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COUNTRY REPORT
CLIMATE RISK MANAGEMENT IN ECUADOR

Regional Integrated Multi-hazard Early Warning System (RIMES)
January, 2013

United Nations Development Programme

CRISIS PREVENTION AND RECOVERY

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LIST OF ABBREVIATIONS AND ACRONYMS

AME	Association of Municipalities of Ecuador
BCPR	Bureau for Crisis Prevention and Recovery
BDP/EEG	Bureau for Development Policy's Energy and Environment Group
CCA	Climate Change Adaptation
CCC	Critical Climate Change
CDR	Regional Development Corporations
CIIFEN	International Center for Research on the El Niño Phenomenon
CNC	National Climate Change Committee
CNRH	National Council of Water Resources
CONCOPE	Consortium for Provincial Governments of Ecuador
CONELEC	National Electrification Council
CRM	Climate risk management
CRM TASP	Climate Risk Management Technical Assistance Support Project
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DRR	Disaster Risk Reduction
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
FRH	Water Resources Forum
GCM	Global Climate Model
GDP	Gross Domestic Products
GEF	Global Environment Fund
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
GLOSS	Global Sea Level Observing System
IITM	Indian Institute of Tropical Meteorology
INAMHI	National Institute of Meteorology and Hydrology
INOCAR	Navy's Oceanographic Institute
IPCC	Intergovernmental Panel on Climate Change
ITCZ	El Niño Southern Oscillation
MoA	Ministry of Agriculture
MoE	Ministry of Environment
NSRM	National Secretariat for Risk Management
RCM	Regional Climate Model
RIMES	Regional Integrated Multi-hazard Early Warning System for Africa and Asia
SENPLADES	National Planning and Development Secretariat
SNC	Second National Communication
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

FOREWORD

Climate change has the potential to exacerbate conflict, cause humanitarian crises, displace people, destroy livelihoods and set-back development and the fight against poverty for millions of people across the globe.

For example, it is estimated that over 20 million people in the Mekong Delta and 20 million in Bangladesh could be forced to move as their homes are affected by saltwater incursion from rising sea levels. Entire populations of some low lying island states, such as Nauru or the Maldives may have to be relocated. In countries like Honduras, where more than half the population relies on agriculture, climate induced risks, such as hurricane Mitch in 1998, which caused over USD 2 billion in agricultural losses, will continue to pose a staggering potential for damage. Similarly, climate risk assessments in Nicaragua show that changes in rainfall patterns, floods and drought could put human health at risk by increasing the prevalence of respiratory and water borne diseases and malnutrition.

Long-term incremental changes will mean that people everywhere must learn to adapt to weather or rainfall patterns changing, or to shifts in ecosystems that humans depend upon for food. Perhaps more worrying however, is that climate variability and change will also bring unpredictable weather patterns that will in turn result in more extreme weather events. Heat waves, droughts, floods, and violent storms could be much more common in the decades to come. Climate change is "loading the dice" and making extreme weather events more likely. These disasters will undermine the sustainability of development and render some practices, such as certain types of agriculture, unsustainable; some places uninhabitable; and some lives unliveable.

As climate change creates new risks, better analysis is needed to understand a new level of uncertainty. In order to plan for disasters, we need to understand how climate change will impact on economies, livelihoods and development. We need to understand how likely changes in temperature, precipitation, as well as the frequency and magnitude of future extreme weather will affect any sector, including agriculture, water-use, human and animal health and the biodiversity of wetlands.

This report is a product of the *Climate Risk Management – Technical Assistance Support Project*, which is supported by UNDP's Bureau for Crisis Prevention and Recovery, and Bureau for Development Policy. This is one in a series of reports that examine high-risk countries and focus on a specific socio-economic sector in each country. The series illustrates how people in different communities and across a range of socio-economic sectors may have to make adaptations to the way they generate income and cultivate livelihoods in the face of a changing climate. These reports present an evidence base for understanding how climatic risks are likely to unfold. They will help governments, development agencies and even the communities themselves to identify underlying risks, including inappropriately designed policies and plans and crucial capacity gaps.

This series is part of a growing body of climate change adaptation resources being developed by UNDP. The Climate Risk Management – Technical Assistance Support Project has formulated a range of climate risk management assessments and strategies that bring together disaster risk reduction and climate change adaptation practices. The project is designing a common framework to assist countries in developing the necessary capacity to manage climate-induced risks to respond to this emerging threat. The climate risk assessments discussed in this report and others in the series will feed into a set of country-level projects and regional initiatives that will inform the practice of climate risk management for decades to come.

Addressing climate change is one of UNDP's strategic priorities. There is strong demand for more information. People at all levels, including small communities want to understand the potential impact of climate change and learn how they can develop strategies to reduce their own vulnerability. UNDP is addressing this demand and enabling communities and nations to devise informed risk management solutions. UNDP recognises that climate change is a crucial challenge to sustainable development and the goal of building resilient nations.

As the full effect of climate change becomes apparent, it is assessments such as these that will become the lynchpin of national responses and adaptation strategies for many years to come. Like the threat from many disasters, there is still time to prepare for the worst impacts of climate change in developing countries if we expand our understanding now.

This knowledge must be combined with real preparedness and action at all levels. Only then will we be able to stave off the worst impacts of climate change in the most vulnerable and high risk countries of our world.

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The Project, its methodology and analytical framework was conceptualized by Maxx Dilley, Disaster Partnerships Advisor and Alain Lambert, Senior Policy Advisor, Disaster Risk Reduction and Recovery Team (DRRT), BCPR with key inputs from Kamal Kishore, Senior Programme Advisor, DRRT, BCPR and in consultation with Ms. Bo Lim, Special CC Advisor, Environment and Energy Group (EEG), BDP.

Within BCPR, the Project implementation process has been supervised by Alain Lambert and Rajeev Issar who provided regular inputs to ensure in-depth climate risk assessments and identification of tangible risk reduction and adaptation options. From BDP, Ms. Mihoko Kumamoto and Ms. Jennifer Baumwoll provided their inputs and comments to refine the assessment and recommendations.

The Project team would like to acknowledge and give special thanks to the main authors of the Report from RIMES.

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The climate risk assessments under the CRM-TASP project have been undertaken with the funding support of the Government of Sweden.

EXECUTIVE SUMMARY

Ecuador is a small country with a land area of 25 million ha. It is broadly divided into four natural regions – the Highlands with 72 volcanoes, the Coastal region, the Amazon and the insular Galapagos Islands. It has a population of over 40 million people, with around 67 percent people residing in urban areas.

Its GDP is around US$ 67 billion (2011). The economy is largely driven by the oil sector that contributes 30 percent of GDP, 60 percent of exports and 40 percent of government revenues (2010). The agriculture sector only contributes around 7 percent to the GDP, but supports 30 percent of the population.

Periodic climate shocks have undone developmental gains and are responsible for persisting poverty of around 35 percent. The Government of Ecuador (GoE) has been forced to divert large resources to reconstruction and rehabilitation programs following disasters. This approach has contributed little to reducing risk and in fact has resulted in accumulation of risk.

Chronic malnutrition affects 26 percent of children under 5 years of age and this could go up to 40 percent in highlands and 47 percent for indigenous populations in the country. The incidence of extreme poverty is around 13 percent but it exceeds 49 percent in some rural areas. Rural areas also suffer from lack of investments in rural infrastructure such as roads and the irrigation systems. The development of the agriculture sector is considered important for reducing poverty in rural areas.

Considering these developmental concerns the GoE has developed a development vision and a National Plan for Good Living (2009-2013). The plan proposes a National Development Plan (2009-2013) to further develop and link rural agriculture based productive system to the national economy and wider markets through specialized agro processing industrial systems.

Ecuador is a highly climate sensitive country. Climate risks caused damages and losses of US$ 5 billion (drought around US$ 4 billion and flood around US$ 1 billion) from the year 2000 to 2010. The new agro based development strategy, is at a high risk from climate variability and change. It is estimated that a minimum of US$ 450 million could be lost to climate risk on an annual basis and this will increase exponentially as more and more development assets are exposed.

Some climate risk reduction options are available to protect development assets from periodic climate shocks in Ecuador. For example appropriate use of climate information on seasonal to 10 days scale could reduce crop production risks considerably. However, despite Ecuador's experiences on applying El Nino based seasonal forecast information and short range weather information, the climate related losses continue to grow. The CRM actions need to be strengthened, intensified and refined by incorporating lessons from past experiences and projection of future risk. Climate risk communication in particular could be strengthened to connect information providers and users. Similarly the designing of infrastructure like roads, communication, irrigation and housing could be responsive to existing and anticipated climate risk with little additional investment.

The recommendations for strengthening climate risk management and risk reduction in Ecuador are focused on the following four broad areas:

i. **Investments in and Institutionalization of Climate Risk Management:** This includes adequate and appropriate financial investment for climate risk reduction; Build and coordinate an institutional mechanism with capacities for CRM with active engagement of relevant ministries and institutions; undertake needs assessment to build capacities of the key institutions; utilize CSOs for introducing and implementing CRM; establish alliances and multi-stakeholder dialogue for sharing climate knowledge for decision making; establish an inter-institutional communication network for communicating and coordinating CRM interventions; develop training programs and professional courses for integrating CRM in development planning and practices; pilot projects in some municipalities with variable local climate risk scenarios by proposing suitable risk management strategies with community participation.

ii. **CRM in the priority sectors of agriculture and infrastructure:**

a. **Agriculture:** Delineate risk zones for food production using climate risk assessment results, water management, agronomic practices, and building on existing agro-climatic zones; implement crop relocation and/or de-concentration of food crop production considering variables of crop growth, future climate trends and their vulnerability to climate shocks; develop a climate information decision-support tool using existing forecasting capacities like ENSO; use climate information to anticipate inter-annual and intra-seasonal variability and transition from from subsistence to market-oriented farming; link weather/climate information with broader input and output related information, like markets, seeds for alternate crops, pest and diseases etc. and; incorporate climate risk management measures into supply chain management.

b. **Infrastructure:** Capacity development of the Ministry of Infrastructure to continually assess and prioritise specific threats to infrastructure assets in the country and to implement adaptive measures. The relevance and constraints of each adaptive measure should be considered in light of the development resources and challenges in the area. For example, while seawalls or realignment work is a low cost long term solution, however, where sea level inundates an existing road the acquisition of land problems may arise.

iii. Strengthened climate information and communication management systems: Develop a user-relevant climate information system; improve national capacities on climate data processing, analysis, modeling and the generation of information and forecast services including its sectoral applications in four strategic sectors: agriculture, health, water resources and energy; strengthen the capacity of governmental institutions to identify and apply climate information in their respective sectors; strengthen research capacity to link existing climate information and make use of it for operational purposes; improve the current climate information communication systems and coordination between INAMHI and national agencies and authorities; develop GIS capabilities for hydro meteorological information in INAMHI ; create a documentation centre to systematize the information on disasters in general and climate risk in particular.

iv. Area specific recommendations: Utilize ENSO related information for understanding climate risks in coastal regions beyond the El Niño forecasts; use available information on climate variability and northern oscillation to for operational forecasting in the Andes-Sierra region; analyze and screen current development projects in the highlands for their exposure and vulnerability to climate risks; observe changes, reduce deforestation and review urbanization stresses related to oil extraction in the Amazon which has low climate variability; develop a dense and well-established observation system for climate variations and information sharing in response to the unique climate influences like ocean currents, Northern Oscillation, ENSO and topography in Ecuador and its potential impact on existing and planned development investments in the power and water sector.

From a development perspective, the proposed approach towards CRM options is to prioritise CRM in agriculture and infrastructure (high climate-sensitive sector), promote agroforestry-based livestock system (a moderately climate-sensitive sector), with gradual shift to non-farm occupations (least climate-sensitive sector), while ensuring it is socially acceptable, environmentally sustainable, and economically viable for Ecuador.

INTRODUCTION

BACKGROUND

Climate risk management (CRM) is an inter-disciplinary, multi-stakeholder process that involves analysis of climate-related risks leading to consensus-based identification and prioritization of risk management actions to anticipate and manage both extant and emerging climate risks.

Climate change can further alter the observed climate mean or cause changes in the nature of extremes (severity, frequency, spread, duration and timing) and possible surprises. The resultant climate risks could resemble current climate variability patterns, but with higher amplitude variations. Hence, CRM suggests that pattern of risks could be anticipated and the experiences of present systems in dealing with these risks could be drawn upon towards building resilience to long-term climate change. For climate "surprises," while past climate patterns may not provide any clue as to how they would unfold and manifest, human experiences in dealing with extreme climate events may provide guidance for dealing with uncertainties associated with climate change-related risks. Thus from a policy point of view, building the capacities of institutions and systems around managing current climate extremes and thereby a resilient development, could also assist in addressing climate "surprises."

