May some people are employed as laborers in commercial agro-industries (melon, watermelon, sugarcane, sesame). There are about 80 hectares of salt-making ponds in the area, and these operate in the dry season, from November to March. About 60 percent of the families in Agua Fria and about 80 percent of the families in La Brea receive remittances from relatives living elsewhere. From this area in recent years there has been a lot of migration to the United States as well as some to Spain.

Fishing boats at low tide, La Brea. Photo by B. Byers, August 2013

A visual comparison of the land cover/land use pie charts of these communities shows that Agua Fria and La Brea, located in Namasigue Municipality, have a more diverse ecological and economic environment than Guameru and Costa Azul. These fishing communities essentially are "squeezed" between agricultural lands — both large-scale commercial farms and traditional pastures and crop lands owned by large landowners — and commercial shrimp farms. Their access to fish and shellfish from which they earn their living occurs only through the estuaries and seasonal lagoons. In contrast, there are more, and more equal, "pieces" of the land use "pie" in the Nacaome communities. There are far more mangroves in the immediate vicinity of those communities, and since mangroves are the main "factory" for fish and shellfish, fishing as a livelihood also may be more resilient there. There is also far more local small-scale agriculture for the production of basic grains. Additionally, more people there work part time as laborers in the melon and sugar industries.

Wood for Fuel and Construction

Wood is one of the two major categories of ecosystem products that underpin the livelihoods of Southern Honduras (wild fish and shellfish are the others). Information gathered in this assessment underlined the fact that wood for both fuel and construction is locally obtained, usually for free or only at the cost of labor, from mostly unmanaged local natural ecosystems. According to key informants, this subsistence use of wood is very important to rural livelihoods. The research found almost no studies of this subsistence wood use, and there remains a significant information gap in understanding its importance and its vulnerability to climate change and other threats.

Wood fuel is the largest source of end-use energy in Honduras according to the National Energy Balance 2008 (National Directorate of Energy, 2008). It contributes an estimated 42.2 percent of the country's energy supply – approximately the same amount as all fossil fuels combined (Flores et al., 2011). Most of this wood fuel is used for domestic energy for cooking and heating. Nationwide, the estimated consumption is 7.5 million m^3. In 2008 the wood fuel market provided employment for 30,000 families, with a market value of more than US$125 million. Although the research team found no studies specific to Southern Honduras, if the consumption and value of wood fuel in the South is similar to that of other regions. The research team estimates that wood fuel consumption in the South, which comprises about 10 percent of the Honduran population, is about 750,000 m^3 of wood per year and has a market value of about US$12.5 million.

Fuel-efficient cook stove designs now make it possible to save from 30 percent to 50 percent of the wood used by traditional stoves. Similar efficiency improvements are probably possible in brick and pottery kilns found in the region.

A warmer, drier climate could potentially reduce forest growth and regeneration as well as increase the frequency of wildfires, leading to reduced wood supply. Mangrove forests might not be affected, although changes in salinity regimes and sedimentation rates could affect the growth and distribution of mangrove species.

5.2 DEPENDENCE ON ECOSYSTEM SERVICES

Water for Domestic Consumption

Water for domestic consumption is the most valuable use of water. Domestic water comes from a combination of surface water taken from streams and rivers, and from groundwater from wells. A warmer, drier climate, as projected by the IPCC Fifth Assessment Report, would place more stress on domestic water supplies by reducing streamflows and lowering water tables. On the coastal plain, saltwater water intrusion in domestic wells caused by reduced upstream flows and rising sea levels would probably become more common.

For reasons described in Chapter 4, Cerro Guanacaure, a small, forested mountain with a multiple-use protected area about 15 km from Choluteca, plays a very large role in the eco-hydrology of the surrounding area. The Río Sampile watershed flows from Cerro Guanacaure, and the city of Choluteca gets approximately 30 percent of its domestic water supply from a gravity-fed system that collects water from several micro-watersheds that start within that protected area.

Pipes take water from Cerro Guanacaure near La Fortuna to supply drinking water to the city of Choloteca.
Photo by B. Byers, August 2013

Located on the slopes of Cerro Guanacaure, the small farming and mining communities in the municipality of El Corpus also get their domestic water from springs and streams in nearby micro-watersheds. The community of La Fortuna, for example, obtains water from the Quebrada Los Amates, a nearby micro-watershed. Small-scale gold mining is an important economic activity in some of these communities and is expanding. Mercury is used in processing the ore to obtain gold, with essentially no environmental controls, which creates a serious health and environmental threat of water contamination not only in the local communities but also downstream for the cities and agro-industries that use water from Cerro Guanacaure.

Community water tank, La Fortuna. Photo by B. Byers, August 2013


Water in stream at San Juan Abajo. It is contaminated with sediments and mercury from small-scale gold mines.
Photo by B. Byers, September 2013

For the coastal communities in Southern Honduras, flows from the five major rivers and also the five micro-watersheds arising in the hills of the coastal plain to the east maintain freshwater aquifers underlying the coastal plain. Those flows push saltwater down and back toward the Gulf, holding back its intrusion into the freshwater aquifer. For their domestic water supply, people here depend on wells that tap the shallow subsurface aquifer.

Basic Grains Production

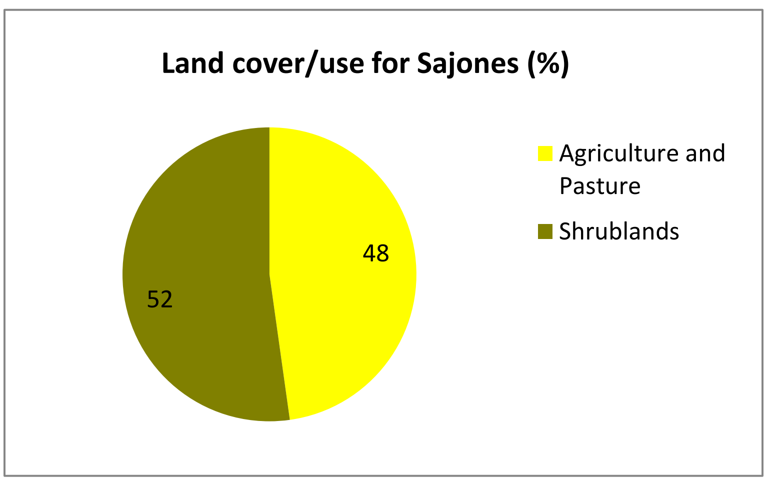
Growing basic grains, mainly maize and beans, on small-scale subsistence farms is the foundation for food security in the area. For fishermen, who don't grow basic grains, income from sales of fish and shellfish is used to purchase basic grains. Income from employment in small-scale agro-enterprises or large commercial agro-industries is also used by some families for buying basic staple foods.

Subsistence agriculture depends on eco-hydrological services for preventing soil erosion, for retaining groundwater and soil moisture through infiltration, and for maintaining soil fertility through bacterial nutrient cycling in crop fields and pastures. However, basic grains are being grown in formerly forested areas of upper watersheds, often on steep slopes, in ways that are clearly unsustainable in the long term because they slowly destroy those eco-hydrological services. This practice threatens not only the future of farming there, but also the downstream eco-hydrological services upon which other communities and industries depend.

A warmer, drier climate would probably reduce yields of basic grain crops especially at lower elevations and would create pressure to expand their cultivation at higher elevations in still-forested areas of upper watersheds. This practice would result in a no-win scenario for all stakeholders in the region.

