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Dry Season, Wet Season: Climate Change and Central America

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Introduction

Central America stands at the narrow hinge of two continents and two oceans, and that geography makes the region uniquely exposed to climate variability and change. Over recent decades, farmers in the Dry Corridor have watched the dry season lengthen and the rains grow more erratic. Coastal communities have seen tides creep inland and storms intensify. Cities from Guatemala City to San Salvador and Tegucigalpa struggle with heat waves that amplify air pollution and overwhelm drainage systems during cloudbursts. These experiences are not isolated anecdotes; they are signals consistent with a growing body of scientific evidence.

This book offers a clear, evidence-based synthesis of how climate change is reshaping agriculture, water security, migration, and disaster risk across Central America. We draw on peer-reviewed research, national meteorological records, regional climate models, and practitioner knowledge from governments, civil society, and communities. By pairing data with grounded case studies, we translate complex findings into actionable insights for policymakers, NGOs, and planners. Our focus is not only on what is changing, but on what can be done—locally, realistically, and equitably.

The chapters are organized to move from physical science to socioeconomic impacts and finally to adaptation pathways. We begin by tracing observed trends in temperature and precipitation, exploring the roles of El Niño–Southern Oscillation and the Caribbean Low-Level Jet, and examining how future projections diverge by season and subregion. We then follow the water: from headwaters through aquifers to estuaries and reefs, identifying the chokepoints where scarcity, contamination, or extreme events translate into livelihood risks. Agriculture anchors the middle of the book, with attention to basic grains, high-value crops such as coffee and cacao, and the livestock systems that knit together rural economies.

Impacts do not stop at the farm gate. Disasters linked to hurricanes, floods, and landslides interact with urban growth patterns, health burdens, and fragile infrastructure. These stressors can compound social inequalities and, at times, contribute to decisions to migrate—within countries, to neighboring states, or northward. We therefore examine migration as both an adaptation strategy and a symptom of risk, emphasizing the importance of safeguarding rights and investing in opportunities that reduce involuntary displacement.

Adaptation is most durable when it is locally led and regionally coordinated. Throughout the book, we highlight solutions that have proven effective: climate-smart agriculture and extension services; watershed restoration and nature-based defenses; water storage and efficiency; urban green-blue infrastructure; risk transfer tools such

as insurance and forecast-based financing; and institutional reforms that align planning, budgeting, and emergency management. We also underscore the knowledge held by Indigenous peoples and rural communities, whose stewardship and practices often anticipate the recommendations of formal studies.

Finally, we argue for practical governance that matches the scale of climate challenges. Rivers cross borders; storms ignore jurisdictions. Regional platforms—when resourced and inclusive—can harmonize data, share early warnings, and coordinate investments that no single municipality or ministry can shoulder alone. By closing the loop between evidence and policy, and between local action and regional cooperation, Central America can navigate both dry seasons and wet seasons with greater resilience.

This book is designed as a toolkit as much as a narrative. Readers can start at the beginning for a comprehensive arc or dip into specific chapters for sector guidance or policy design. Each chapter concludes with concise takeaways and decision points. Our hope is that the synthesis here equips leaders, practitioners, and communities to move from reactive crisis management to proactive, place-based adaptation—protecting lives and livelihoods today while laying the groundwork for a more secure 2030–2050 horizon.

CHAPTER ONE: The Geography of a Hotspot: Central America's Climate System

Central America is a narrow bridge between continents and oceans, and that bridge carries both moisture and heat in pronounced seasonal pulses. It is a geography that concentrates climate variation. Pacific waters lie to the west, Caribbean seas to the east, mountain ranges spine the region, and lowlands flank both coasts. The land itself is narrow—no more than a few hundred kilometers across in most places—so weather systems sweep through quickly, yet they do so with a sharpness that reflects the topography and the seas around it. This chapter sets the physical stage: the landscapes and marine influences that structure Central America's climate and define its exposure to variability and change.