The CRM framework has been developed to assist countries in developing capacities to manage risks associated with climate variability and change. It is developed by the United Nations Development Programme (UNDP), through its Bureau for Crisis Prevention and Recovery (BCPR), responsible for assisting countries to develop capacity to better manage disaster risks, and Bureau for Development Policy's Energy and Environment Group (BDP/EEG), responsible to assist countries to develop capacities to adapt to climate change. The Climate Risk Management Technical Assistance Support Project (CRM TASP) has been developed to facilitate operationalization of CRM frameworks by integrating CCA and DRR. The Regional Integrated Multi-hazard Early Warning System for Africa and Asia (RIMES) in collaboration with the Asian Disaster Preparedness Center has been tasked with implementing the CRM TASP framework into development planning, by assessing risk management priorities and capacity needs, in four countries in the first phase, including Ecuador.

APPROACH AND METHODS

The CRM TASP was initiated through an inception meeting organized it Bangkok, Thailand on October 2008, with UNDP focal points from the four project countries. In Ecuador the project is implemented in close collaboration with UNDP and International Center for Research on the El Niño Phenomenon (CIIFEN),, an international organization based in Ecuador which functioned as a consultant to the project (see table 1.1). The focus of the analysis was on the sectors of agriculture and infrastructure in Ecuador.

TABLE 1.1: PROJECT STEPS AND METHODS

PROJECT STEP & PURPOSE		SPECIFIC STEPS APPLIED IN ECUADOR
1. Initiation	Introduce CRM TASP	• Country engagement facilitated by UNDP Ecuador
2. Collaborative Analysis	To prepare baseline information and preliminary analysis	• Undertaken in collaboration with UNDP and CIIFEN the designated national consultant. • Training on analysis of extremes was organized in March 2009, at the Indian Institute of Tropical Meteorology (IITM) in Pune, India. The National Institute of Meteorology and Hydrology (INAMHI) participated and analysed the preliminary methodology and assessment findings
3. Consultation with key national agencies	Validation of research findings	• A mission was undertaken by a team of RIMES professionals to consult with national stakeholders and gather additional information. It was facilitated by CIIFEN, following which the preliminary CRM TASP report was revised further.
4. Consultation Workshops	Share draft report and findings	• A consultation meeting was organized at UNDP to present the findings of the Ecuador CRM TASP draft report, and several comments for its improvement were received. • RIMES professionals met with several national user agencies to identify areas of improvement in climate risk information systems. • The CRM TASP report was discussed, revised and finalised at the CRM TASP Final Workshop at Quito, with the support of stakeholders.
5. Documentation & Report writing	Documentation and finalisation of the CRM TASP report	• The final draft report was prepared and submitted to UNDP.

REPORT STRUCTURE

Chapter 1 captures the process steps and methods adopted. Chapter 2 focuses on the development context and trends in Ecuador and the rationale for prioritization of climate sensitive issues. Chapter 3 provides an overview of the geo-physical environment and climate risk features in Ecuador covering past trends, current developments and future projections. The assessment of climate threats to development in the context of past climate risks and anticipated climate change projections are covered in Chapter 4. Current Climate Risk Management (CRM) processes, policy and institutional systems are discussed in Chapter 5, while Chapter 6 focuses on ownership of CRM within the government, assessment of capacity needs, and recommendations for future actions.

DEVELOPMENT PROFILE

This chapter identifies development conditions in Ecuador, both past and current. It also captures the planned future directions for development, as identified in national plans.

CURRENT DEVELOPMENT CONDITIONS, TRENDS, AND CHALLENGES

Populated with approximately 14,483,499 people in 2011, Ecuador is a melting pot of diverse ethnic groups including American-Spanish (locally known as *mestizo*), indigenous, Caucasian, and Afro-Ecuadorian. The capital, Quito, is home to about 15 percent of the population. The country has a total area of about 276,840 square kilometers and is divided into 24 administrative units (provinces), including Azuay, Bolivar, Canar, Carchi, Chimborazo, Cotopaxi, El Oro, Esmeraldas, Galapagos, Guayas, Imbabura, Loja, Los Rios, Manabi, Morona Santiago, Napo, Orellana, Pastaza, Pichincha, Santa Elena, Santo Domingo de los Tsachilas, Sucumbios, Tungurahua, and Zamora-Chinchipe. Peru, Colombia and the Pacific Ocean flank Ecuador on the east and south, north, and west, respectively (Figure 2.1). Gifted with biodiversity, it has four distinct natural regions, including the amazon, the mountains, the coastal region and the insular (Galapagos) islands. About 94 percent of the population is concentrated in coastal and mountain areas, with the majority living in cities and towns.

Source: United Nations Department of Peacekeeping Operations, Cartographic Section, 2004

Figure 2.1 Ecuador Map

Poverty and Human Development

Ecuador is classified as a medium human development country. In 2011, it ranked 83rd in the Human Development Index. It was placed 80th on GDP ranking, with GDP per capita of USD 8,268.

There is wide social disparity in Ecuador. The indigenous people are significantly poorer than other ethnic groups. Approximately 29 percent of its population below the poverty line is (2011). To address issues on poverty, the Ministry of Welfare and Social Inclusion implements various monetary compensation and food support programmes. Several years of political and economic instability, prevalence of poverty, and the devastating impacts of the some disasters, prompted many Ecuadorians to migrate and work abroad. Remittances from migrants currently constitute a big chunk of the country's income.

Education

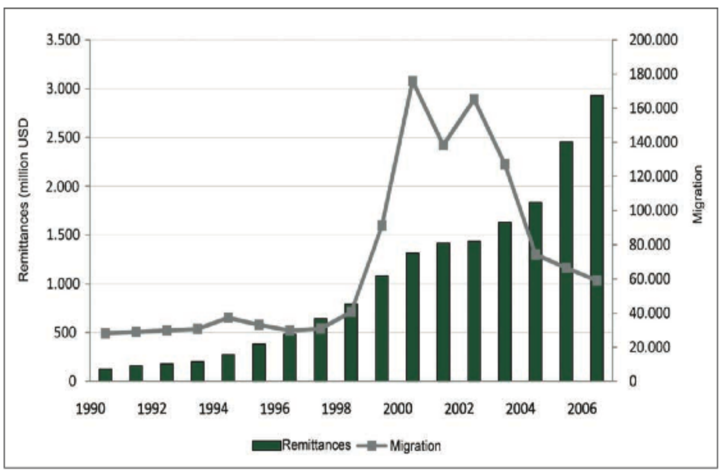
The literacy[1] rate is about 91 percent, disaggregated into male literacy at 92.3 percent and female literacy at 89.7 percent, as per the 2011 census. Public education is subsidized by the government, and school attendance of children aged 6-14 is compulsory. Many children however quit school before 15 years of age. In rural areas, only about 30 percent finish elementary. Enrolment has seen an increasing trend averaged at 4 percent annually. By 2006, about 91 percent of the target children population was enrolled in primary schools.

The increase in enrolment rates however, compounded with budget deficiencies and politics in the education system resulted in deterioration of education standards. In addressing the issue, the government has recruited 1,224 teachers in 2006. To continually encourage school attendance, contributions from families to offset expenditures on management of schools were removed.

Health

Maternal mortality rate was recorded at 110 deaths for every 100,000 births in 2010. Mortality rate for infants around 20 deaths per 1,000 births. Common diseases include diarrhea, typhoid fever, hepatitis A, malaria and dengue fever among others. Deaths attributed to HIV/AIDS are approximated at around 2,200 and around 37,000 people infected from it (2009).

In 2009, the health sector received around 5 percent of the GDP. Hospital facilities however were largely insufficient. This includes hospital bed density of only 1.5 bed for a population of 1,000 in 2008. and physician density of 1.48 to 1,000 individuals as of 2000.



Source: Banco Central del Ecuador, Instituto de Estadisticas y Censos, as cited in the National Development Plan 2009

Figure 2.2: National revenue from migramt remittances, 1990-2006

Economy

1999 and 2000 were difficult years for Ecuador. Its GDP slumped by more than 5 percent as a result of the economic crisis, thereby escalating poverty. The dollarization of the legal tender lent stability to the economy and the period from 2002 to 2006 saw an average economic growth of 5.2 percent annually. 2008 recorded an economic growth at 7.2 percent; that fell to 0.4 percent in 2009; and improved to 3.6 percent and 6.5 percent in 2010 and 2011, respectively. The national GDP has reached an estimated USD 66.38 billion in 2011 *(Ibid).*

Ecuador's economy is largely reliant on the country's petroleum-based resources that constitute over 50 percent of export revenues and about 40 percent of revenues from the public sector. In 2009, it is approximated that oil exports reached about 333,000 bbl/day. 2010 saw oil production at a rate of about 500,000 bbl daily.

In terms of the overall national GDP, the service sector contributes 58.9 percent; industry 34.6 percent; and agriculture, 6.5 percent (2011 estimates). Remittances from migrant workers largely contribute to services revenues. Industries include petroleum, textiles, food processing, chemicals and wood products. The main agricultural crops are banana, cocoa, coffee, tapioca, potato, rice, sugar cane and plantains (Figure 2.2). Livestock products include cattle, sheep, pigs and their by-products and fisheries products are mainly fish and shrimp. Commodity exports are essentially petroleum and agricultural products. *(Ibid)* The unemployment rate is placed at 4.2 percent in 2011 *(Ibid).*

Gender

Although the Second National Report on the Millennium Development Goals, notes improvement in women's availment of education, their participation in gainful employment is still largely limited. About 70 percent of women do not have an income and the rate of unemployment among women is higher than that among men. Some cases of gender violence have also been recorded.

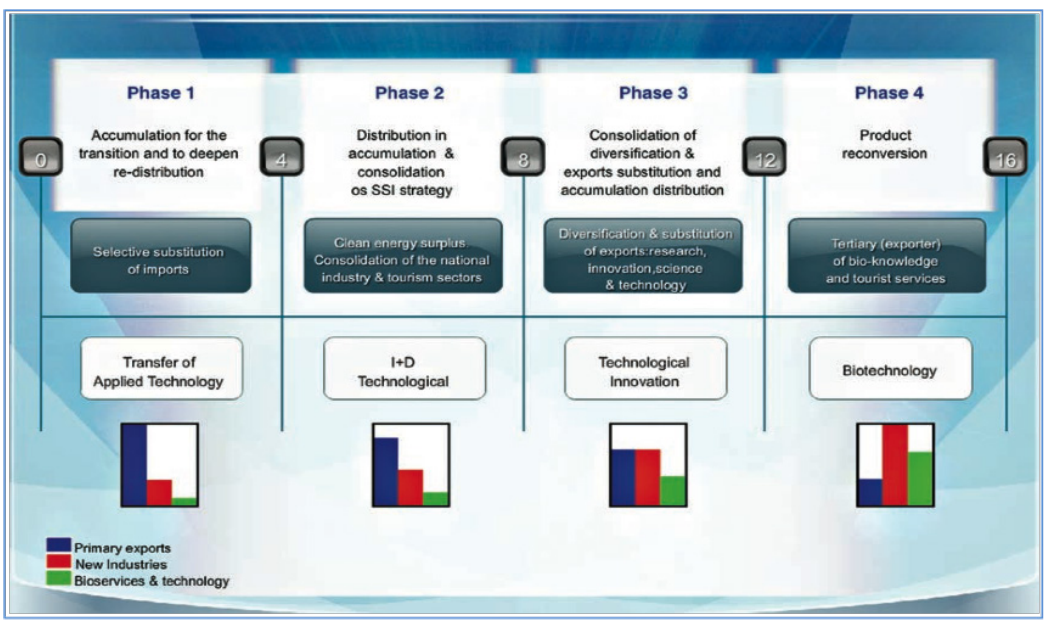
Environment

The World Wildlife Fund (WWF) has determined Ecuador as a biodiversity-rich country. However, the Ecuadorian economy's dependence on natural resources has deteriorated the environment. Agricultural development has encroached into forest areas and the timber industry has infiltrated into forest reserves. The oil industry have also led to significant deforestation, with an estimated area of 1,225,000 hectares in a span of 6 years (1994 to 2000) being deforested. Overall the rate of deforestations is pegged at 1.7 to 2.4 percent, putting at risk diverse species, many of which are endangered.

Land and water pollution are another result of human economic activities. As of 2010, 19 percent of the country's was categorized as protected areas. This however falls short of the national target of 36 percent. Fishery resources are also threatened by unregulated fishing.

NATIONAL DEVELOPMENT VISION, OBJECTIVES AND POLICIES

According to the World Bank, inequality and poverty remain key concerns in Ecuador. The 2009-2013 National Development Plan, known as the National Plan for Good Living, aims to address these concerns with a paradigm shift from development to "good living". The national long-term (16 to 20 years) plan for development is guided by the framework for "endogenous sustainable strategy to satisfy basic needs". This framework has a four phase strategy as illustrated in Figure 2.3.



Source: SENPLADES, 2009 as appearing in the 2009-2013 National Development Plan

Figure 2.3. Phases of endogenous sustainable strategy to satisfy basic needs

The National Development Plan 2009-2013 is focused on fulfilling the first phase of the endogenous sustainable strategy. The plan involves redistribution of resources to boost systemic production outputs. To achieve the targets for the first phase, the government has laid out 12 strategies in its 4-year medium term development plan, which is captured in Box 2.1. These strategies are founded on the objectives carried over from the 2007-2010 National Development Plan and updated to assimilate current needs.