The community of Sajones is located in Apacilagua municipality, about 25 km northeast of Choluteca, on the western side of the Río Choluteca. This is the driest area of Honduras, the so-called *corredor seco*, or "dry corridor," in the rain shadow of the highlands to the north. Sajones and its neighboring community of El Arenal have a population of about 1,250 people in 250 households. There are no protected areas nearby. The land cover/land use "snapshot" for the area resembles that for Las Trojas, discussed in section 4.1. The landscape is approximately half crop or pasture lands and half shrublands, which are mainly fallowed crop or pasture lands on which natural dry or mixed forest species are slowly regenerating.

FIGURE 5.3 SUBSISTENCE AGRICULTURE IN THE *CORREDOR SECO*



Livelihoods here are completely based on growing basic grains — maize, beans, and sorghum — and small-scale livestock keeping. All families in the communities engage in these activities that provide food and also some income. Sixty percent of household income comes from growing and selling basic grains, and 30 percent comes from sales of livestock (e.g., cattle, pigs, chickens). The average family cultivates between 1.5 and 3.5 hectares, 70 percent of which is not owned by them but share-cropped. Crops are grown mostly on valley and hill slopes using traditional methods. Soils are of low fertility, soil conservation measures are not used, and inputs such as fertilizer and pesticides are generally not used.

The average family has between three and five cattle. Almost no one here grows vegetables or fruits. Because of isolation and poor roads, almost no one works as laborers in commercial agro-industries farther to the south. When young people graduate from secondary school, they generally migrate to other parts of Honduras. About 10 percent of household incomes here come from remittances from relatives working elsewhere in Honduras or overseas. Water is very scarce, comes from springs, and is used for domestic purposes only. There is no potential for crop irrigation from surface water.

Río Choluteca near Sajones community.
Photo by L. Caballero, November 2013

Maize field near Sajones community.
Photo by L. Caballero, November 2013

Commercial Agro-Enterprises

The three largest commercial enterprises — shrimp, sugar, and melons — all highly depend on sustainable flows of freshwater entering the coastal plain and coastal zone. These industries generate a very important fraction of the employment and income that drives the economy of the region (Table 5.2). As discussed in the previous chapter, stable flows of clean water for domestic consumption and for irrigation depend on the condition of forest ecosystems and other permanent land cover in upper watersheds. Therefore, commercial agro-industries depend on this eco-hydrological service). As one representative of the melon industry said when asked, *What is the perceived threat of climate change to the melon industry?*: "Climate change affects the whole operation of the industry because we depend on water for it." (Personal communication, Antonio Oviedo, Farm Manager, Montelibano Farm, 5 December 2013; see Annex F for full interview).

TABLE 5.2 ECONOMIC STATISTICS FOR THREE MAJOR INDUSTRIAL PRODUCTS OF VALLE AND CHOLUTECA

Crop	Area (ha)	Production/year	Income (US$/ year)	Employees	Income/ha (US$/year)
Sugarcane	20,000[1] (6,300 Azucarera Choluteca and 13,700 Pantaleon) 10,780[2]		$140 million domestic market, $60 million U.S. market[2]	Between 4,000 and 5,000 (70 percent part-time jobs and 30 percent full-time jobs)[1] 7,200 direct and 28,800 indirect[2]	$4,860/ha/yr[1] $10,000/ha/yr[2]
Melons	10,500[3] 12,600[2]	224,000 tons[2]	$31.9 million[2]	21,000 part-time jobs; 900 full-time jobs[3]	Approx. $2,500/ha/yr[2]
Cashews	1,550[2]		$395,000[2]		
Commercial Shrimp **2012–2013**	18,300[4] 18,500 ha constructed; 17,600 in production; 37,000 ha under concession[2]	57 million pounds[4]	$170 million[4]	30,000 (direct)[4] 40 percent women[2]	

1 Interview with Ing. Sergio Salina, Azucarera Choluteca, 5 Dec. 2013; see Annex G for full interview.

2 SEPLAN, 2013.

3 Interview with Ing. Antonio Oviedo, Farm Manager, Agrolibano Montelibano Farm, 5 Dec. 2013; see Annex F.

4 Interview with Ing. Ricardo Gomez, Honduran Aquaculture Association (ANDAH), 20 Aug. 2013.

Both sugarcane and melon production depend on irrigation. For sugarcane, 56 percent of the area under cultivation is in the lower Choluteca or Sampile watersheds, 30 percent of the crop is grown in the middle Choluteca watershed, 10 percent in the Nacaome and Goascoran watersheds, and 4 percent in the Río Negro valley. Melon cultivation is also centered in the lower Choluteca and Sampile, with 75 percent of the crop grown there, followed by 15 percent in the Nacaome and Guascoran, and 10 percent in the Río Negro.

Cost figures provided by representatives of the sugar and melon industries and from SEPLAN (SEPLAN, 2013) provide a starting point for estimating the value of water to these industries. For example, most sugarcane (80 percent) is grown with sprinkler irrigation, at a cost estimated at $188 per hectare per 180-day irrigation cycle for pumping and equipment, representing about 15 percent of the cost of sugarcane production (personal communication, Ing. Sergio Salina, Assistant Manager, Azucarera Choluteca, 5 December 2013; see Annex G for full interview). Water use for sugarcane irrigation is approximately 8,000 m^3 per hectare per 180-day irrigation cycle. Gravity-fed irrigation of sugarcane (costing approximately $123/ha/yr) is cheaper than sprinkler irrigation, so growers use gravity irrigation when possible; however, availability of land where gravity can be used limits its use to about 20 percent of the crop area. Drip irrigation of sugarcane is much more water efficient and also much more expensive, at around $251/ha/yr; so far it is used on only about 2 percent of the crop area.

For the melon industry, which generates about $32 million in income per year as well as 900 full-time and 21,000 part-time jobs, water is also essential for production. Drip irrigation systems for melons with plastic ground cover represent about 20 percent of the cost of production (personal communication, A. Oveido, 5 December 2013; see Annex F for full interview).

Giant melon sculpture, Choluteca city. Photo by B. Byers, August 2013

Groundwater pumping for sugarcane irrigation on the coastal plain creates a risk of saltwater intrusion in some areas, which could cause the salinization of domestic and irrigation wells and even of soils. This result makes pumping too much groundwater for sugarcane a self-defeating proposition, of course. Groundwater flows that depend on land cover in upper watersheds are critical in maintaining the hydrological pressure that protects coastal aquifers areas from saltwater intrusion. Climate change could exacerbate the problem by reducing flows from upper watersheds and increasing the demand for water for irrigation. Even the five small watersheds between Choluteca and Nacaome are important for maintaining the water table gradient flowing to the coast, holding back the underground saltwater lens, and minimizing the risk of saline intrusion. Therefore, sugar producers on the coastal plain should have significant incentives to maintain the eco-hydrological health of upper watersheds. Their other alternative would be to install drip irrigation systems that are more costly than sprinklers. The difference in cost between sprinkler and drip irrigation systems, about $63/ha, could be the value these growers would be willing to pay to maintain stable groundwater levels in the coastal freshwater aquifer.

A warmer, drier climate would increase the demand for irrigation in commercial crops such as sugarcane and melons. Pumping groundwater from aquifers in the coastal zone for these crops could exacerbate the problem of saltwater intrusion and the salinization of domestic and irrigation wells. Production in commercial agro-industries could decrease unless forest conservation and regeneration as well as better land-use practices in upper watersheds were to be used to maintain or improve recharge rates, which in turn would increase the water supply for irrigation. Another option would be to significantly increase the use of water-efficient irrigation practices and technologies.