At the heart of the system are two big oceans that behave differently. The Pacific is vast and largely basin-wide, with ENSO signals traveling across it and shaping global atmospheric teleconnections. The Caribbean, meanwhile, is more enclosed, with warm waters that fuel tropical cyclones and a low-level atmospheric current that channels moisture westward into the interior. The region sits in the crossfire of these influences, with onshore flows from both coasts meeting over mountain belts. Where these air masses collide and lift, rainfall concentrates; where they are cut off, droughts take hold. Seasonally, the pattern flips, and that flip is what defines the dry and wet seasons that give this book its title.

The dry season, locally known as *verano*, typically runs from November to April. Over the Pacific slope and interior valleys, skies often clear, winds steady, and humidity drops. The Caribbean side may still see showers, but the interior often experiences long stretches of bright, dry days. This is not a desert climate; rainfall can still occur during the dry season, particularly in the east and along coastal fringes. However, for agriculture and water supply, the dry season is defined by the reliability of limited rainfall and the long gap before the onset of the wet season. That gap can be measured in weeks, but its consequences stretch through entire crop cycles and water budgets.

The wet season, or *invierno*, usually begins in May and runs through October, with a pronounced peak around June to August. Convection builds over heated land surfaces, moisture streams in from both oceans, and thunderstorms erupt across afternoons and evenings. The wet season delivers the majority of annual rainfall, but not in a uniform, gentle drizzle. It arrives in bursts—intense downpours, multi-day rain events, and occasional tropical cyclones that can unload extraordinary totals in a short time. The timing of onset and retreat, and the frequency of dry spells within the season,

matter greatly for crops like maize and beans, which can be sensitive to interruptions at flowering.

A defining feature of Central American climate is the midsummer drought, known locally as the *veranillo* or *canícula*. This is a temporary reduction in rainfall during July or August, often lasting one to three weeks. It is not a fluke; it is a regular feature driven by shifts in trade winds, cloudiness, and the positioning of the intertropical convergence zone. Farmers time planting to avoid the most sensitive crop stages during this window. Variability in the *canícula*—its onset, duration, and intensity—can make or break yields. Understanding this midseason pause is key to interpreting rainfall totals; two seasons with similar totals can have very different agricultural outcomes if the dry spell interrupts flowering.

Topography magnifies these patterns. Mountain ranges run through Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica, with peaks rising above 2,000 meters and, in some cases, approaching 4,000 meters. Orographic lift forces moist air to rise, cool, and condense, creating rain shadows on leeward slopes. This leads to strong gradients: a few kilometers can separate lush forest from dry woodland, or a coffee farm receiving steady drizzle from a valley floor baking under clear skies. High-elevation areas often collect more rainfall over the year and experience cooler temperatures, which can buffer crops against heat stress but increase disease risk under persistent cloudiness.

Coastal plains add another layer of contrast. The Caribbean lowlands of Honduras, Nicaragua, Costa Rica, and Panama are generally wetter and more humid than Pacific slopes. Trade winds carry moisture inland, and the Caribbean Sea maintains warm temperatures year-round, sustaining convection even during the dry season in some years. Pacific coastal plains vary: in Guatemala and El Salvador, they are narrow and often rain-shadowed; in parts of Nicaragua and Costa Rica, they broaden and experience more pronounced wet seasons. Mangrove forests along these coasts act as buffers against storm surge and saline intrusion, but their health depends on freshwater inputs and land-use practices upstream.

River networks reflect these climatic gradients and shape water availability. Major basins include the Lempa, which runs from Guatemala through El Salvador and Honduras to the Pacific; the Motagua in Guatemala, which empties into the Caribbean; the San Juan and Tempisque in Costa Rica and Nicaragua, flowing toward the Caribbean and the Gulf of Nicoya; and the Sixaola on the Costa Rica–Panama border. These rivers are fed by rainfall from both slopes and highlands, and their regimes shift with seasonal pulses. Dry-season flows are often low, relying on baseflow from groundwater and mountain springs; wet-season flows can surge dramatically, carrying sediment and at times causing destructive flooding. Their transboundary nature makes water management a regional affair.