BOX 2.1. ECUADOR'S 2009-2013 MEDIUM TERM DEVELOPMENT

1. Democratization of the means of production, redistribution of wealth, and diversification of the forms of property and organization;
2. Transformation of the economy's model specialization through selective substitution of imports;
3. Increase of real productivity and diversification of exports, exports and markets;
4. Ecuador's strategic and sovereign insertion in the world, and Latin American integration;
5. Transformation of higher education and the transfer of knowledge in science, technology and innovation;
6. Connectivity and telecommunications for the information and knowledge society;
7. Change of energy matrix;
8. Investment for good living within sustainable macroeconomics;
9. Inclusion, social protection and security, and guarantee of rights within the framework of the constitution;
10. Sustainability, conservation, knowledge of the natural heritage, and promotion of community tourism;
11. Territorial development and organization, deconcentration, and decentralization;
12. Citizen power and social protagonism.

Source: 2009-2013 National Development Plan of Ecuador

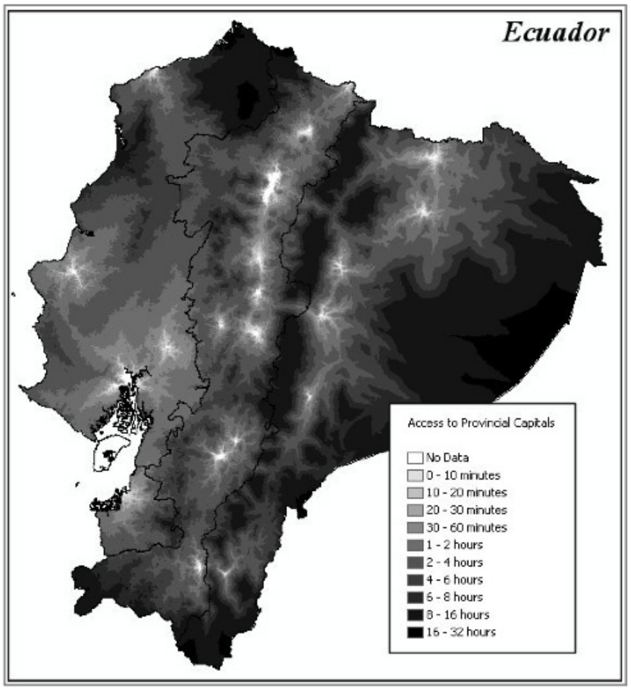
CURRENT DEVELOPMENT CONDITIONS, TRENDS AND CHALLENGES IN THE PRIORITY SECTORS

Agriculture and infrastructure are considered priority sectors for the analysis, owing to their implications on the development of the country in general and vulnerable population groups in particular.

a. Agriculture

Although agriculture contributes only 6.5 percent to the country's GDP, it provides livelihood to about 30 percent of the population. Only 11 percent of Ecuador's total land area is cultivable and 18 percent is pastural land. Despite the agriculture sector's slow growth in the 1970s, annual increases have been recorded since 1985. Agricultural products include rice, banana, coffee, tea, beans, sugar, potatoes, corn, fruits and vegetables. In the mountain areas, agricultural products mainly include barley, corn, kidney beans, wheat, potatoes, and soybeans which are mostly used for local consumption. Coastal agriculture is targeted at exports. Cocoa plants are concentrated on big plantations of more or less 60 hectares/plantation. Coffee and banana are cultivated by smallholder-farmers. The country leads the banana export industry, exporting with 3.5 million tons in 2001. Revenue from coffee was estimated at USD 51 million in 2001.

Agriculture is highly sensitive to climate variability. As 30 percent of the population depends on agriculture, irregular rainfall affects a large percentage of households. El Nino events of 1982-83 and 1997-1998 for example resulted in significant agriculture losses prompting some of the affected to seek labor in urban areas.



Source: Farrow, et al.

Figure 2.4 Access to provincial capitals

b. Infrastructure

Roads: According to Solberg, et al., (2003), the road network in Ecuador totals to 43,197 km. Primary and secondary roads in the Red Vial Principal measure 5,609 km and 3,876, respectively. Tertiary roads total to 11,106 km while secondary roads are around 22,606 km. Of these roads, 5,600 km is paved; gravel roads are about 22,500 km; and dirt roads are about 12,000 km. Approximately 22,000 km are in the mountain region; 16,400 in the coastal zone; and 4,800 in East Ecuador.

Poor road condition challenge access to provincial capitals and in many areas, requires lengthy travel time as indicated in Figure 2.4. The absence of location-specific construction codes challenges infrastructure resilience against the impacts of various hazards. The existing codes on construction are an amalgamation of codes from other countries and not based on analysis of local conditions. Enforcement of the existing codes is inadequate further challenging their structural integrity.

Irrigation systems cover 863,370 hectares of land essentially in western Ecuador. Ecuador has a high requirement for irrigation as more than 90 percent of water needs are dependent on surface water.

In highland areas, private and government irrigation facilities operate in parallel and government construction does not consult with private sector water stakeholders. According to the US Army Corps of Engineers (1998), practices in both cultivation and irrigation are resulting in erosion negatively impacting water bodies and hardening soil. The increasing frequency of disasters in Ecuador, and the projected influences of climate variability are expected to further exacerbate the concerns of the irrigation sector.

The **communication** infrastructure in Ecuador includes fixed telephone, mobile phones, internet system, and broadcast communication, among others. In 2009, an estimated 2 million fixed telephone lines and more than 13 million mobile communication lines were active. Repeater systems for both radio and television services are distributed throughout the country. Internet had an estimated 3.3 million users in 2009. The communication infrastructure has been prone to impacts of recurrent hazards like floods and landslides in various areas in the country.

KEY MESSAGES (DEVELOPMENT PROFILE)

- Ecuador is a small country with land area of 25 million ha and a population of 15 million people.
- It has four natural regions including the highlands, the coastal areas, the amazon and the insular (Galapagos) island region.
- In recent years its GDP has grown at 8 percent in this oil driven economy. GDP contribution from industry-35 percent, service sector-58 percent and agriculture-7 percent. Ecuador is middle income country with per capita income of 8000US$/annum.
- Although agriculture has modest contribution to Ecuador's GDP it is significant owing to its support to the livelihoods of 30 percent of its population. It is highly sensitive to climate related risks.
- The development trends reveal a high investment of resources in social sectors and minimal investment in the agriculture sector.
- The infrastructure sector, primarily roads, irrigation and communication infrastructure is also exposed to climate risks, especially floods, rains and secondary hazards like landslides. Their limited development in general and damage during disasters particularly affects vulnerable groups in Ecuador.

CLIMATE PROFILE OF ECUADOR

NATIONAL WEATHER AND CLIMATE CONTEXT

Ecuador has four main regions based on topography and resulting variations in climate. These are the mountain region (altitude variations from 1,200 to 6000 meters), lowland (in the Amazon area), insular (Galapagos Islands) and coastal regions (next to the Pacific Ocean).

A key driver of Ecuadorian climate is the El Nino Southern Oscillation (ENSO). It is also influenced by geographical latitude, altitude, mountain system direction, vegetation, distance from the Pacific Ocean, ocean currents, and winds. Table 3.1 provides a summary of these factors:

TABLE 3.1. FACTORS INFLUENCING THE ECUADORIAN CLIMATE

FACTORS	DESCRIPTION
Geographical latitude	It is located on the equator, hence the climate is warm. Regional variations in climate are a result of the following factors.
Altitude	Temperature ranges from hot in the coastal zones, tropical in the lowlands and freezing in areas with very high altitudes.
Mountain system direction	Warm air cannot pervade the inter-Andean valleys, as it is buffered by the Andes mountain system.
Vegetation	Evaporation rate in the coastal and lowland areas is high due to sparse vegetation, resulting in high rainfall in both areas.
Distance from the Pacific Ocean	Temperature changes in the coastal areas are experienced based on distance from the Pacific Ocean.
Ocean currents	The Humboldt Current decreases the temperature from Cabo Pasado up into the Torrid Zone. The areas experience scarce precipitation as Pacific winds, characteristically humid and warm, are prevented by the Humboldt current from passing through. Warm currents, especially during El Nino events, increases temperature and rainfall in the coastal areas.
Winds	Temperature in low-altitude areas is cooled by winds coming from the Andes. Increase in rainfall results from the collision of cold winds with humid and hot winds.

Rainfall

Spatial rainfall distribution is highly variable in Ecuador based on topography. The rainfall characteristics of three major regions *(Neill & Jorgensen, 1999[2])* are as follows:

a. Mountain/Andean Region: Shifts in the Intertropical Convergence Zone (ITCZ) cause bimodal precipitation distribution in this high-altitude region. Rainfall peaks are in March to April and October, interspersed with dry periods from July to September (main dry season) and January. Variation in the quantity of mean annual rainfall is large, with about 1,250 mm in Quito, while Riobamba only receives about 400 mm.

b. Coastal Region: It experiences a unimodal rainfall scheme. The rainy season is from December to April/May and the rest of the months are dry. Annual rainfall is lowest in the west, with about 250 mm, and highest in the east with approximately 3,000 mm. The occurrence of El Nino highly influences rainfall in the coastal areas. Significant increase in rainfall is experienced during El Nino events.

c. Lowland/Amazon Region: Areas endowed with thick vegetation experience a relative constancy in rainfall. Orographic and convective influences cause precipitation in the afternoon/evening or drizzles throughout the day. Lesser rain is received in this region from August to January due to ITCZ shifts. Highest annual precipitation, from 3,000 to 4,000 mm, is recorded in the Amazon region and Northeastern Esmeraldas.

Temperature

Across the country, monthly variation in mean temperature, , is very minimal, with temperature variations not rising above 3°C and not falling below 1°C. Daily temperature fluctuations are high, with about ≥ 20°C in high-elevation areas and 10°C in the lowland.

TABLE 3.2. APPROXIMATE MEAN TEMPERATURE AT DIFFERENT ELEVATIONS

ELEVATION	TEMPERATURE °C
Sea level	25.0
500 m	22.5
1000 m	20.0
1500 m	17.5
2000 m	15.0
2500 m	12.5
3000 m	10.0
3500 m	7.5
4000 m	5.0

Source: Neill, D.A. & P.M. Jørgensen. 1999

Altitude influences temperature. Areas with very high elevation experience freezing temperature while those with elevation of 1,500 to 3,000 m experience average temperature of 10 to 16°C. Yearly average temperature in the coastal and eastern areas is 24 to 26°C. In these areas, extreme temperatures are around 14°C and 36°C. (Neill & Jorgensen, 1999[3]). Table 3.2 indicates mean temperatures vis-à-vis elevation in Ecuador.

CURRENT CLIMATE VARIABILITY AND CLIMATE EXTREMES

Climate drivers: The climate of Ecuador is driven by factors like the global circulation system of El Niño Southern Oscillation (ENSO) and the Inter Tropical Convergence Zone (ITCZ).

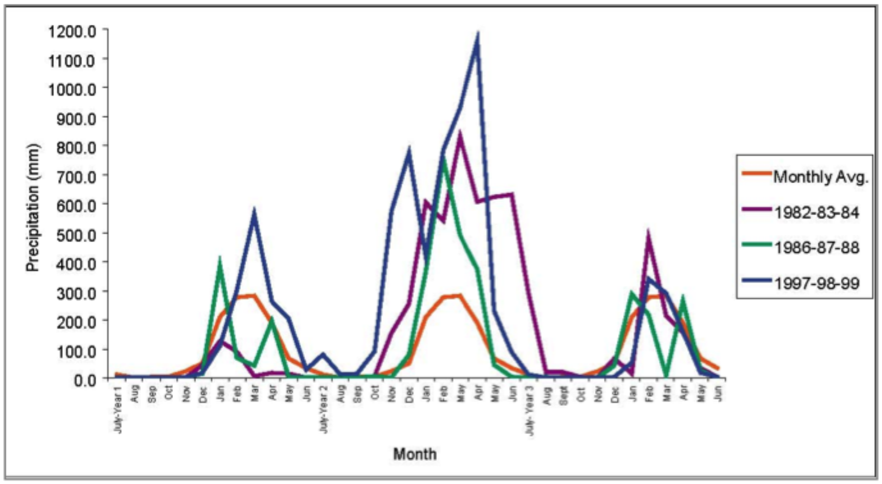
The ENSO cycle refers to the coherent and sometimes very strong year-to-year variations in sea-surface temperatures, convective rainfall, surface air pressure, and atmospheric circulation that occur across the equatorial Pacific Ocean. El Niño and La Niña represent opposite extremes in the ENSO cycle. El Niño refers to the above-average sea-surface temperatures that periodically develop across the east-central equatorial Pacific. It represents the warm phase of the ENSO cycle, and is sometimes referred to as a Pacific warm episode. La Niña refers to the periodic cooling of sea-surface temperatures across the east-central equatorial Pacific. It represents the cold phase of the ENSO cycle, and is sometimes referred to as a Pacific cold episode.