A warmer and drier climate in the region could reduce the flows of freshwater into estuaries that help to maintain their water quality. Barring changes in aquaculture practices or technologies, decreased water quality could reduce yields as well as associated income and employment in the commercial shrimp industry.

5.3 GENDER AND SOCIOECONOMIC SENSITIVITY

Women often are involved in livelihood and economic activities that depend on ecosystem products and services in different ways than men. This assessment identified several such gender-linked livelihoods. For example, 40–50 percent of the workers in commercial shrimp packing plants are women (SEPLAN, 2013; personal communication, Granjas Marinas, 21 August 2013). Gathering *curiles* and collecting mangrove crabs on foot in the mangrove zone (*pesca a pie*), is also done more by women (and children) than by men. Several organized women groups in fishing communities (e.g., Gaumeru, Agua Fria) are trying to develop microenterprises in order to diversify income and become less dependent on fisheries. All of these livelihood activities depend on ecosystem products or services that would be negatively affected by predicted climate changes. Adaptation strategies should be developed to respond to the differentiated roles of men and women.

Girl selling mangrove crabs (in Spanish, "punches") – near Monjarás. Photo by B. Byers, September 2013

5.4 KEY FINDINGS

- Fish and shellfish, harvested from the natural ecosystems of the Gulf of Fonseca, are by far the most important ecosystem products that support livelihoods in Southern Honduras. In the coastal zone, fishing is a major source of food, employment, and income; however, its importance lies more in the number of jobs generated and the food security it provides than the total economic revenue generated. Mangrove ecosystems are critical to the sustainable production of fish and shellfish.
- Wood is another ecosystem product that underpins the livelihoods of Southern Honduras. Wood fuel is the largest source of end-use energy in Honduras. Wood for both fuel and construction is locally obtained, usually for free or at only the cost of labor, from natural ecosystems. The research team found almost no studies of this subsistence wood use – a significant information gap in understanding its importance and its vulnerability to climate change and other threats.
- Water for domestic consumption comes from a combination of surface water taken from streams and rivers, and from groundwater from wells, both of which are the result of eco-hydrological processes taking place in the watersheds of the region.
- Growing basic grains, mainly maize and beans, on small-scale subsistence farms is the foundation for food security in the area. Subsistence agriculture depends on ecosystem services for preventing soil erosion, for retaining groundwater and soil moisture through infiltration, and for maintaining soil fertility through bacterial nutrient cycling in crop fields and pastures. Three large commercial agro-industries — sugar, melons, and shrimp — generate a very important fraction of the employment and income that drives the economy of the region. These industries all highly depend on sustainable

flows of freshwater entering the valleys and the coastal zone, and so have significant incentives to maintain the eco-hydrological health of upper watersheds.

- Some jobs in commercial industries and in fishing communities that would be affected by climate change are more commonly done by women than by men. Adaptation strategies should be developed to respond to the differentiated roles of men and women.
- All current livelihoods (subsistence to agro-industrial) are sensitive to changes in ecosystem products and services and will need to adapt to potential climate-driven changes.

6.0 CAPACITY TO ADAPT TO CHANGES IN ECOSYSTEM BENEFITS

Conventional thinking on climate change adaptation asserts that to the extent that people can and will respond and adapt, they can reduce their vulnerability to climate change even if the factors of exposure and sensitivity do not change. As with the other terms in the vulnerability equation, adaptive capacity is a heuristic concept, not a strict mathematical construct. It is possible, however, to find evidence-based methods of assessing adaptive capacity and developing indicators for it.

6.1 DEFINING ADAPTIVE CAPACITY

The USAID indicator, "adaptive capacity" is defined as "the ability to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (U.S. Department of State, 2013, Standard Indicator 4.8.2-26). Institutional adaptive capacity is defined as "Institutions with improved capacity will be better able to govern, coordinate, analyze, advise, or make decisions related to adaptation…" (U.S. Department of State, 2013, Standard Indicator 4.8.2-14). Writing about adaptive capacity in eco-sociological systems in general, Walker et al. (2004) state that "Adaptability [i.e., adaptive capacity] is the capacity of actors in the system to influence resilience – in a social-ecological system, essentially to manage it."

Adaptive capacity depends on the capacity of individuals, households, communities, and institutions to identify options and take advantage of opportunities to reduce their exposure or sensitivity to climate change. Public awareness, information, knowledge, and communication are underlying requirements for such adaptive changes in governance or technology. Changes in policies, laws, regulations, plans, and management systems are part of governance, of course. Land and resource tenure may be impediments to resilience, and reform of land and resource tenure arrangements may be an important aspect of adaptive capacity (USAID, 2011). Adaptive capacity is needed at all levels of government, in community-based organizations (e.g., producer cooperatives) and NGOs, and in the private commercial sector.

6.2 ADAPTIVE CAPACITY OF ENVIRONMENTAL MANAGEMENT INSTITUTIONS

Interviews, meetings, focus groups, and workshops with representatives of environmental management institutions in Honduras from the national, regional, and municipal levels revealed a strong general impression that although communities, municipalities, NGOs, the private commercial sector, and national and regional government agencies are aware that climate variability and change will affect them, the human, financial, and technical capacity of relevant institutions to respond adequately to potential climate changes and to non-climate threats is currently weak.

In a recent biodiversity threats assessment conducted by the United States Forest Service (USFS) International Program Office for USAID/Honduras (USAID-Honduras, 2013), two major cross-cutting issues that "drastically reduce the effectiveness of biodiversity policies in protected areas, buffer zones, and all other areas of biological importance" were identified. Those are: 1) weak central and local government agencies that lack the ability to implement public policy and development programs; and 2) weak Government of Honduras presence at the regional and municipal levels due to contradictory policies and poor coordination (USAID-Honduras, 2013:28–29). According to their report, these institutional weaknesses cause two major, direct threats to biodiversity in Southern Honduras:

1. loss and conversion of broadleaf forests in upper and middle watersheds, and of mangroves in the coastal zone; and
2. over-exploitation of fish and shellfish in the coastal and marine zone.

Despite the apparently weak capacity of many institutions to implement actions that would reduce the vulnerability of Southern Honduras to climate change, the research team found that awareness of climate vulnerability, whether to interannual variability and extreme events or to climate change, is generally good at all levels. People in rural communities, municipalities, NGOs, national and regional government offices, and the private sector were all aware of the need to think about climate adaptation. Because awareness of a problem is a necessary factor in taking action to address it, this positive finding indicates that a foundation for building climate change resilience exists if human and financial resources can be found to do so.

6.3 ADAPTIVE CAPACITY AND THE PROTECTED AREA SYSTEM

The 11 protected areas in Southern Honduras are critical anchors of the region's natural resilience to climate change because they protect significant areas of permanent vegetation, as discussed in Chapter 4. Therefore, the capacity to take adaptive management actions that would maintain the ecosystem benefits from protected areas in the face of climate change is one important component of adaptive capacity.