Groundwater systems are integral but often less visible. In coastal areas, aquifers face saline intrusion as sea level rises and as excessive pumping lowers freshwater heads. In volcanic terrains, porous basalt can host productive aquifers, while tuff and limestone layers may yield more modest storage. Recharge depends on rainfall intensity and land cover; forests and perennial vegetation promote infiltration, whereas paved surfaces and steep slopes encourage runoff. In many towns and cities, wells supplement surface water during the dry season, revealing the tight coupling between rainfall variability and groundwater response. Monitoring networks are improving, but gaps remain, especially in cross-border basins where data sharing is inconsistent.

Temperature patterns follow elevation more than latitude. Coastal plains and lowlands experience consistently warm conditions, often with daytime highs in the upper 20s to low 30s Celsius, while highland valleys and plateaus are cooler, sometimes by 10°C or more. Humidity varies with proximity to the Caribbean and the Pacific, with the Caribbean side generally more humid year-round. Diurnal temperature ranges can be substantial in drier interior areas, where clear skies allow rapid cooling at night. These thermal regimes influence crop choice and pest dynamics. For example, coffee thrives in mid-elevation zones with moderate temperatures; bananas require consistent warmth and moisture; maize and beans are cultivated across a range of altitudes but are sensitive to heat stress and moisture deficits at critical growth stages.

The region's climate is also shaped by large-scale atmospheric currents. The Caribbean Low-Level Jet, a wind corridor located roughly between 700 and 900 hPa, transports moisture from the tropical Atlantic into Central America and the Caribbean basin. Its intensity varies seasonally, strengthening during late spring and summer, and it is linked to the development of the wet season and the occurrence of hurricanes. A stronger jet can enhance rainfall on Caribbean-facing slopes and influence the distribution of storms, while a weaker jet can delay onset or reduce precipitation. The jet interacts with sea surface temperatures across the tropical oceans, tying local rainfall to global climate patterns.

ENSO—El Niño and La Niña—exerts strong but variable influence across Central America. El Niño typically brings drier and warmer conditions to the Pacific slope during the wet season, with increased rainfall anomalies on the Caribbean side in some years. La Niña often enhances Pacific slope rainfall and can increase the likelihood of more active hurricane seasons. These are not strict rules; impacts vary by subregion and season, and other factors modulate ENSO effects. The timing of ENSO phases relative to crop calendars and water planning cycles matters, as does the interaction with other oceanic patterns, such as the Atlantic Multidecadal Variability and the Pacific Decadal Oscillation. Understanding these teleconnections helps interpret anomalies and prepare for likely seasonal shifts.

Tropical cyclones represent a critical hazard concentrated in the wet season but possible outside it. Storms form in both the Atlantic and Pacific basins and can affect Central America via direct landfall or indirect rainfall impacts. The Caribbean coast is historically exposed to Atlantic systems, while the Pacific coast faces storms forming closer to the Central American coast or migrating from the far Pacific. The topography can enhance rainfall totals dramatically when storms interact with mountain ranges, producing flash floods and landslides. Even storms passing well offshore can draw in moist air and trigger intense convection over the interior. Frequency and tracks vary from year to year, but the risk is a constant feature of the climate system.

Coastal processes are influenced by both ocean temperature and large-scale wind patterns. Sea surface temperatures around Central America have warmed in recent decades, increasing the potential intensity of cyclones and altering the thermal gradient that drives convection. Sea level rise, driven by global warming and local subsidence in some areas, exacerbates storm surge and chronic flooding in low-lying coastal zones. Mangrove retreat and reef degradation reduce natural protection, amplifying exposure. Fisheries respond to these changes, as warm anomalies can shift fish distributions and affect nearshore productivity. Coral bleaching events are more frequent during strong warm phases, with knock-on effects for tourism and local livelihoods.