The ITCZ is a low pressure zone near the equator, from about 5° north and 5° south, where the northeast trade winds and southeast trade winds converge. Solar heating in the region forces air to rise through convection which results in a plethora of precipitation.

Rainfall variability: The ENSO represents the dominant influence on inter-annual climate variability. During El Niño events, the peak monthly rainfall amount increases several fold in comparison to normal years and the rainy season is longer (see Figure 3.1). El Niño is also associated with extreme rainfall events that trigger destructive floods. The ENSO influence is superimposed on a marked intra-seasonal variability in coastal Ecuador. The amplitude in variability increases from North to South with a distinct rainy and dry season. (Sperling et al., 2008[4]).

Increase in rainfall has been recorded in coastal areas and in low-altitude western Andes (below 1800 masl), especially in the Southern and Central parts of the country. February to March marks the peak rainfall season. Coastal zones lying along the central part of the country and North Peru are established as focal areas impacted by El Nino, with variations in rainfall during normal and El Nino years being very high, above +2000 percent. (Bendix A& Bendix J, 2006[5])

In Ecuador, El Nino originating from Nino 1.2 region has more devastating impacts than that originating from Nino 3.4 region. El Nino events of 1982-83, 1997-98, inter alia, manifested in precipitation anomalies of around +6000 percent in some areas in the country. Precipitation anomaly in moderate El Nino cases could be within 200 to 1000 percent range. During the 1995-96 and 2002-2003 El Nino events, lower than average rainfall was recorded in coastal zones. (IBID[6])



Source: Sperling et al., 2008[7]

Figure 3.1 Monthly precipitation averages and totals in El Niño years in Guayaquil, Ecuador

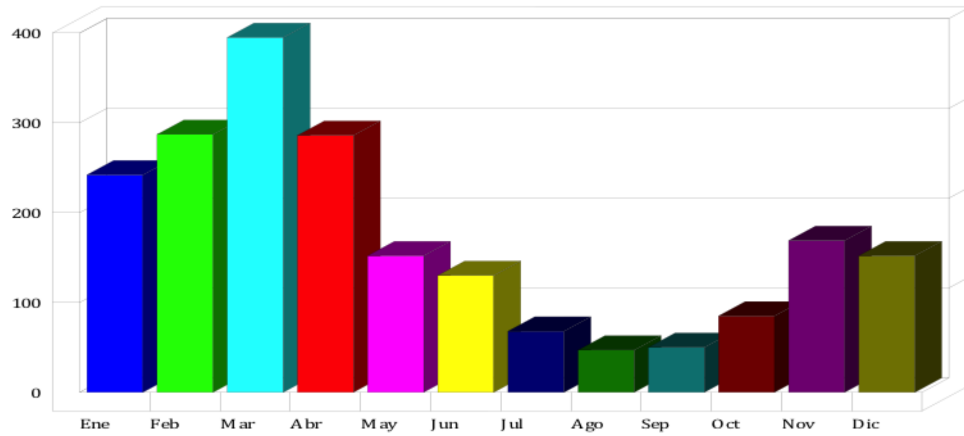
Temperature: Inter annual variability of mean temperature in Ecuador indicates that the year to year fluctuation ranges from -1°C to 1.25°C.

Extremes: Extreme events associated with El Nino were recorded in 1925-26, 1982-83, and 1997-1998, with early rainfall onset and extended wet season. While El Nino manifests with positive rainfall anomaly in the southern and central parts of the country, the manifestation is reversed in northwestern and eastern Ecuador. In these areas, El Nino results in lower than average rainfall, in some cases resulting in droughts.

Extreme rainfall and severe floods in Ecuador are also recorded in ENSO-neutral years from 1992 to 1993. Above normal rainfall was recorded for years succeeding the occurrence of El Nino, which indicates that other drivers significantly impact the Ecuadorian climate.

High altitude areas experience frost. The number of occurrences is reduced due to warmer temperature at a rate of one day per quarter of a century, falling to approximately 18 frosts annually from an annual average of 22 frosts in the early part of the century (Wahlberg et al. 2006[8])

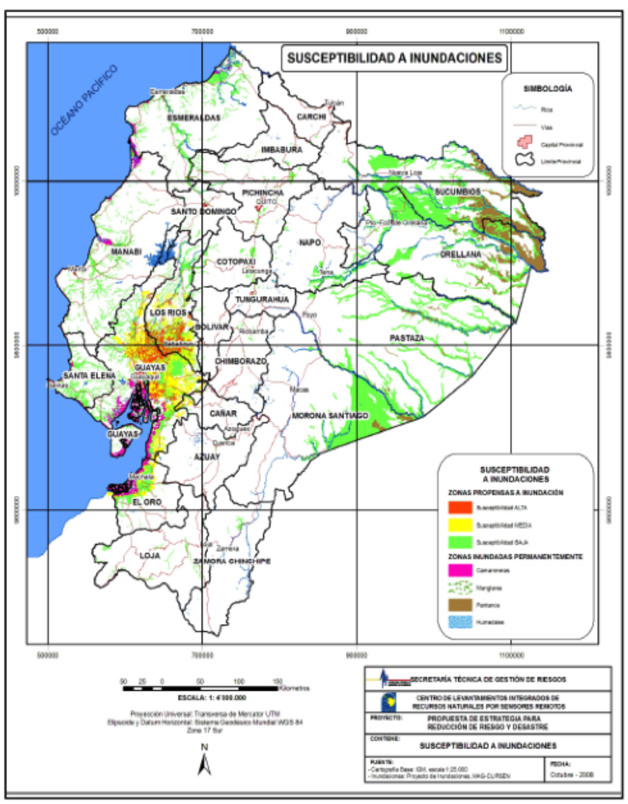
Climate hazards: Climate hazards in Ecuador include floods, drought, landslides and frosts. Figure 3.2 presents the monthly frequency of climate-disasters, recorded from 1970 to 2003. It should be noted that the frequency is highest in March, during the peak of the rainy season.



Source: DesInventar, La Red, 2009

Figure 3.2: Monthly frequency of climate-related disasters in Ecuador, 1970-2003

a. Flood: Of the climate-related hazards, floods are most frequent in Ecuador, with 9 years of occurrence from 1970 to 2009. According to World Bank (2009), flood affects about 63 percent of the population in Ecuador as indicated by Figure 3.3. They mainly affect the coastal and low elevation areas.



Source: TSRM, 2009

Figure 3.3 Flood prone areas in Ecuador

The areas affected by floods have steadily increased from the 1970s to the 1980s, now covering Quito, Guayaquil and the coastal regions. In the 1990s a larger number of cantons were affected and the 2000s the risks has spread to the Amazon region and decreased in the Sierra region, although Quito and Guayaquil are still affected (Calva and Juarez, 2009[9]).

b. Drought: According to World Bank (2009), about 25 percent of Ecuador's total area suffers from droughts. Based on the recurrence of droughts, the most affected provinces are Manabi, El Oro, and Guayas. Other provinces are Los Rios, Loja, Pinchincha, Azuay, Ezmeraldas, Tungurahua, Carchi, and Santa Elena. Based on the number of people affected by a single event, the 1990 drought in Azuay has been the worst recorded. Drought counts as among the most critical concerns of the government.

c. Landslides: Landslides are mostly a result of heavy rainfall in high elevation areas.

d. Frost: Frost occurs in high-elevation areas. Generally, the risk for frost is directly proportional to altitude. Frost is considered as a major concern for the agriculture sector in the highlands.

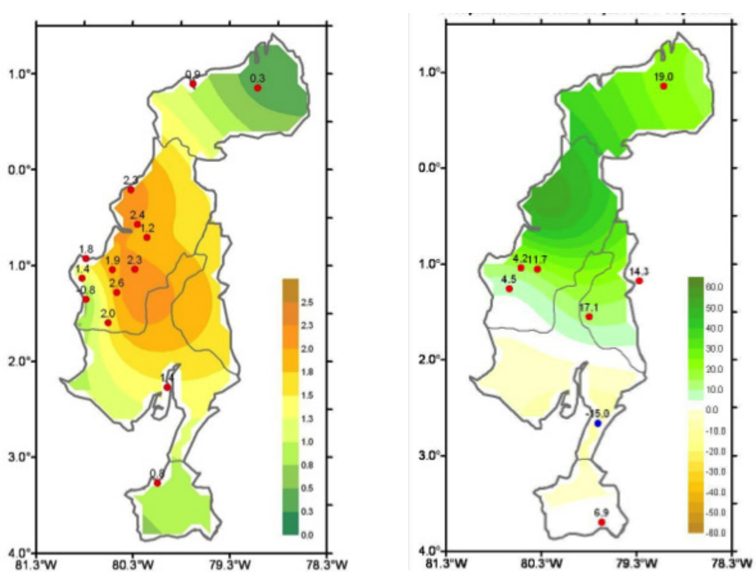
OBSERVABLE CHANGES IN CLIMATE VARIABLES AND HAZARD

Considering the assessments of climate change scenarios as determined by the IPCC, and the efforts made in Ecuador to determine the trends of meteorological variables like precipitation and temperature, it is understood that extreme weather and climate events are likely to occur more frequently and in areas that were previously at low risk.

a. Rainfall: Ecuador's Instituto Nacional de Meteorologia e Hidrologia (INAMHI) noted the following trends in rainfall based on past data (2007):

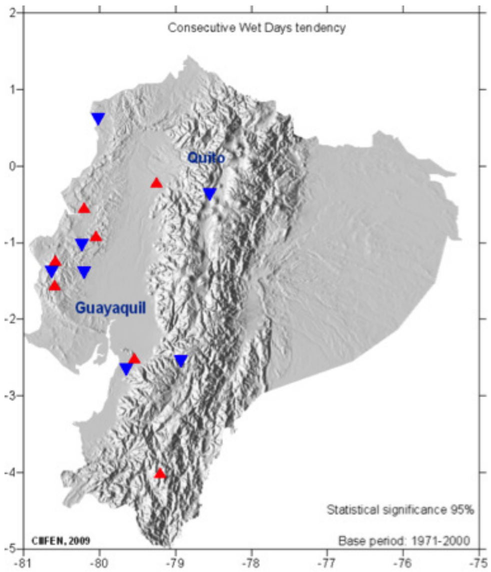
- **i** Increase in total rainfall was recorded despite more dry days;
- **ii** Frequency of several-days-rain increase in the foothill areas;
- **iii** Frequency of extreme rainy days are increasing;
- **iv** Frequency of tornadoes are increasing in coastal zones.

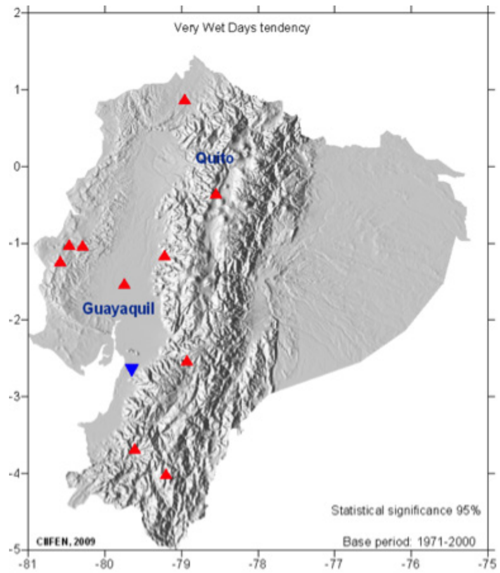
Overall a greater variability of rainfall was observed. Recently it also observed the onset of the 2008-2009 wet season, on January 11, instead of the usual mid-December begining. An analysis of the coastal rainfall scheme indicated that although rainfall amount has not altered, the frequency, distribution and number of extreme rainfall events have changed, as shown in Figure 3.4. Further, the analysis pointed to the increasing trend of consecutive dry days along the central coastal zones.