Protected areas in Honduras are co-managed through agreements between ICF — whose own institutional weaknesses were discussed above — and several types of organizations that enter into co-management agreements with ICF, including NGOs and municipalities. The existing co-management agreements legally transfer responsibilities to the co-managers of protected areas without ensuring that those co-management organizations have the financial and human capacity to carry out those responsibilities. The decentralization of government policies and the transfer of responsibilities to municipalities have, in general, weakened the coordination between national agencies responsible for protected areas and biodiversity (e.g., ICF, SERNA DiBio) and the co-managers of protected areas in Southern Honduras. The government agencies legally responsible for protected areas often have not fulfilled those responsibilities, but the co-management organizations frequently are then blamed for weak implementation of protected area management plans. According to key informants, there has not been a strong policy to implement the law regarding protected areas in a transparent manner, which in some cases has led to the selection of co-management organizations that lack the financial, human, and technical resources to effectively co-manage the protected area. Additionally, in many cases municipal, local, and community authorities have not been effectively involved in developing co-management strategies. So far, it often has not been possible to develop effective coordination between the actors and organizations that have a stake in the management of a protected area because of their dependence on the ecosystem benefits from the area.

In order to resolve these weaknesses, most current co-management agreements need to be revised in order to bring them into line with the real potential of a given protected area and the real financial, human, and technical capacity of the NGO or other co-management organization that has taken on the challenge of co-management. The national government should provide appropriate technical and financial resources to the co-management partner. The government should strengthen financial support schemes through the Honduran Fund for Protected Areas and Wildlife, *Fondo de Áreas Protegidas y Vida Silvestre* (FAPVS). Many of the co-management agreements refer to international conventions and treaties, such as the Convention on International Trade in Endangered Species, the Convention on Biological Diversity, the Ramsar Convention, and the United Nations Framework Convention on Climate Change, for which SERNA's Directorate for Biodiversity is the responsible national agency. Although SERNA is nominally responsible for upholding international conventions, its financial and human resources to do so are often stretched thin. SERNA should not expect protected area co-managers to assume these international obligations without being provided dedicated resources to do so.

A member of the assessment team reviewed the management plans of each protected area in the region. Only one of the 11 management plans, that of the Bahía de Chismuyo Habitat/Species Management Area, explicitly mentions climate change. It discusses a land management approach that will maintain natural processes and social benefits as well as consider climate change adaptation and mitigation. It calls for "… the conservation of biodiversity and maintenance of existing environmental goods and services." Two specific management objectives for maintaining biodiversity and responding to climate change are: 1) to maintain optimal habitat conditions to protect species, biotic communities, and physical features of the environment, and to maintain the ecological processes of the zone; and 2) to facilitate scientific research and environmental monitoring of natural resources and environmental goods and services in the management area, especially those related to eco-hydrological services, carbon sequestration, scenic beauty, and biodiversity.

Although the 10 other protected area management plans from the region do not explicitly mention climate change, some have components that could provide a platform for addressing climate change vulnerability. For example, since Montaña La Botija was declared a multiple-use protected area, a major focus of the management plan has been to maintain the forests of the area as upper watershed infiltration areas for groundwater recharge, because the area is the main source of domestic water for the city of San Marcos de Colón. This focus provides a clear, if not explicit, link with the need for adaptive management actions to respond to climate change. Sustainable livestock grazing, harvest of wood products, nature conservation, and tourism are also components of the management plan. While the management plan for the La Berbería Habitat/Species Management Area does not specifically mention climate change, it does call for an institutional strengthening process to build local capacity to implement actions, initiatives, and projects that will promote socioeconomic alternatives and encourage the participation of local actors in the implementation of the management plan. The development of contingency plans to reduce vulnerability to natural hazards such as floods has been proposed, and such plans could provide a platform for addressing climate change vulnerability.

6.4 ADAPTIVE CAPACITY AND ECONOMIC DIVERSITY

Although even the poorest individuals, families, and communities of Southern Honduras are resourceful, for a variety of reasons they often do not have many livelihood options and economic opportunities. Section 7.2 of this report provides more information on the diversity of those options and opportunities in selected rural communities. One source of information was the land cover and land use pie charts introduced in sections 4.1, 5.1, and 5.2 of this report. The pie charts provide a visual summary of the diversity of both the ecological and economic environments of a community. Another source of information was focus group discussions in the communities. Those discussions (see Annex E) gave us a profile of the livelihoods and economies of the communities, and the research team used this information to rank them in terms of the diversity of their economic options for adapting to potential climate changes, which the team calls a Livelihood Diversity Score. Communities with the least economic diversity, such as Sajones (section 5.2) and Las Trojas (section 4.1) where subsistence agriculture is the dominant livelihood, or Guameru (section 5.1) where fishing is the main livelihood, were ranked as "1" on a scale of 1 to 3.

Communities such as Las Trojas and San Juan de Duyusupo (section 4.1), which produce products such as fruits, vegetables, or coffee for local and regional markets in addition to basic grains for subsistence received a score of 2 out of 3. Finally, communities with even more livelihood diversity, such as having members employed in the commercial agricultural sector, having a balance between fishing and subsistence farming, and/or having other enterprises such as salt-making, brick-making, or gold mining, received a Livelihood Diversity Score of 3 out of 3. These somewhat subjective, but nevertheless evidence-based rankings were used in the research team's overall assessment of vulnerability, as described in the next chapter (see section 7.2).

6.5 ADAPTIVE CAPACITY AND THE HUMAN DEVELOPMENT INDEX

Some of the factors that reduce livelihood opportunities and economic options, and perpetuate poverty, are linked to education, health, and income. Increasing the resilience of the people of Southern Honduras to the potential effects of climate change will require addressing these factors.

The United Nations Development Programme (UNDP) Human Development Index (HDI), or *Índice de Desarrollo Humano* (IDH) in Spanish, is a composite indicator with three dimensions: education, health, and income. According to the UNDP, the HDI is designed "to serve as a frame of reference for both social and economic development" (UNDP, 2013a). For health, the quantitative indicator is life expectancy at birth. For education, two quantitative indicators are used: mean of years of schooling for adults aged 25 years, and expected years of schooling for children just reaching school age. The standard of living component is measured by gross national income per capita. The HDI sets a minimum and a maximum for each dimension, called "goalposts," and then shows where a given population stands in relation to these goalposts, expressed as a value between 0 and 1.

The HDI allows comparisons among countries and within regions of a single country. Between 1980 and 2012, Honduras's HDI annually rose by 1.3 percent, from a national average of 0.456 to 0.632 today. This figure places Honduras 120th out of 187 countries with comparable data. The HDI of Latin America and the Caribbean as a whole region increased from 0.574 in 1980 to 0.741 today, and so Honduras is below the regional average (UNDP, 2013b). The National Development Plan of Honduras uses the HDI statistic as a measure of national development. In the profile of the Gulf of Fonseca Region (SEPLAN, 2013), HDI is used to compare the 45 municipalities in Valle and Choluteca Departments. The highest HDI in the region, 0.719, is found in the Municipality of San Lorenzo; Choluteca's HDI is 0.710, followed by Goascorán (0.690); Amapala (0.688); and Nacaome (0.687). The municipality with the lowest HDI in the region is Curaren, at 0.553.

People and communities with higher HDI scores (i.e., better education, health, and income) are better equipped to take advantage of opportunities and influence their options in life. They have socioeconomic resources with which to withstand and bounce back from climate-induced shocks (i.e., extreme rainfall events and flooding) and they can also invest these resources in capital improvements that will reduce their vulnerability (i.e., plant trees on hillsides and relocate to areas less prone to flooding). Thus, almost by definition, they have more adaptive capacity. The following chapter uses HDI as one indicator for adaptive capacity, assuming that the lower the HDI score for a municipality, the fewer socioeconomic resources people have and the more difficult it is for the general population to adapt to challenges that may be posed by climate change.