Land cover interacts strongly with climate processes. Deforestation in upland areas can reduce evapotranspiration and cloud formation, potentially diminishing orographic rainfall. Conversely, forested watersheds tend to sustain baseflow and reduce the intensity of landslides during heavy rain. Agricultural expansion into steeper slopes increases erosion risks, while urbanization adds impervious surfaces that accelerate runoff and exacerbate flooding. Pasturelands dominate large parts of the landscape; their management influences soil health, fire risk, and the capacity to absorb rainfall. The way the land is used is not just a consequence of climate; it shapes the climate experienced locally.

Microclimates proliferate across the region due to the interplay of topography, land cover, and oceanic influences. A valley can experience morning fog and afternoon sun, while the next ridge is windy and dry. Coastal breezes modify temperatures near the shoreline; interior basins trap heat during calm conditions. Farmers have long adapted to these microclimates by selecting crop varieties and planting calendars that match local conditions. Understanding microclimate variability is essential for designing site-specific adaptation measures. One-size-fits-all strategies often fail because conditions change quickly over short distances, and local knowledge can complement formal climate data to improve decision-making.

Climate variability is layered on long-term trends. While this chapter focuses on the physical geography and baseline climate behavior, subsequent chapters will delve into observed changes and future projections. What is clear from the outset is that Central

America's climate system is a coupled ocean-land-atmosphere system where variability is the norm, not the exception. Droughts are part of the seasonal and interannual rhythm; intense rainfall events are too. The challenge is that this rhythm is being altered, with the amplitude and timing of seasonal swings shifting in ways that stress systems built around historical patterns.

Water availability reflects the seasonal rhythm and the capacity to store and manage it. Rivers carry the pulse of the wet season, while groundwater and reservoirs provide the buffer during the dry season. Infrastructure—dams, canals, wells, and distribution networks—must be designed for highly variable inputs. In some basins, the distribution of rainfall across elevation zones means that headwaters are critical for downstream users; protecting forests and soils in those zones is a direct investment in water security. In others, siltation reduces reservoir capacity, making sediment control a key element of climate adaptation.

Marine systems complete the picture by influencing coastal climate and livelihoods. The Caribbean Sea's warm waters sustain rain and storms; the Pacific's vast expanse ties the region to ENSO and broader oceanic cycles. Coral reefs and mangroves are not just biodiversity assets; they are climate buffers. Their degradation reduces the region's natural resilience to storms and sea level rise. Fisheries, in turn, are sensitive to ocean warming and acidification, with implications for food security and coastal economies. The two-ocean context means Central America experiences climate impacts from both sides, sometimes simultaneously, sometimes in contrasting ways.

Atmospheric moisture sources shift across the year. In the dry season, trade winds dominate and the Caribbean remains a steady source of moisture, especially for eastern slopes. In the wet season, both oceans feed convection, and the positioning of the Caribbean Low-Level Jet and upper-level winds determines which side gets the heavier downpours. Upper-level features like tropical waves and mid-tropospheric troughs can trigger widespread thunderstorm activity. Sometimes, a dry season system stalls offshore, delivering rain to coastal areas while interior valleys remain dry. These patterns highlight the need for regional monitoring that accounts for both local and remote drivers.

Regional geography also shapes wind patterns that influence climate. Chorros de viento, or wind corridors, form where topography funnels airflow; these can enhance evaporation and affect crop physiology. In mountainous regions, katabatic and anabatic flows develop as slopes heat and cool, shaping cloud formation and rainfall timing. Along coasts, sea breezes provide cooling but can also push storm systems inland. Understanding these local wind regimes is important for planning energy infrastructure and agriculture, as wind patterns influence disease spread, pollination, and the effectiveness of irrigation through evapotranspiration losses.