Source: INAMHI-CIIFEN, 2007

Figure 3.4: Tendency of rainy days with rainfall >95 percentile (left) and consecutive dry days (right)





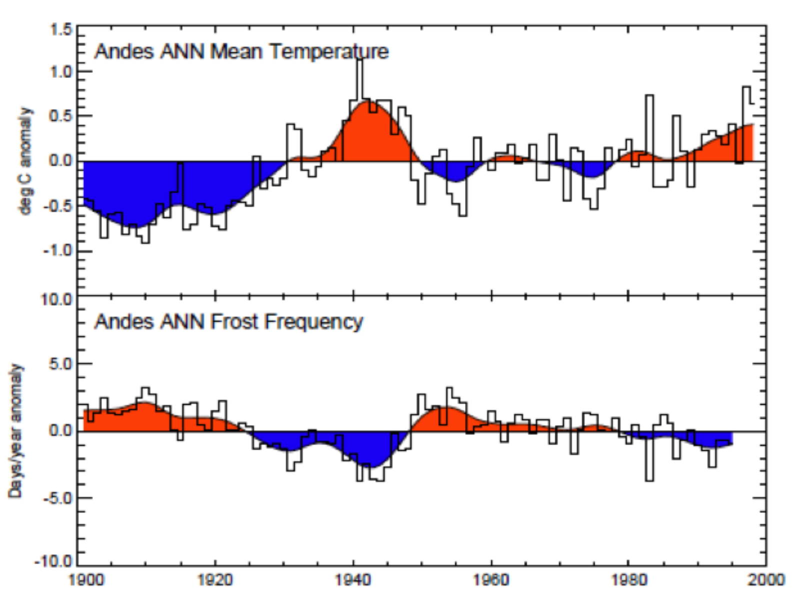
Source: CIIFEN INAMHI 2007

Figure 3.5: Trend of Consecutive Wet Days CWD

Figure 3.6: Total annual precipitation that PRCP> 99 percentile

The analysis of climate change indicators shows the increasing probability of "Indian summers" or consecutive dry days in the central coast of Ecuador (Guayas river basin and Chone) and periods of heavy rainfall in the northern part of the coast and foothills of the Andes. The foreseen changes are not expected to alter the total amount of rain on the coast, however will alter the distribution, frequency and occasional episodes of localized heavy rains. Refer to Figure 3.5 and 3.6[10]

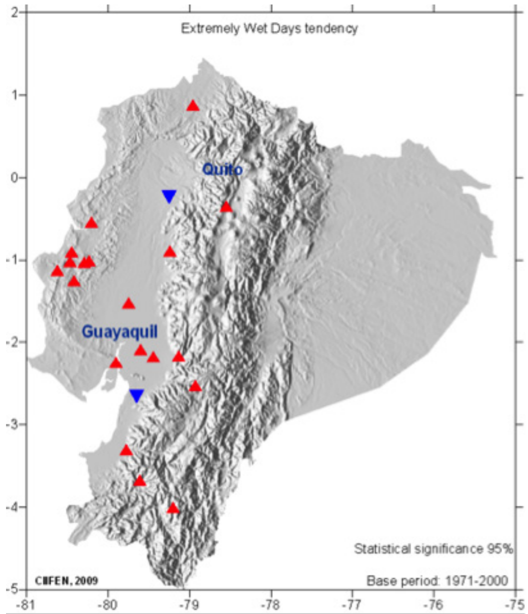
b. **Temperature**: In the previous century, an increase in annual mean temperature of approximately 0.8°C was observed in the North Andes. The decades of 1940s and 1990 were the warmest, with 1941 and 1997 the warmest 2 years. Figure 3.7 features alteration in annual mean temperature from 1901 to 1998 and frost frequency from 1901 to 1996 over the North Andes.



Source: CIIFEN 2009

Figure 3.7: Changes in mean annual temperature, 1901-1998 (top) and annual frost frequency, 1901-1996 (bottom), over the northern Andes region.

Extreme events: Northern Guayas, Los Rios, and Central Manabi, noted increased occurrence of extreme rain as indicated in Figure 3.8.



Source: CIIFEN 2009

Figure 3.8: Total annual precipitation that PRCP> 99 percentile. R99p

Sea level: Although information on sea level rise trends is not specifically available for Ecuador, a study indicates the sea level is actually decreasing in Ecuador (http://ecotretas.blogspot.com). The data for Ecuador at Galapagos GLOSS 169, shows a decline in sea level of 21 cm from 2000 to 2009. The analysis of 53 sea level stations obtained from GLOSS stations, distributed all over the world, suggests declining sea level in the Pacific coast of North, Central and South America.

Glacier Retreat: Glacier retreat analysis of Ecuador shows that there was a rapid retreat between 1995 and 1999, which was 7 to 8 times faster than during the previous period from 1956 to 1993. From 1999 to 2001 glaciers advanced, because of a wet phase associated with La Niña conditions in the tropical Pacific. Since 2001 glaciers have again been rapidly retreating. Cotopaxi glaciers were almost stagnant between 1956 and 1976 and then lost approximately 30 percent of their surface area between 1976 and 1997. (Vuille et al. 2008[11])

PROJECTED CLIMATE TRENDS

a. **Rainfall**: In tropical Andes, rainfall is projected to increase during the rainy season and decrease in the dry season. Emission scenarios show similar spatial scheme. However, change is stronger in the A2 scenario. Global models indicate precipitation fluctuations for some regions. Regional models denote none or slight increase in precipitation. Decreases in precipitation in north Amazon and increases in south Amazon region are projected.

b. Temperature: Uncertainties in temperature projections in the Andes are due to low resolution Global Circulation Model (GCM) outputs. SRES A2 scenario suggests that tropical South America will likely be warmer by around 3 to 4°C than the continent's Southern areas. Different scenarios and model outputs point to increase in temperature in all areas in the country. *(Vuille et al. 2008[12])*

c. Sea level rise: Sea level rise is predicted at around 10 to 20 cm in the subsequent 20 years along the mainland area. The impacts are expected to be similar to those in the 1982-83 and 1997-98 El Nino years where sea level had risen to about 20 to 40 cm. However, sea level rise due to climate change is likely to be permanent and presumed to exacerbate El Nino impacts and storm surges, among others. Notable sea level rise impacts are predicted by 2080s. (Cornejo & Cedeno[13])

d. Glacier Retreat: Glaciers are projected to retreat in the Andean system and many are likely to disappear, and hence changes in stream flow. (Vuille et al. 2008[14])

STATUS OF CLIMATE AND HAZARD INFORMATION AT NATIONAL AND REGIONAL LEVEL

ENSO trends are not captured by the Intergovernmental Panel on Climate Change (IPCC) models, hence the behavior of the phenomenon and its impact on climate and related hazards is unknown. Since ENSO is a key driver of precipitation, its omission lends to higher uncertainties in rainfall scenarios. The complexity of the topography and climate drivers in the Andes and Amazon requires more research to facilitate better understanding of emerging scenarios. Better and more extensive observation network on the behavior of glacier retreat would also help enhance projections.

Observation and monitoring systems on climate by the INAMHI are largely insufficient in the providing usable location-specific information. Thus the capacity of INAMHI to generate needs-based information should be enhanced. The processes of decision-making and provision of guidance based on climate information should be assessed and understood to help develop these capacities.

KEY MESSAGES ON CLIMATE PROFILE OF ECUADOR

- The ENSO and ITCZ are key climate drivers in Ecuador.
- While El Nino influences the climate and related hazards in the coastal region,the ITCZ influences the Andean region.
- El Nino often brings heavy rain and thus causing flooding. Heavy rainfall in April-May and in October could cause flash floods and landslides in the Andes region.
- Observable trends indicates no change in El Nino frequency, however indicates rise in temperature.
- Climate projections indicate increase in sea level rise and increase in frequencies of climate related hazards and extreme events.
- The low resolution of global climate models, absence of ENSO in climate models and the complexity of topography and climate drivers in parts of Ecuador suggest the need for localised studies to understand the trends and impact of climate change on the country and its diverse regions.
- The capacity of local institutions like the INAMHI need to be strengthened to help Ecuador better assess, understand and address (manage and reduce) the risks associate with climate variability and change.

CLIMATE IMPACTS AND RISKS FOR AGRICULTURE

PAST CLIMATE IMPACTS IN ECUADOR

Climate related disaster have killed more than 2000 people, affected more than 2 million people and led to direct losses of more than 2 million USD in Ecuador from 1970 to 2010 (EMDAT, 2010). Refer to Table 4.1 for a breakdown of disaster events and their impacts. A summary of climate-related disasters across different provinces and affected people is noted in Table4.2.

TABLE 4.1 CLIMATE RELATED DISASTER AND ITS IMPACT IN ECUADOR FROM 1970 TO 2010

DISASTER TYPE	FREQUENCY	NO. OF DEATHS	NO. OF PEOPLE AFFECTED	LOSS IN US$
Drought	2	0	141500	1700
Epidemic	10	568	123161	0
Flood	23	826	1818246	1557470
Landslides	9	799	81456	500000
Wildfire	2	0	800	0
Total Climate hazards	46	2193	2165163	2059170
Earthquake	*11*	*5096*	*298303*	*1515000*
Volcano	*11*	*6*	*549383*	*160975*

Source: EMDAT

TABLE 4.2. CLIMATE-RELATED HAZARDS IN ECUADOR, 1970-2009

EVENT	YEAR	PROVINCES	AFFECTED PEOPLE
Floods	1970	Esmeraldas	NI
	1982	Esmeraldas, Manabí, Guayas	21273
	1995	Pichincha	3000
	1997	Loja, Galápagos, Guayas, El Oro, Pichincha, Los Ríos, Manabí, Orellana	103043
	2001	Tungurahua	2005
	2002	Zamora Chinchipe, Tungurahua, Manabí	
	2006	Esmeraldas, El Oro, Guayas, Los Rios, Manabi and Pichincha	60,000
	2008		12,794
	2009	Los Rios	
Heavy Rainfall	1995	Pichincha	3000
	1997	Orellana	100
	1999	Chimborazo	22800
	2002	Tungurahua, Pichincha, Manabí	14000

TABLE 4.2 CONTINUED

EVENT	YEAR	PROVINCES	AFFECTED PEOPLE
Drought	1968	Loja	NI
	1990	Azuay	400000
	2002	Azuay	250
	2009	Manabí	
Landslides	1993	Azuay	14071

Data obtained from DesInventar, La Red, GLIDE, Reliefweb, processed by CIIFEN, 2009

El Niño Southern Oscillation (ENSO)

ENSO events in Ecuador have been recorded in the following years: 1925, 1934, 1941, 1953, 1957, 1958, 1965, 1972-1973, 1976-1977, 1982-1983, 1986-1987, 1997-1998[15], 2002-2003, 2006-2007 and 2009-2010. Their impacts include excessive rainfall events, triggering floods that destroy houses, roads and bridges. Communities face difficulty in accessing the markets to sell their produce or livestock. Increase in water and vector borne diseases, such as malaria, dengue and cholera have also been noted. Agriculture and livestock are affected during excessively wet periods and inundation of agricultural lands, increase pests and animal diseases (Sperling et al, 2008[16]).

The total losses of ENSO events 1982-1983 and 1997-98 is presented in Table 4.3

TABLE 4.3 TOTAL LOSSES DUE TO EL NIÑO EVENTS (1982-83 AND 1997-98)

SECTOR AND SUBSECTOR	1982-1983		1997-1998	
	US$ MILLONS	%	US$ MILLONS	%
Total	**1.051**	**100,00**	**2.882**	**100,00**
Social sectors	*39*	*3,71*	*205*	*7,11*
Housing	10	0,95	153	5,31
Health	18	1,71	33	1,15
Education	11	1,05	19	0,66
Productive sector	*665*	*63,27*	*1.516*	*52,60*
Agricultural	383	36,44	1.201	41,67
Fishing	192	18,27	42	1,46
Industry and commercial	90	8,56	273	9,47
Infrastructure	*347*	*33,02*	*830*	*28,80*
Transport	343	32,64	787	27,31
Others	4	0,38	43	1,49
Prevention-Emergency	*...*	*0,00*	*331*	*11,49*

Source: CIIFEN, 2009

A case study of 1997/1998 ENSO event is enumerated in Box 4.1

BOX 4.1 IMPACTS OF THE 1997/98 ENSO:

Micro-economic and demographic impacts

The El Niño impacted the coastal and island populations of Ecuador, which according to the National Institute for Census and Statistics (INEC), accounts for 50 percent of the country's population. 34 percent of the affected were under 15 years of age, 69 percent of the affected were located in urban areas and 31 percent in rural areas *(UN University[17])*.

Most of the flooded cities had problems with water supply, sewage and infrastructure damages. The areas affected included Chone (60,296 inhabitants), Esmeraldas (120,317 inhabitants), Portoviejo (172,178 inhabitants), Bahía (26,306 inhabitants), Santa Rosa (41,900 inhabitants) and Milagro (121,823 inhabitants). Even though the affected urban population was larger, the rural population was more severely affected as they were cut off and lost their harvests and agriculture products due to flooding and destruction of highways, bridges and roads. This resulted in higher product prices in the marketplace. Impacts were severe as the affected area economy (agriculture, livestock (cattle) and fisheries) provide for 17 percent of the GDP, 60 percent of the total exports and 85 percent of the country's non-petroleum exports*(Ibid)*.

Agricultural impacts

Anomalies in the weather pattern-especially in precipitation, air temperature and humidity-were observed along coastal Ecuador as early as August, owing to anomalous oceanic conditions. At this time some export crops like mango, asparagus, and melon, were not sown or were lost because of a lack of flowering. Of the 900 million pounds of expected sugarcane crop, only 50 million pounds (5.5 percent) was harvested resulting in import of sugar to meet demands in 1997. After August, heavy rainfall inland affected the entire agricultural sector. By February 1998, total losses in rice, soy, banana (lack of production), and sugar cane (not sown) crops were up to US $302.9 million. Losses were 50 percent more than that of 1982-83 event (US $200 million). However, a known post-El Niño benefit for agriculture is that the soil receives a lot of nutrients and it is better prepared for the next crops, due to the heavy rainfall and flooding. By June 1998, the positive impacts on agriculture were estimated to be at least US $ 15.3 million *(Vos et al., 1999[18])*.