6.6 KEY FINDINGS

- Decreasing eco-social vulnerability and increasing resilience could involve decreasing the vulnerability of ecosystem benefits to climate change, decreasing socioeconomic dependence on ecosystem benefits, and/or increasing the adaptive capacity of communities and institutions.
- Awareness of climate vulnerability, whether to interannual variability and extreme events or to climate change, is generally good at many levels – in communities, municipalities, NGOs, the private commercial sector, and national and regional government offices. This awareness is a necessary factor in building climate change resilience.
- Institutional adaptive capacity to respond adequately to potential climate changes and non-climate threats currently is weak.
- Only one of the protected area management plans of the 11 protected areas in the region explicitly addresses the need for climate change adaption. A few others provide a foundation for doing so without explicitly mentioning climate change.
- The diversity of livelihood opportunities and economic options available in a community influence its adaptive capacity; the greater the diversity, the greater the adaptive capacity. A community's economic diversity is reflected in the local land use profile and in the mix of subsistence activities and employment available to its members.
- The UNDP HDI is an indicator of social and economic well-being. The better off a community and municipality is, the better equipped the citizens are to address the challenges of climate change. Many municipalities and communities in Southern Honduras have HDI scores that are below the national average, which is already one of the lowest in Latin America.

7.0 SOCIOECONOMIC VULNERABILITY

Following the logic of the conceptual model (Figure 1.2), this chapter addresses the vulnerability of human well-being — livelihoods and incomes — as it relates to ecosystem products and services that are affected by climate changes.

7.1 ASSESSING VULNERABILITY

In assessing the vulnerability of people and ecosystems in Southern Honduras to the effects of climate change, three factors must be considered. They are:

1. the ***exposure*** of ecosystems and people who depend on the services provided by the ecosystems to climate changes;
2. their ***sensitivity*** to the impacts of exposure resulting in a loss of those benefits, as reflected by their dependence on them; and
3. their ***adaptive capacity***, which involves either capacity to carry out actions that reduce the vulnerability of ecosystem benefits to climate change, or capacity to reduce their dependence on those benefits.

Chapter 4 described how the ratio of permanent land cover in the landscape — essentially a measure of the extent to which natural ecosystems have been conserved — is a good indicator of the vulnerability of ecosystem benefits in a watershed or a municipality to climate change, and therefore of the exposure of the socioeconomic system. The higher the ratio of permanent land cover in an area, the lower the ecological vulnerability and socioeconomic exposure.

Chapter 5 clearly demonstrated that the economy and livelihoods of Southern Honduras, from the poorest fishing or farming communities to the large commercial agro-industries, depend heavily on ecosystem products and services. Everyone, in every segment of society, depends on ecosystems, even if in different ways; thus, all are highly sensitive to a reduction in ecosystem benefits that could be caused by climate change. The study did not propose an indicator of this sensitivity to the loss of ecosystem benefits, because the ways in which these losses would affect different communities and industries are so diverse that they do not lend themselves to any single, comparable measure.

Chapter 6 concluded that the adaptive capacity of relevant institutions, at all levels, is currently weak. While the study does not attempt to develop an indicator of institutional capacity, the research did reveal that communities differ in the diversity of livelihood options and economic opportunities, and that this difference affects their adaptive capacity. Using a ranking system, the assessment points to livelihood diversity for several representative communities. The UNDP HDI provides one measure of adaptive capacity relative to socioeconomic standing.

7.2 ECO-SOCIAL VULNERABILITY AND RESILIENCE OF REPRESENTATIVE COMMUNITIES

To gain more insight into the range of livelihood challenges that people face, representative communities in eight municipalities were selected and visited. The municipalities were selected because they represent the range of climatic, ecological, and socioeconomic conditions in the region. Communities were chosen to include upper, middle, and lower watershed communities, as well as three coastal communities representing the fishing livelihoods of the area. Figure 7.1 shows the locations (circled in red) of the research team's sample of representative communities on the land cover/use map. Most of the communities are either within, or close to, one or more of the 11 protected areas in the region (see Figure 4.7). Some of these communities already have been introduced in the pie charts found in Chapters 4 and 5. A summary of the information gathered from site visits and focus group discussions in the communities the assessment team visited can be found in Annex E.

The communities dramatically differ in the land cover and land use in their immediate vicinity. To characterize the differences, the research team calculated the area under each type of land cover or use within a radius of 4 km from the community — a total area of about 50 km^2 — and plotted them in pie charts to provide a land-use "snapshot." The pie diagrams (Figure 7.2) show the percentage of the area surrounding the community that is covered by natural ecosystems of various types (i.e., permanent land cover) or agricultural land uses of various kinds (i.e., non-permanent land cover). Because human land uses reflect local economic activity, the pie charts give an integrated, visual summary of both the local ecology and local economy.

FIGURE 7.1 LOCATIONS OF REPRESENTATIVE COMMUNITIES ON LAND COVER/USE MAP (RED CIRCLES CENTER ON EACH OF THE COMMUNITIES)