Temperature extremes are felt differently across elevations. Lowland heat can stress

outdoor labor, reduce crop yields, and increase energy demand for cooling. Highland frosts, while rare, can damage sensitive crops during cold snaps. The variability between day and night temperatures is critical for plant growth; nights that remain warm can accelerate pest cycles, while cool nights can slow development. The interaction of temperature and rainfall defines cropping windows: too much heat with too little rain reduces yields; intense rain with cool temperatures can increase disease pressure. Matching crops to thermal regimes is an ongoing process, especially as baseline temperatures shift.

Seasonal transitions themselves carry risk. The onset of the wet season is often gradual, with scattered storms before widespread rain. False starts—early rains that dry up—can tempt farmers to plant too soon, leading to crop failure. Late onsets shorten the growing window and compress harvests. Similarly, early retreat of the wet season can leave crops thirsty at grain-filling. These timing issues are as important as total rainfall amounts. Communities watch the sky and the calendar; extension services and forecasts now complement these traditions to reduce the risks associated with the swing from dry to wet and back again.

The region's climate is also modulated by large-scale patterns that operate on multi-year timescales. Variability in Atlantic sea surface temperatures can influence rainfall distribution, especially in the Caribbean-facing areas. The Pacific decadal modulation of ENSO alters the frequency and intensity of El Niño and La Niña events, which in turn shape regional drought and flood risk. While these patterns are global, their effects are felt locally, reinforcing the need for climate information that bridges scales. Understanding the background state of the oceans helps interpret why some years are exceptionally dry or wet, beyond the immediate seasonal cycle.

Central America's position near the equator but within the tropics means it experiences relatively stable day length year-round, but not uniform heating. Seasonal shifts in the sun's position and cloud cover modulate surface temperatures. In clear dry-season skies, solar radiation is high, driving evaporation; in cloudy wet-season afternoons, radiation drops, but humidity remains high. Energy budgets differ between coast and interior, influencing soil moisture dynamics. For water planners, this variability means that potential evapotranspiration is not a fixed number but a moving target tied to cloudiness, wind, and humidity. Irrigation demand follows these patterns closely, with peaks during the dry season.

Understanding Central America's climate system requires appreciating the tight coupling between oceans, mountains, and the land surface. Rain does not fall out of context; it is the product of moisture transport, lift, and surface conditions. Drought is not simply lack of rain; it is a build-up of deficits interacting with high temperatures and soils that lose moisture quickly. Floods are not just heavy rain; they are rain falling on slopes already saturated or on degraded terrain. The geography of the region makes these interactions rapid and visible. Adaptation must therefore consider the

whole system, not just isolated elements.

As a hotspot of climate risk, Central America's exposure is amplified by its exposure to multiple, intersecting hazards. The same mountains that make the region lush also create landslides under heavy rain. The same coasts that welcome tourism are vulnerable to storm surge and erosion. The same rivers that irrigate crops can also flood them. This multi-hazard reality is rooted in the physical geography. Planning for climate change means acknowledging that hazards are interconnected and that the geography itself—ridge and valley, coast and sea—shapes both risk and opportunity.

With the physical stage set, the following chapters examine how this climate system is changing and what that means for people and ecosystems. Observed trends in temperature and rainfall will show whether the seasonal rhythm is shifting. Future projections will explore how scenarios of global emissions translate into local outcomes. The dry season's intensification, the wet season's extremes, and the roles of ENSO and the Caribbean Low-Level Jet will be explored in detail. Water security, agriculture, coastal systems, and disaster risk will be linked back to the geography described here, grounding impacts in the landscapes and waters that define Central America.

This chapter has outlined the key elements of Central America's climate system: two oceans, mountain chains, coastal plains, river networks, and groundwater systems; seasonal cycles marked by dry and wet seasons with a midsummer pause; atmospheric drivers like ENSO and the Caribbean Low-Level Jet; and local processes such as orographic lift and coastal breezes. The region's narrow geography concentrates variability, making it a hotspot where climate signals are strong and decisions carry immediate consequences. This physical context is the foundation for understanding the evidence and impacts discussed throughout the book.

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