The short cycle crops were the most affected. Rice and corn for the second harvest in 1997 were totally lost. The rains during the El Niño episode flooded fields for long durations, and impeded the initial sowing of these crops in 1998. Other crops such as beans, vegetables and fruit, were affected almost totally because of flooding over a long period and premature flowering because of rain. The affected commercial crops include sugar cane, banana, coffee and cacao. The floods on the plantations damaged the first two crops, and the last two crops were damaged because of the rains during flowering. The banana plantations in the country was not directly damaged, losses however were due to transportation problems owing to damaged highway and bridges. *(Ibid)*

The production of coffee and cacao crops was diminished because they were substituted by new crops, mainly vegetables and fruit. The effects of El Niño had been dramatic for commercial agriculture, especially for food crops such as yucca, beans, orange and mango. The total area affected by El Niño was 613,000 ha; some of which suffered a double impact because the 1997 harvest was lost, and because the fields were flooded, affecting mainly rice and hard corn. The area affected by El Niño was approximately 15 percent of the total agricultural land of the coastal area. *(Ibid)*

The direct loss estimated in agriculture was US $524 million, including the crops ready to be harvested and those lost in 1997 due to lack of transportation. The indirect loss was estimated at US$441.2 million resulting in total damage of US $996 million *(Ibid)*.

Health

There were 4 major epidemics during the 1997-98 El Niño were cholera, leptospirosis, dengue and malaria. The number of cholera cases during the 1991-92 El Niño was 17 times of the 1997-98 event, suggesting that the magnitude of an event is not necessarily an indication of its impact on disease outbreak and spread. Another cause of the dramatic decrease in disease is the contingency planning measures implemented by the Public Health Ministry targeting epidemiological diseases such as malaria, cholera, dengue and leptospirosis *(Ibid)*.

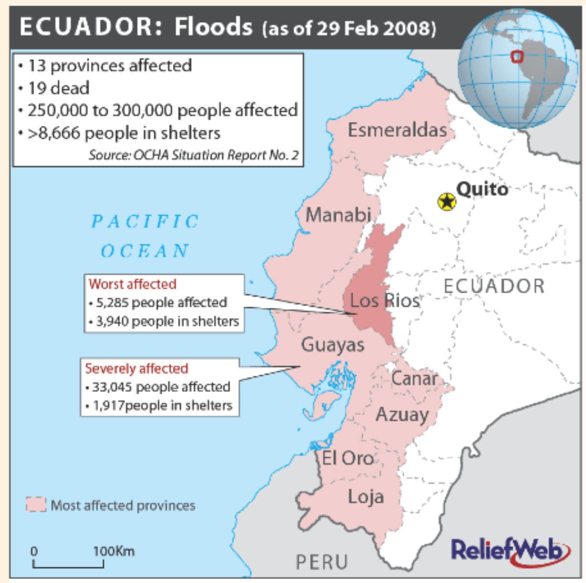
Floods

The floods of March 1997 affected 10 of the 24 provinces or half of Ecuador. It affected several provinces in the coastal, Andean and the Amazon regions. The 1998 floods severely affected the Manabi, Guayas, and Los Ríos provinces, resulting in seclusion of several cities. Between February and March 2006, heavy rainfall resulted in serious flooding, overflowing of rivers and landslides in 5 of the 24 provinces in Ecuador, and affected most of the coastal region. The case of 2008 flood is presented in Box 4.2.

BOX 4.2 IMPACT OF THE 2008 FLOODS IN ECUADOR

In January/February 2008, the wet season heavy rains in coastal regions flooded low-lying areas mainly in the Provinces of Guayas, Los Ríos, El Oro and Manabi. La Niña event prevalent at that time, which in Ecuador usually results in decreased levels of rain, had no such effect. The intense atmospheric activity that occurs in the Amazon region and conducive to generating the rain clouds in the Amazon this year by wind action entered the coastal region. Although rainfall levels recorded did not exceed normal values significantly, it resulted in floods and overflowing rivers mainly because it was concentrated in a few weeks *(UNETF, 2010[19])*.

During the first weeks of January relatively heavy rainfall affected the 6 coastal provinces of Esmeraldas, Manabi, Guayas, Los Ríos, El Oro and Santa Elena and l provinces of the Sierra and Canar, Bolivar, Santo Domingo de los Tsáchilasin low-lying areas. The impact was initially restricted to 9 provinces primarily in rural areas resulting in a response by civil institutions and aided by regional actors. 24 of the 84 cantons of the nine provinces were affected mainly in Guayas and Los Rios. However, in mid-February heavy rains continued over time, and the number of affected provinces increased from 9 to 13, and affected counties from 24 to 66. The impacts were also felt increasingly in major urban centers with higher population density, resulting in a state of emergency in more than half of the 24 provinces. *(Ibid)*



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: Reliefweb

Map showing affected region in Ecuador

TABLE 4.4. IMPACT OF THE 2008 FLOODS IN ECUADOR

IMPACTS		NUMBERS
Provinces affected		13/24
Townships affected		66/149
Population housed		14.122
TOTAL Hostels		331
TOTAL distributed food rations		198.220
Total people served, HEALTH		104.387
TOTAL Deaths		37
Missing Persons TOTAL		3
Hectares affected and lost	Affected	137.315 ha
	Lost	85.170 ha
Activities and lost livestock affected	Affected	2808
	Lost	2900
Number of people who have lost livelihoods	Livestock	1457
	Agricultural	33.961

Drought

Droughts in Ecuador impact the agriculture sector severely. The 1997drought caused due to prolonged low rainfall in southwest Ecuador acutely affected the provinces of Loja and El Oro where more than half the rural population is engaged in small scale agricultural activities. It led to migration of thousands of people to urban areas. The 2009 drought, that hit the Andes region was one of the worse in four decades. It led to water shortage in Ecuador's main hydro-electric power plant at Paute, reducing average production by half. This led to electricity blackouts in Ecuador[20], especially in Quito, and Guayaquil. In 2009 the El Niño related drought affected an estimated area of 69,000 hectares, worsening the water problems in Manabi province, and causing severe damage to agricultural production and livestock.

However, not all droughts are related to ENSO. For example, the 2005 drought, one of the most intense droughts in the last hundred years affected large sections of southwest Amazonia, particularly population along the Amazon River and the Madeira Rivers. The rivers fell to historic low levels and resulted in suspension of navigation (Marengo, 2005[21]). The case of the 2009 drought is explained in Box 4.3.

BOX 4.3 IMPACTS OF THE 2009 DROUGHT IN MANABI PROVINCE

Cause: Poor rainfall in 2009

Period: 2009

No. of people affected: 21000

Crop Area Affected: 7800ha

Other Impacts:

- 1587 rice farmers suffered losses of US$3 million
- Decrease in milk production and its derivatives increased prices and impacted household economy.
- Quality of life in counties and parishes deteriorated.
- Water deficit in coastal areas rendered thousands of hectares of land infertile.
- Extensive grasslands disappeared, leading to cattle mortality
- Lack of energy resources

Source: Reliefweb, 2011[22] and Map Sources: FAO and UNCS

Droughts also affect different groups in the supply chain differently. For example, insufficient rains impact the maize crop and its implications across the farmer, food processor and poor urban consumer chain.

Landslides

Landslides are very frequent and accompany heavy rainfall episodes in higher regions of Ecuador. Heavy rains in 1998 resulted in landslides affecting the provinces of Esmeraldas, Manabí, El Oro, and Azuay. In 1993, heavy rains caused a very large landslide (estimated at 30 million cubic metres) in the province of Azuay, resulting in the blockage of the Paute river. More than 50 people were killed or injured and 75,000 people affected as houses, cropland and major roads were damaged or washed away, and a thermal power station was flooded.

Frost

Frost is regarded as a major hazard by rural population in the highlands of Ecuador. A substantial part of land is left uncultivated due to excessive frost risk or low temperatures. Frost risk increases with altitude, and although farmers can cope by staggering planting dates, planting on east-facing slopes, using crop ridges and growing short-season crops, frost is seen as a serious problem. These impacts are multiplied by environmental risks resulting from deforestation and/or unsustainable agricultural practices like mono-cropping systems without incorporating climate knowledge.

FUTURE CLIMATE IMPACTS

The climate variability and El Niño phenomena is expected to continue as the major factor in extreme events like floods and droughts, at least through 2030. The climate risks are expected to impact the various regions in Ecuador, albeit with some variations including:

- *Coastal Region:* Studies do not foresee any changes in either frequency or amplitude of floods caused by El Niño. Thus the coastal regions could be subject to periodic floods as in the past. The impacts could be more severe due to the non-climatic stresses such as improper land-use planning, mono-cropping systems, mismanagement of water resources, urbanization and outward migration of productive population.

- *Amazonian Region:* Oil-related industrialization and urbanization due to resettlement from other regions could be increasingly exposed to climate risks. For example, no flood disasters were reported in these areas prior to 1970, but n recent decades more and more areas are suffering from floods and this trend is expected to continue.

- *Andean Region:* There is already evidence of a steady decrease of glacier extent in upper regions of the Andes, and this trend could be expected to continue. As glaciers retreat, they have added to a temporary increase in runoff. This increase would not last very long, as the frozen water stored in glaciers diminishes. But as downstream users are quickly adapting to enhanced water availability and planning future development accordingly, it could lead to sustainability concerns[23], especially because the runoff would continue to increase only for another 25–50 years before a decrease eventually sets in. However, the studies that make this projection need to be interpreted cautiously as the glacier evolution in these models depends solely on temperature *(Pouyaud, 2005[24])*.

a. Projected Impact on Agriculture

The climate change on crop production is modeled using the DSSAT program for optimistic and pessimistic scenario and the results are tabulated in Table 4.5. This indicates a drastic surface area reduction. Hard corn and potato shows resistance to climate change in the optimistic scenario. However potato shows -34 percent reductions in 2030. Overall rice, soybean and potato are likely to face reduced production in 2030 *(NCC,2000[25])*

TABLE 4.5 PROJECTED IMPACT ON CROP CULTIVATED AREA AND PRODUCTION IN 2030

CROP	OPTIMISTIC SCENARIO		PESSIMISTIC SCENARIO	
	SURFACE (%)	PRODUCTION (%)	SURFACE (%)	PRODUCTION (%)
Rice	-51	-3	-51	-60
Hard Corn	-25	309	-25	137
SoyBean	-38	-3	-38	-5
Potato	-38	120	-38	-34

Source: (NCC,2000[26])

b. Projected Impact on Water Resource

The WATBAL model for water resource balance in a climate change scenario for Ecuador indicates fluctuation and decline from -6 to 61 percent across years. The analysis suggests that the months of October to December qill be highly affected, and the deficit will reache its peak in the month of December over all scenarios. Refer to Table 4.6 for details.

The watersheds of the following rivers are threatened: Esmeraldas, Portoviejo, Chone, Jama, Briseño and Pastaza rivers (up to the Agoyán Project), Paute (up to the Daniel Palacios dam), Mira, Carchi, and Napo (lower basin of Quijos River up to the Quijos station in Baeza and the lower basin of the Jatunyacu river up to the hydrometric station of Jatunyacu after it joins the Iloculin River). Any change in river flow might affect hydro-energy production since it constitutes 76 percent of the total energy production in the country. *(NCC, 2010)*

TABLE 4.6 CLIMATE CHANGE IMPACTS ON WATER RESOURCE BALANCE FOR ECUADOR

CLIMATE CHANGE SCENARIO	DECLINE IN WATER RESOURCE BALANCE
Rise in temperature by 1° C, decline in rainfall by 15%	-6 to -60
Rise in temperature by 1°C, rise in rainfall by 20%	-11 to -41
Rise in temperature by 2° C, decline in rainfall by 15%	-6 to -61%
Rise in temperature by 2° C, rise in rainfall by 20%	-11 to 42 %

Source: NCC, 2010

c. Forestry and Biodiversity

The climate change impacts in Ecuador could threaten 37.1 percent of forest areas by the year 2030 and the protected areas by 20.7 percent. All the modeled scenarios indicates a clear trend towards desertification, the dry zones is likely to increase by 75 percent compared to the current situation, which is 44 percent of the country's total surface. (NCC, 2000[27])

d. Coastal zones

The coastal zones are likely to be threatened by sea level rise and ENSO events associated floods (NCC, 2010). Although sea level rose to about 20-40cm during 1982-83 and 1997-98 El Nino years, the climate related changes to SLR will be more permanent, hence the damages could be much higher than a storm surge (Cornejo & Cedeno[28]). The flooding in extreme cases that have a 100 year return period would affect more than 600 sq.km. and in normal years, affect around 500 sq.km. (NCC, 2010)

e. Glaciers

Glaciers will retreat and many will completely disappear, with significant consequences for local populations. It is likely that the change in streamflow, due to the lack of a glacial buffer during the dry season, will significantly affect the availability of drinking water, water for hydropower production, mining and irrigation. *(Vuille et al. 2008[29])*

CLIMATE SENSITIVITY

A) Crops

The projected impacts of climate variations can be understood by reviewing the past impacts of El Nino events. For example, during the 1997-1998 El Nino year the impact on various crops was estimated at US$ 331 million (*Vos et al. 1999*[30]). Additionally, climate projection models and studies have estimated impacts on different crops as noted below.