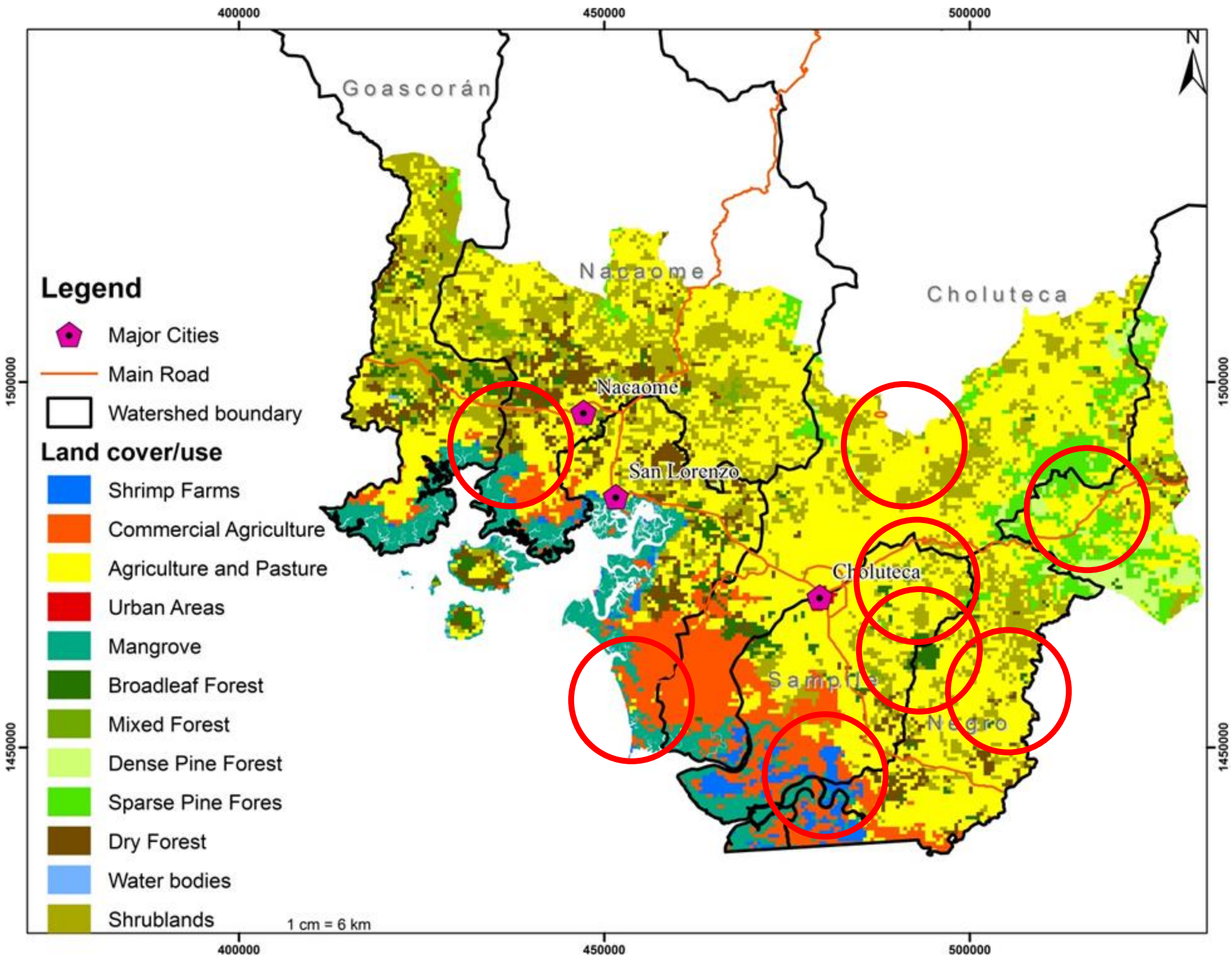
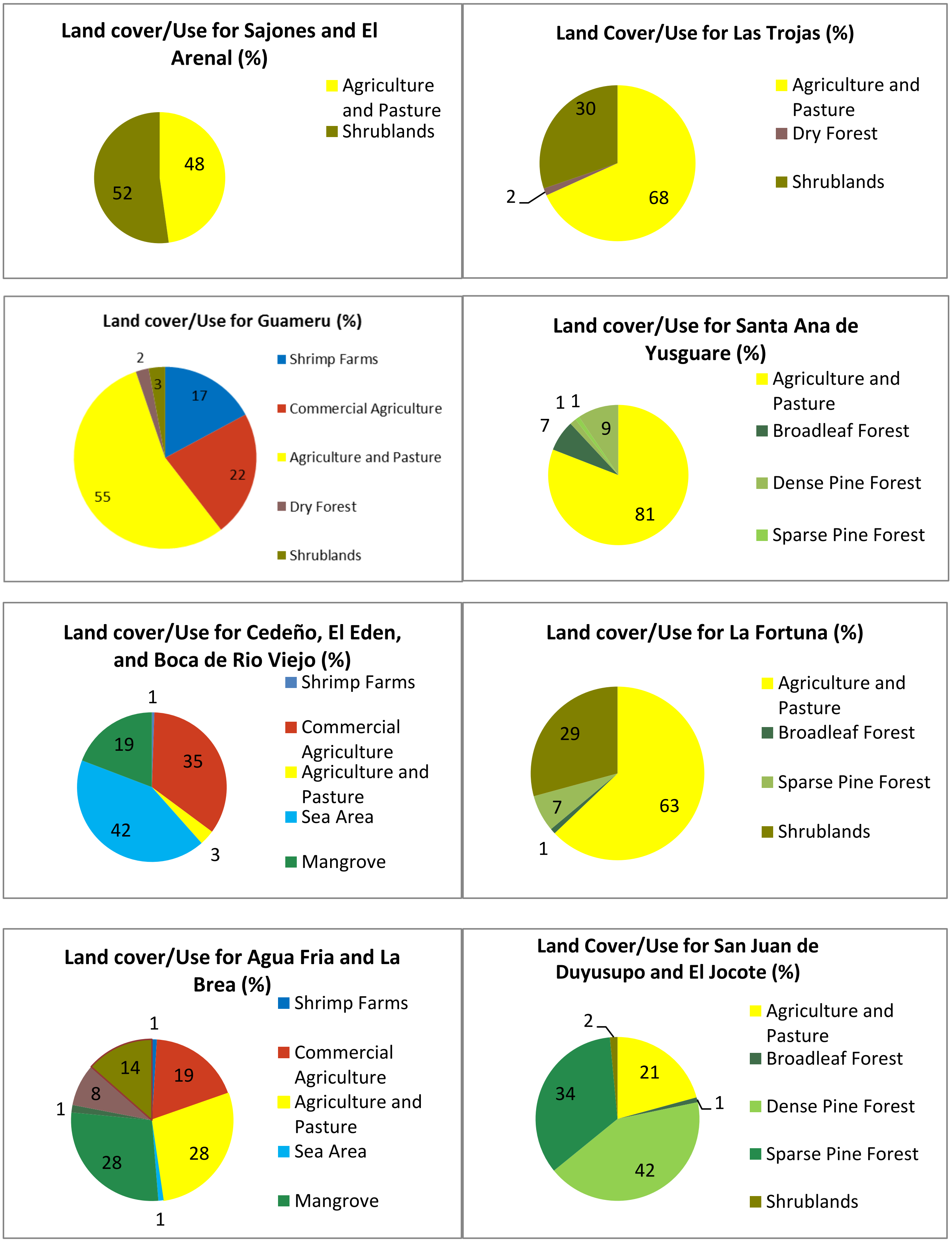


FIGURE 7.2 PIE CHARTS OF LAND COVER/USE, REPRESENTATIVE COMMUNITIES



Source: Rivera et al., 2011; L. Caballero, Team Hydrology Specialist

To develop a composite measure, which the research team calls the Eco-Social Resilience Index (ESRI), the team combined information on:

- **exposure**: the vulnerability of ecosystem benefits to climate change (indicator is the permanent land cover ratio in the municipality where the community is located); and
- **adaptive capacity**: involves either capacity to reduce the vulnerability of ecosystem benefits to climate change, or dependence on those benefits (indicators are the Livelihood Diversity Score of the community, as described in Section 6.4, and the municipal HDI).

The research team did not attempt to develop a quantitative indicator for ***sensitivity*** — the dependence on ecosystem benefits — for reasons discussed above.

The research team multiplied the permanent land cover ratio by the Livelihood Diversity Index and the HDI to obtain the value for the Eco-Social Resilience Index (Table 7.1).

Two inland communities and one fishing community fall in the most vulnerable group, with Eco-Social Resilience Index values of less than 0.10. Two other inland communities and one group of fishing communities fall in an intermediate group, with ESRI values between 0.20 and 0.25. A final group, with ESRI values around 0.7, are the most resilient in the research team's sample. Even those communities, however, face significant challenges in adapting to the region's possible climate changes.