Paddy is grown in 393,137ha and its annual production is 1,706,190 tonnes. During years with climate shocks, the production could go down by 17 percent and in favourable years it could go up to 28 percent. (Figure 4.1)

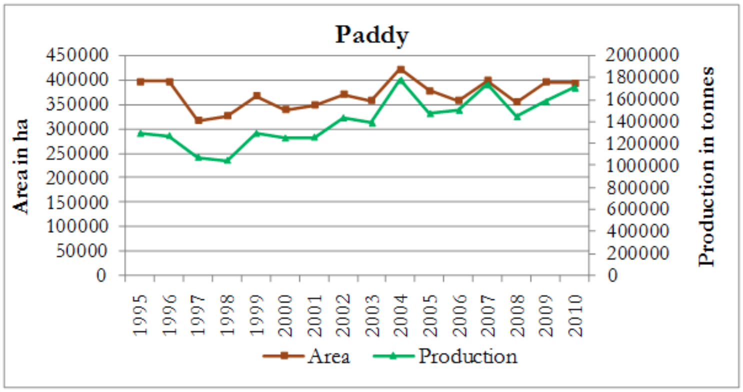


Figure 4.1: Paddy cultivated area and its production from 1995 to 2010

Banana is grown in 215,647ha and its annual production is 7,931,060 tonnes. The production could decline by 27 percent during extreme years and in favourable years the it could go up to 31 percent. (Figure 4.2)

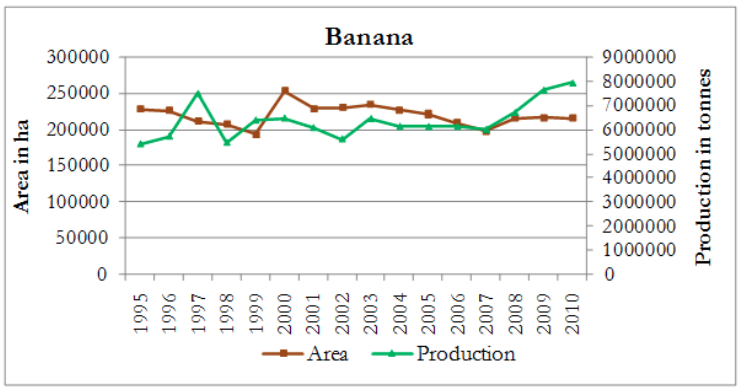


Figure 4.2: Banana cultivated area and its production from 1995 to 2010

Maize is grown in 440346 ha of land and its annual production is 7,984,096 tonnes. The production could decline by 45 percent during extreme years and in favourable years it could go up to 73 percent. (Figure 4.3)

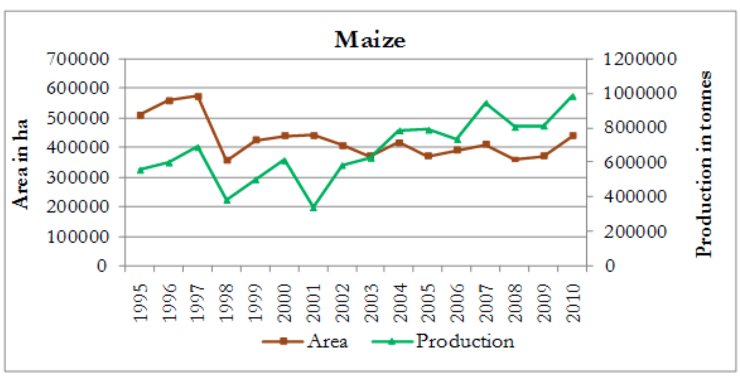


Figure 4.3: Maize cultivated area and its production from 1995 to 2010

Cocoa is grown in 360025 ha and its annual production is 132,100 tonnes. It is highly climate sensitive and its production could fall to 58 percent during years with climate shocks and go up to 170 percent in favourable climate years. (Figure 4.4)

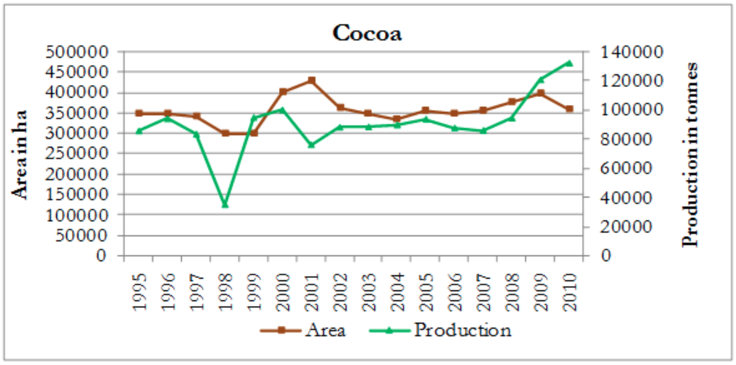


Figure 4.4: Cocoa cultivated area and its production from 1995 to 2010

Coffee is grown in 144931 ha of land and its annual production is 31347 tonnes. The fall in production could be 69 percent during years with climate shocks and in favourable climate years it could go up to 176 percent. (Figure 4.5).

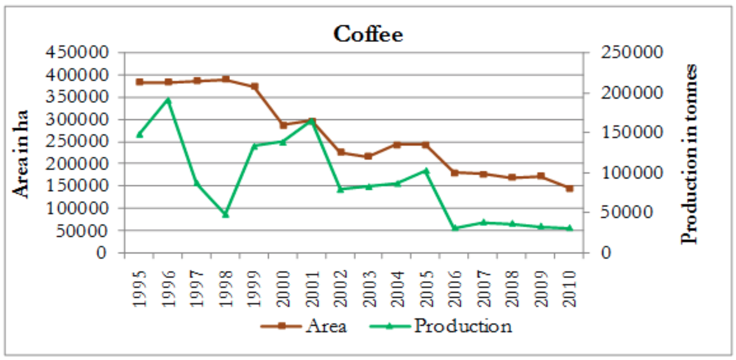


Figure 4.5: Coffee cultivated area and its production from 1995 to 2010

Sugarcane is grown in 106928 ha and its annual production is 8347180 tonnes. The fall in production could be 25 percent during years with climate shocks and in favourable climate years it could go up to 40 percent. (Figure 4.6)

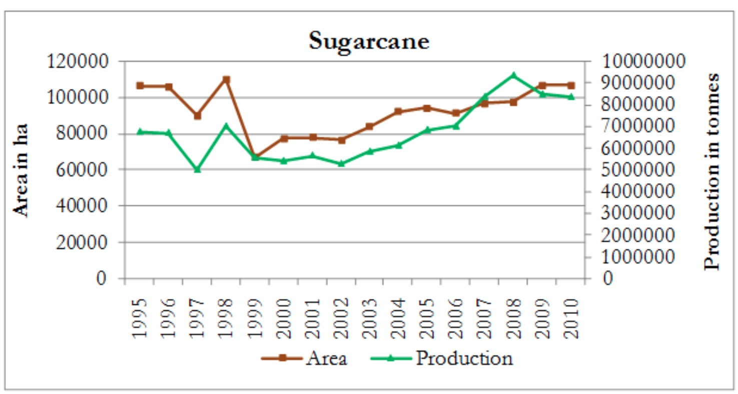


Figure 4.6: Sugarcane cultivated area and its production from 1995 to 2010

B) Employment Losses

Crop loss has resulted in employment loss for small farm holders and has forced a large number of people below the poverty line. Table 4.7 identifies loss of employment and foregone earnings as a result of loss of different crops.

TABLE 4.7 EMPLOYMENT LOSSES AND RELATED FOREGONE EARNINGS IN AGRICULTURE

CROP	AFFECTED AREA	LOSS OF DIRECT EMPLOYMENT		FOREGONE WAGE EARNINGS IN MILLION US$
		AFFECTED WORKERS	INCREASE IN UNEMPLOYMENT (MAN-YEARS)	
Pasture	82,487	4,126	2,063	2.7
Rice	105,336	43,716	21,858	28.4
Corn (maízduro)	130,676	20,228	10,114	13.1
Banana	25,380	3,427	1,714	3.6
Sugar cane	27,540	8,262	4,131	5.4
Coffee	74,640	11,556	5,778	7.5
Cocoa	49,290	11,332	5,666	7.4
Other	45,340	9,071	4,536	5.9
TOTAL	540,689	111,718	55,859	73.9

Source: Ministry of Agriculture (MAG); MAG-ORSTOM; and Vos, Velasco and De Labastida (1998) cited in Vos et al. 1999[31]

C) Fisheries

The fisheries sector is affected by different aspects of climate risk, including change in air temperature, precipitation patterns, sea level rise and water chemistry (temperature, salinity and oxygen properties). These changes influencing migration of fish and affects the catch for the season. This is likely to impact both food security and livelihoods of coastal communities. (UNDP, 2007[32])

D) Infrastructure

The impacts of climate change are likely to increase the stress on infrastructure. Baseline thresholds in critical climate change (CCC) parameters like temperature alterations, rainfall variability, sea level rise and extreme events, could pose threats to regular undertakings and infrastructures. CSIRO Australia (2006) has identified climate change impacts and the degree of risk to different infrastructures. Refer to Table 4.8 (next page).

The following infrastructure is highly sensitive to climate variations and hazards.

Roads: Of the total 43200 km of road network in Ecuador, 9500km (22 percent) are national, primary and secondary road and the rest are rural and tertiary roads. The road network consists of three zones, the Sierra zone (51 percent), coastal zone (38 percent) and amazon zone (11 percent).

The mountainous terrain of Ecuador makes road systems vital for socio-economic movement. Since rural communities and small farm holders live in isolated locations, road connectivity is essential for maintaining agriculture productivity, to both obtain inputs from markets and sell outputs to the market. The road service index is 3.4km/1000 people, which is well below the regional average of 5.4 km/1000 people. Only 40 percent of rural roads are somewhat functional. This has resulted in high cost of transportation owing to longer routes. The road network has also deteriorated due to recurring natural hazards like mudslides, floods, and heavy rains. This fosters a sense of socio economic isolation. Key challenges include absence of a road maintenance program, inadequate decentralization to local institutions and unclear mandate among responsible national institutions.

Infrastructure Type	Climate Change Impacts											
	Increased Solar Radiation	Decrease in Available Moisture	Increased Variation in Wet/Dry Spells	Increased Temperature & Heatwaves	Decrease in Rainfall	Increase in Extreme Daily Rainfall	Increase in Frequency and Intensity of Storms	Increase in Intensity of Extreme Wind	Increased Electrical Storm Activity	Increase in Bush Fires	Sea-Level Rise	Humidity
Water	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible	Negligible	Definite	Negligible	Negligible
Sewer	Negligible	Definite	Definite	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Stormwater	Negligible	Definite	Definite	Definite	Negligible	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Electricity	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Negligible	Negligible
Gas and Oil	Negligible	Definite	Definite	Negligible	Negligible	Definite	Definite	Negligible	Negligible	Definite	Definite	Negligible
Fixed Line Telecom Network	Definite	Negligible	Negligible	Definite	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible
Mobile Network	Negligible	Definite	Negligible	Negligible	Negligible	Negligible	Negligible	Definite	Negligible	Negligible	Negligible	Negligible
Roads	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Negligible	Negligible	Negligible	Negligible	Negligible
Rail	Negligible	Negligible	Negligible	Definite	Negligible	Definite	Definite	Negligible	Definite	Negligible	Negligible	Negligible
Bridges	Definite	Negligible	Negligible	Definite	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Negligible
Tunnels	Negligible	Negligible	Negligible	Negligible	Definite	Definite	Definite	Negligible	Negligible	Negligible	Definite	Negligible
Airports	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Definite	Negligible	Definite	Negligible	Negligible
Ports	Negligible	Negligible	Negligible	Negligible	Negligible	Definite	Definite	Definite	Negligible	Negligible	Definite	Negligible
Buildings and Structures	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite	Definite
Urban Facilities	Definite	Definite	Definite	Definite	Negligible	Definite	Definite	Definite	Definite	Definite	Definite	Negligible

Table Legend

(green)	**Negligible Risk – Presents "negligible" risk within the probability of natural variation**
(orange)	**Definite Risk – Presents "definite" risk within the probability of natural variation**

Source: CSIRO Australia, 2006

Table 4.8. Climate change exposure and infrastructure sensitivity matrix

E) Irrigation

The irrigation systems are severely challenged with only 26 percent of the land area under irrigation. High frequent climate risks like droughts and floods affect the functionality of the already weak irrigation system. Absence of maintenance programs and limited participation of people's affects its upkeep.