TABLE 7.1 ECO-SOCIAL RESILIENCE OF REPRESENTATIVE COMMUNITIES & MUNICIPALITIES

Municipality	Community	Livelihoods	Perma-nent Land Cover Ratio A x	Liveli-hood Diversity Score B x	HDI C	Eco-Social Resilience Index =
Apacilagua	Sanjones and El Arenal	Maize, beans, sorghum, livestock	0.07	1	0.614	0.04
Concepción de Maria	Las Trojas	Maize, beans, sorghum, livestock; fruits and vegetables to sell in local/regional markets; work in commercial agro-industries	0.04	2	0.613	0.05
Namasigue	Guameru and Costa Azul	Fishing (75 percent of adults); work in commercial agro-industries (10 percent); maize, cowpeas (10 percent)	0.11	1	0.611	0.07
Santa Ana de Yusguare	Santa Ana de Yusguare	Maize, beans, livestock; fruits and vegetables to sell in local/regional markets; work in commercial agro-industries; brick-making	0.10	3	0.652	0.20
Marcovia	Cedeño, El Eden, and Boca del Río Viejo	Fishing; tourism	0.32	1	0.642	0.21
El Corpus	La Fortuna and San Juan Abajo	Maize, beans, livestock; fruits and vegetables to sell in local/regional markets; small-scale gold mining; work in commercial agro-industries	0.13	3	0.624	0.24
San Marcos de Colon	San Juan de Duyusupo and El Jocote	Livestock; coffee; maize, beans; fruits and vegetables to sell in local/regional markets	0.50	2	0.686	0.68
Nacaome	Agua Fria and La Brea	Fishing; maize, livestock; work in commercial agro-industries; salt-making; remittances	0.35	3	0.687	0.72

7.3 KEY FINDINGS

- All socioeconomic groups in the region, from the poorest fishing or farming communities to the large commercial agro-industries, are vulnerable to climate change because of their strong dependence on ecosystem products and services that are threatened by climate change.
- Communities differ in the diversity of their economic options and resources, and concluded that this diversity affects their adaptive capacity. Communities in areas with low permanent land cover ratios, low diversity of economic activities, and/or low HDI scores are more vulnerable to climate change and other non-climate stresses than are communities with more natural vegetation, more diverse livelihoods, and more human and financial resources.
- So-called "non-climate stressors" — threats other than climate change, such as loss of natural forests and biodiversity — are already reducing eco-social resilience and increasing vulnerability. Evidence for this trend is the already very low ratio of permanent to non-permanent land cover in many watersheds, which exacerbates both flooding and water scarcity in the dry season.

La Berberia Habitat/Species Management area looking toward Cerro Guanacaure.
Photo by B. Byers, August 2013

8.0 ADAPTIVE OPTIONS AND RECOMMENDATIONS

8.1 DESIGNING ADAPTIVE OPTIONS

The results of the assessment presented in the preceding chapters lead to adaptive options for reducing the vulnerability and increasing the resilience of people and ecosystems in Southern Honduras to predicted climate changes. Below are several key points to consider when designing actions for addressing climate change vulnerability and resilience:

- Sustainable and stable flows of water from upland watersheds are a key ecosystem service upon which all communities and municipalities, and the entire regional economy, depend.
- All socioeconomic groups are vulnerable to the climate changes — and non-climate stressors — projected for Southern Honduras because of systemic connections in the whole eco-sociological system (from the upper watersheds to the coastal/marine zone).
- An ecosystem-based approach to climate change adaptation is needed in Southern Honduras because of the high dependence of the socioeconomic system on ecosystem products and services.
- Many of the adaptive options for responding to climate variability and for conserving ecosystem benefits in the face of non-climate threats are the same as those for responding to climate change. Climate change projections add urgency but generally do not change the strategy for sustainable development of the region.
- Adaptive actions should build on the institutional framework that already exists rather than dramatically restructure it.
- Honduras should take advantage of the current wetter-than-average climate trend in the southern region to promote reforestation and a shift to more permanent land cover in watersheds before the predicted warming and drying of the climate begins (probably within one to two decades).

8.2 ILLUSTRATIVE OPTIONS AND ACTIONS

Because there are three components to the concept of vulnerability in eco-sociological systems, there are three main categories of options for decreasing vulnerability and increasing resilience to projected climate changes (see section 7.1). These three categories follow:

1. Decrease vulnerability of ecosystem benefits to climate changes (i.e., decrease socioeconomic exposure to loss of such ecosystem products and services);
2. Decrease socioeconomic dependence on ecosystem benefits (i.e., reduce socioeconomic sensitivity to loss of ecosystem products and services); and
3. Increase adaptive capacity to manage for resilience.

Effective and sustainable responses for reducing vulnerability and increasing resilience to climate change in Southern Honduras will require a combination of actions from these three categories. Table 8.1 lists possible options and actions that would reduce the vulnerability of ecosystem benefits to climate change (category 1). Since that vulnerability is caused by a loss of natural habitats and overexploitation of wild species, any action that stops the loss or degradation of natural habitats and restores them is one type of adaptive action. Any action that stops overexploitation of species and restores their populations to sustainable levels is another type of adaptive action. In general, adaptive actions are those that increase the ratio of permanent to non-permanent vegetation in the landscape.

TABLE 8.1 ACTIONS TO DECREASE THE VULNERABILITY OF ECOSYSTEM BENEFITS TO CLIMATE CHANGE

1. Actions to Decrease Vulnerability of Ecosystem Benefits
1.1 Conduct a study to establish baseline information on the eco-hydrology of targeted watersheds (e.g., Río Negro, Sampile, Nacaome).
1.2 Conduct a study to establish baseline information on the eco-hydrological functioning of mangroves and their effects on flows of water in the Gulf, water quality and salinity, saline intrusion in coastal aquifers, etc.
1.3 Develop incentives to stop the clearing of forest on steep slopes for basic grains production.
1.4 Restore forests on steep slopes that have been cleared for basic grains production or pasture, using native tree species.
1.5 Implement on-farm and municipal actions that increase water retention and infiltration (e.g., ponds, sand dams, contour strips, increased permanent ground cover).
1.6 Implement on-farm soil and water conservation techniques to decrease runoff and soil erosion.
1.7 Protect/maintain/restore streambank vegetation.
1.8 Promote a shift from basic grains to agroforestry systems (e.g., fruits, coffee).
1.9 Control commercial and artisanal gold mining (El Corpus municipality) to prevent mercury and cyanide contamination of domestic water supplies, commercial crops, and shrimp.
1.10 Reduce groundwater pumping on the coastal plain to prevent salt water intrusion and salinization of coastal aquifers.
1.11 Protect currently forested hills within the coastal plain as groundwater recharge zones through management agreements, change in legal status, etc.
1.12 Remove or redesign infrastructure of commercial shrimp ponds that block escape of freshwater to Gulf and/or prevent filling of seasonal freshwater lagoons.
1.13 Develop incentives to stop further clearing of mangroves for any use (e.g., shrimp ponds, sugarcane).
1.14 Restore mangroves where they previously existed if possible.
1.15 Remove or redesign infrastructure of commercial shrimp ponds that modify mangrove hydrology and reduce water quality.
1.16 Conduct or update studies of main species of commercial importance to the local fishing economy in terms of population dynamics, spawning areas and seasons, and other information needed to create

species management plans and set quotas.
1.17 Develop sustainable management plans/regimes for the major economically important fish and shellfish species.
1.18 Establish "no take" reserve areas for fish species if needed in order to rebuild populations based on scientific knowledge, local knowledge, and community participation.
1.19 Conduct or update studies on the use of wood for cooking fuel in all zones.
1.20 Conduct or update studies on the use of wood for brick- and tile-making in all zones.
1.21 Conduct or update studies on the use of wood for building in all zones.

Table 8.2 presents illustrative options and actions that would decrease societal dependence on ecosystem benefits, whether products or services (category 2).

TABLE 8.2 ACTIONS TO DECREASE SOCIOECONOMIC SENSITIVITY TO LOSS OF ECOSYSTEM BENEFITS

2. Actions to Decrease Socioeconomic Sensitivity to Loss of Ecosystem Benefits
2.1 Shift from basic grains to agroforestry crops (e.g., fruits, nuts, coffee) that are not as vulnerable to too much or too little rain because they tap deeper soil water sources and retain soil.
2.2 Increase market access and strengthen value chains for agroforestry crops.
2.3 Increase access to water on small farms and increase efficiency of use through practices and technology.
2.4 Increase water-use efficiency in commercial agro-industries (e.g., melons, sugarcane).
2.5 Increase cultivation of coffee varieties resistant to coffee leaf rust fungus (*roya*).
2.6 Increase use of climate-smart varieties of basic grains (i.e., those adapted for the kinds of climate variability that exists now and that is predicted).
2.7 Develop tourism options in fishing communities (e.g., restaurants, mangrove tours, bird watching, sea turtle viewing).
2.8 Reduce fuelwood use/demand through improved cookstoves or substitute fuels.
2.9 Reduce fuelwood use for brick and tile making through improved kiln designs.
2.10 Design and build infrastructure to accommodate rainfall and river flows greater than historical averages.
2.11 Encourage maize farmers not to plant immediately after early first rains in the first wet season, but wait until historical dates for the start of the main rains (e.g., mid-May).

Table 8.3 lists actions that would increase the adaptive capacity of communities and relevant institutions (e.g., local and national government agencies, NGOs, private commercial sector) to manage the resilience of the eco-sociological system (category 3). As discussed in Section 6.1, these actions involve

changing the behaviors or practices of individuals or institutions in ways that would lead to the first or second categories of adaptive actions described above.[2]

TABLE 8.3 ACTIONS TO INCREASE ADAPTIVE CAPACITY

3. Actions to Increase Adaptive Capacity
3.1 Improve enforcement of current environmental laws and regulations that protect habitats, forests, watersheds, soils, and species.
3.2 Improve communication and collaboration between national agencies, co-management agencies, municipalities, and communities for better local monitoring and enforcement of laws and regulations.
3.3 Revise management plans of all protected areas to adapt conservation management for projected climate changes.
3.4 Improve watershed-scale planning and management (i.e., improve capacity for integrated watershed management).
3.5 Improve integrated planning and management for the coastal zone that recognizes the eco-hydrological linkages between inland and open waters of the Gulf (i.e., improve integrated coastal zone management).
3.6 Develop local and regional schemes for payment or other compensation for ecosystem services for water.

8.3 RECOMMENDATIONS

Donors including USAID have been working with government, NGO, and private sector actors in Honduras for decades. In many cases they have carried out activities and projects similar to the options identified above, or that would contribute to some of them. Annex H provides information on all of these previous projects that have experience with activities relevant to increasing eco-social resilience to climate change in Southern Honduras.

An integrated, ecosystem-based approach to climate change adaptation is a necessary component of any effective strategy for food and livelihood security in Southern Honduras. Sustainable adaptation options must link upper watershed and coastal zone ecosystems and communities because of the ecological and socioeconomic interconnections between them. The research team strongly believes that new interventions need to consider the interconnections between people, families, and communities and the larger landscape of the region at a watershed and landscape scale, from the mountains to the coast. Ecosystem products and services need to be valued at this scale, beyond the immediate areas where they are produced or used.

In Southern Honduras, water shortages and floods are affecting both subsistence and commercial agriculture, and the interconnectedness among upstream and downstream resource users is more

2 Many of the actions identified in this assessment that would increase resilience to climate change were also identified as actions needed to address threats to biodiversity in a recent biodiversity threats assessment conducted for USAID/Honduras by the U.S. Forest Service International Programs Office (USAID/Honduras, 2013:24).

evident — and recognized by a greater range of stakeholders — than in many other parts of the country. Due to the potential impacts of climate change and climate variability, water resources development and management present unique opportunities for collective actions by diverse stakeholders to protect and restore ecosystems that provide eco-hydrological services. Water is a felt need among different actors, especially in the southern dry corridor, and awareness of climate change and variability might have a substantial positive effect in raising the political will to act on long overdue water development and watershed protection and restoration initiatives.

Honduras has experienced some success with promoting soil and water conservation. Many best practices for productivity and soil and water conservation on hill-slope farms were developed and transferred through a farmer-to-farmer process. The USAID LUPE Project, for example, developed and taught around 40 best practices. Past projects have shown results at the level of the farm, and quite a few farmers have adopted those technologies and practices. For example, many of these past projects show good evidence of some success in promoting the adoption of agricultural practices that would affect vulnerability to climate variability and change, such as: conserving, not burning, crop residues; adopting permanent cropping systems (agroforestry and fruit crops); adopting improved crop varieties; and improving protection of community water sources.

Future programs should define entire watersheds as priorities, and within those, focus on strategic sites of intervention, such as protected areas that conserve a large proportion of the permanent land cover in the area, or critical micro-watersheds that produce water for domestic use in communities or for small- or large-scale irrigation on farms. Future programs should also integrate established commercial agro-industries of the valleys and coastal plain into programs of upper watershed conservation for priority watersheds. Those industries could contribute to the establishment of hydro-meteorological stations that would generate scientific information and lead to a better understanding of the eco-hydrology of the entire region. That understanding, in turn, would allow the industries to make better decisions about the sustainability of their investment and expansion.

New programs to promote tree crops and agroforestry as a means to increase the permanent land cover ratio throughout the region should be carefully targeted and concentrated in key watersheds and ecosystems in order to have tangible positive effects on ecosystem products and services.
Before any tree crop is promoted, value chain analysis should demonstrate that the market will determine its widespread adoption and sustainable management once the project ends.

The commercial melon and sugar industries of the region are aware of how much they depend on eco-hydrological services to provide the quantity and quality of water they need for their industries (see Annexes F and G). A melon farm manager said, "the sustainability of the enterprise depends on a healthy watershed that provides a clean and steady water supply" (personal communication, A. Oviedo, Farm Manager, Agrolibano Montelibano Farm, 5 December 2013; see Annex F for full interview).

Representatives of these industries expressed an interest in developing mechanisms of payment or other compensation that would protect and restore upper watersheds. The assistant manager of Azucarera Choluteca, the second largest sugar grower in Southern Honduras, said, "we are already investing in environmental protection, we just need to reorient financial resources and select priority areas within catchments" for this type of a mechanism (personal communication, S. Salina, Azucarera Choluteca, 5 December 2013; see Annex G for full interview) . He specifically expressed interest in the Rio Namasigue/Quebrada Seca, where they grow around 1,000 hectares of sugarcane with very limited water supply for irrigation. This watershed is among the most water-stressed in the area due to increased water competition between melon and sugarcane growers and cattle farmers, and because the watershed lacks an exploitable groundwater aquifer and requires surface water for irrigation and livestock (see Annex G).

The Tres Valles Sugar Company, producing sugarcane on approximately 5500 hectares in the Moroceli, Talanga, and Yeguare valleys in Francisco Morazán Department, may be the most proactive sugarcane producer in Honduras and probably in Central America in terms of water management. The company may provide a model that could be replicated in Southern Honduras. Tres Valles has identified some critical watersheds in their growing area and are making investments to monitor climate and streamflow, protect forest cover, and restore permanent land cover through reforestation and improved community land management. Tres Valles holds the co-management agreement with ICF to manage the Chile Biological Reserve (see Annex I).

USAID support for implementation of some of the adaptive actions identified above could integrate USAID Biodiversity and Climate Change Adaptation funds and make an essential contribution to food and livelihood security and economic growth for Southern Honduras.

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LIST OF ANNEXES

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