F) National Level

Climate risks and shocks could setback agriculture GDP by 10-20 percent and the national GDP by 3 percent. Refer to Figure 4.7

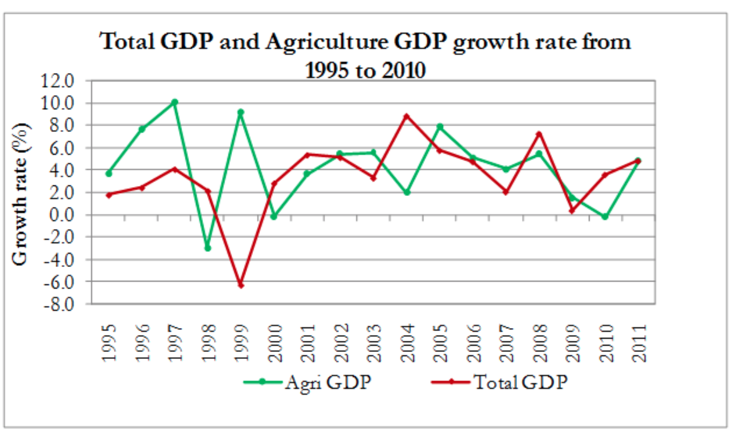


Figure 4.7 Total GDP and Agriculture growth rate in Ecuador from 1995 to 2011

Recurring floods and droughts entail huge economic losses. A WFP assessment suggests that Ecuador has lost US$ 4 billion from drought alone in the last decade. The CRM-TASP assessment for agriculture GDP (Table 4.9) indicates a loss of about US$ 1.2 billion. The impacts of climate risk have forward and backward linkages with manufacturing and service sectors and ultimately affect the national income. The data for the linkages is not readily available. However considering the average GDP from 2001 to 2011, the loss could be around US$4 billion that represents 1 percent of GDP.

TABLE 4.9 ECONOMIC LOSS IN ECUADOR DUE TO CLIMATE SHOCKS IN THE AGRICULTURE SECTOR

YEAR	AGRICULTURE GROWTH RATE	DEVIATION FROM POTENTIAL (ASSUMING 7.8% AS POTENTIAL)	AGRICULTURE GDP IN MI US$	LOSS FROM POTENTIAL AGRICULTURE GDP IN MI US$
2001	3.6	-4.2	1896.4	-78.9
2002	5.4	-2.4	2053.1	-49.5
2003	5.6	-2.2	2229.3	-49.6
2004	1.9	-5.9	2236.1	-131.0
2005	7.8	0.0	2473.4	0.0
2006	5.1	-2.7	2797.7	-75.3
2007	4.1	-3.7	3039.8	-113.9
2008	5.4	-2.4	3478.2	-82.3
2009	1.5	-6.3	3524.8	-222.8
2010	-0.2	-8.0	3824.3	-307.1
2011	4.8	-3.0	4419.5	-132.6
			Total	-1242.9

ADAPTIVE CAPACITY

a. National capacity: The Ecuadorian economy is dominated by the oil sector, that contributes about 30 percent of GDP, 40 percent of government revenues and 60 percent of export earnings as of 2010. A downfall in global petroleum prices in combination with an extreme event could seriously undermine the government's adaptive capacity to cope with climate risks. As most of the oil revenues are diverted for social safety nets, no systematic effort is made to reduce climate risk. Hence climate risk is accumulating and retained by 30 percent of the population, that depends on agriculture.

The 2009 economic crisis forced the government of Ecuador to borrow large amount from China bilaterally. This caused serious budgetary deficit and long term liabilities. Since the key agriculture commodities of corn and wheat are imported, a fall in their production due to climate risk could have a serious impact on foreign exchange reserves. This would further reduce the governments capacity to address risks and their impacts.

b. Household capacity

Farm owners, agricultural workers and domestic traders face the most risk and the least capacity to adapt to it. About 1.5 million small farm holders are particularly at risk. The direct cost borne by this vulnerable section of the population is detailed in Table 4.10 With the exception of shrimp farmers, who benefit from El Nino (warm waters is conducive for good larval growth), all other farmers face crop loss dur to floods and droughts.

TABLE 4.10 ESTIMATION OF THE OVERALL DIRECT COSTS OF DAMAGE BY THE 1997-78 EL NIÑO EVENT (VALUES IN MILLION US DOLLARS)

	1997-8 (UNTIL JUNE 1998)		
	COSTS	BENEFITS	NET COSTS
Agriculture	182.3	15.3	167.0
Farmers-owners	50.8	6.7	44.1
Agricultural workers	73.9		73.9
Domestic traders	57.6	8.6	49.0
Livestock	7.7		7.7
Livestock farmers-owners	2.4		2.4
Wage-earners in livestock	2.7		2.7
Shrimp farming	7.5	75.5	-68.1
Fishing	12.4	6.7	5.7
Traditional fishing	12.4		12.4
Industrial fishing boats		6.7	-6.7
Total Agriculture, Livestock and Fishing	209.9	97.5	112.3
(% of agricultural GDP)	8.8%	4.1%	4.7%
(% of total GDP)	1.1%	0.5%	0.6%

Sources: Vos, Velasco and De Labastida (1998) cited in Vos et al. 1999[33]

THREATS TO DEVELOPMENT

Despite the oil based economy of Ecuador, agriculture remains a key sector supporting 30 percent of population, most of whom are small farm holders. Periodic climate shocks seriously impact them and challenge the Government of Ecuador's (GoE) efforts to reduce poverty. They also affect rural infrastructure like roads that connect rural population and markets. For example the 1997-98 El Nino damaged transportation infrastructure of US$ 2.4 million. As most government resources are diverted to social spending, the investment for climate risk reduction (CRR) and maintenance of rural infrastructures is not commensurate with requirements. This trend could impact the achievement of Ecuador long term development goals and the overall health of the fragile economy. Climate shocks are an important factor in persistent poverty in the country. Increase in projected risks in the future are likely to further reduce the capacities of vulnerable communities and possibly lead to urban migration and increased urbanization.

KEY MESSAGES ON CLIMATE IMPACTS AND ITS RISK

- Climate risks of droughts, floods and landslides cause severe damage to Ecuador.
- Floods and droughts alone cost around US$ 5 billion damage from 2000 to2010.
- Ecuador is a high climate sensitive country. Climate risks and events adversely affect agriculture systems, fisheries, infrastructure and the overall economy.
- Ecuador has a low adaptive capacity to climate risks due to its narrow based oil economy and low institutional capacities of the government.
- Small farm holders are particularly at risk of climate variability and hazards, especially because they have very limited risk management support.
- Periodic climate shocks are a threat to development of Ecuador that already has 35 percent of its population under the poverty line.
- Climate shocks are an important factor in persistent poverty in the country. Future climate events are likely to further reduce the capacities of the government and vulnerable groups to manage and address them.

CURRENT CLIMATE RISK MANAGEMENT IN ECUADOR

This chapter examines the current capacities for CRM, particularly in the form of institutional and policy arrangements for CRM from frameworks of development planning, disaster risk management and climate change. A capacity assessment for CRM is also undertaken for key functions of CRM, primarily assessment, prioritization, coordination and information management.

INSTITUTIONAL AND POLICY ARRANGEMENTS FOR CRM

Three distinct frameworks address climate risks in Ecuador. These include the frameworks for development planning, disaster management, and climate change adaptation.

A. Development Planning Framework

Ecuador's National Development Planning Council (NDPC) guides the national planning development process with the participation of key economy sectors, ministries and departments. SENPLADES is the technical secretariat of the NDPC.

The government's *"National Plan for Good Living 2009-2013"* guides the development vision and planning of Ecuador. It is being implemented by SENPLADES and has following objectives *(SENPLADES, 2009[34])*.

a. To Foster Social and Territorial Equality, Cohesion, and Integration within Diversity;
b. To Improve the Citizens' Capacities and Potentialities;
c. To Improve the Population's Quality of Life;
d. To Guarantee the Rights of Nature and Promote a Healthy and Sustainable Environment;
e. To guarantee Sovereignty and Peace; and to Promote the Strategic Insertion in the World, and Latin American Integration;
f. To Guarantee Stable, Fair, and Dignified Work in its Diverse Forms;
g. To Build and Underpin Public and Intercultural Spaces for Common Encounter;
h. To Affirm and Strengthen National Identity, Diverse Identities, Plurinationality, and Interculturality;
i. To Guarantee the Validity of Rights and Justice;
j. To Guarantee the Access to Public and Political Participation;
k. To Establish a Solidary and Sustainable Economic-Social System;
l. To Build a Democratic State for Good Living.

B. Disaster Risk Management Framework

Ecuador's recently-approved constitution has risk management as a national policy, making risk management obligatory for the state. The policy aims to increase Ecuador's capacity to respond to emergencies and disasters; and create a decentralized risk management framework. The constitution mandates the following actions 1) risks affecting the territory should be identified; 2) generate information to mitigate risks adequately; 3) identify actions; and 4) guarantee sufficient financing through decentralizing risk management.

The Technical Secretariat for Risk Management (TSRM) replaced the Civil Defense. It was created for institutionalizing and translating constitutional provision for risk management into practice. It is considering the following strategies:

i. Make risk management a cross-cutting concern in the National Development Program;
ii. Publish a national strategy for reducing risks;
iii. Develop risk management laws, that would mandate the creator of risks to absorb the causes/consequences of it and require investments to conduct a risk study;

iv. Conduct training programs for community-based organizations on how to receive and use risk information;

v. Create a risk management unit in each agency.

The TSRM was reorganized to become the National Secretariat of Risk Management (NSRM) following the Executive Order 42 on September 10th, 2009. The new National Secretariat's mission is to lead the decentralized national system for climate risk management and guarantee protection for people and communities through policies, strategies and standards for risk management. The long-term objective of the NSRM is the development of a culture of prevention. Its medium-term goal is to build the National Decentralized Risk Management System as a regulatory framework for Risk Management and the short-term goal is to increase capabilities to address disaster events.

The NSRM was created to link various institutions and ensure that synergies are in the production of maps and data collection. Some representatives express that NSRM could exercise greater leadership to invest resources in climate risk management systems and risk reduction measures over emergency response.

C. Climate Change Framework

The Ministry of Environment (MoE) is working on developing a national strategy on climate change. It is working with the National Planning and Development Secretariat (SENPLADES) to coordinate climate change initiatives. UNDP is considered a counterpart of the MoE in implementing climate change projects. Its limited control over implementation resources across sectors has been a factor in limiting its influence in these initiatives.

Climate-related institutional and governance issues have undergone major changes during the last decade. The Climate Change Unit (CCU) of Ecuador's MoE was created in 2000. In year 2008, the Unit was turned into a National Direction within the Undersecretariat of Environmental Quality. Despite limited staff and other resources, it has been successful in taking advantage of funding opportunities in the last decade. The CCU hosts the coordination and preparation of the Second National Communication (SNC) to the UNFCCC, due in year 2010 (UNDP, 2008[35]).

The MoE is also the head of the National Climate Committee (CNC), which has the mandate for directing and leading the policy and strategy process for climate change mitigation and adaptation. The CNC is a collegiate body composed of representatives from several ministries (environment, energy and mines, foreign affairs and planning), business organisations, NGOs and academics. The MoE presides over the CNC and the INAMHI serves as the secretariat.

The National Capacity Self Assessment (NCSA) report states that considerable opportunities for integrating CCA into the policy arena are being lost due to lack of inter-institutional coordination and insufficient national and local capacities. Except for INAMHI and MoE, no other public or private institutions have specialized units for climate change-related issues. The production of data for national communications is usually carried out by ad-hoc teams or by staff from other agencies *(Ibid)*.

Despite the publication of the First National Communication to the UNFCCC, a considerable body of information on climate change remains dispersed. While there are centres of scientific excellence located in Ecuador, and institutions such as INAMHI, the Navy's Institute of Oceanography and the International Center for Research on the El Niño Phenomenon (CIIFEN), have contributed to monitoring climate variability and long term changes in climate patterns in Ecuador, much of the scientific information is not readily available or in a useful form for national and local decision making processes *(Ibid)*. Knowledge brokering between core stakeholders in the climate change community is expressed as a major need. Other needs include an outreach strategy to mainstream adaptation policies across various sectors, which would benefit from timely, accurate and accessible information on climate trends and risks in Ecuador.

MAJOR ONGOING ACTIVITIES FOR CLIMATE RISK MANAGEMENT

The MoE in partnership with GEF/UNDP support has developed an online application tool (www.pacc-ecuador.org) for the display of climate change scenarios of various models- ECHAM, HadCM3, PRECIS, and the TL959 Japanese model. This tool has been developed by experts from the Meteorological Institute of Cuba and INSMET, in close collaboration of the National Meteorology Institute (INAMHI) of Ecuador.

The Regional Adaptation to the Impacts of Rapid Glacier Retreat in the Tropical Andes (covering Ecuador, Peru and Bolivia) is funded by GEF and implemented by the World Bank. The project aims to strengthening the resilience of local ecosystems and economies to the impacts of glacier retreat in the Tropical Andes, through the implementation of specific pilot adaptation activities that illustrate the costs and benefits of adaptation. It involves design and pilot adaptation measures, and support to monitor glacier retreat in the region.

CAPACITY ASSESSMENT FOR CLIMATE RISK MANAGEMENT

An assessment for climate risk management capacities and gaps was undertaken using the World Resources Institute's National Adaptive Capacity framework (WRI, 2009). It revealed the following findings:

a. Assessment function: Some efforts are being made to develop a methodology for vulnerability assessment and validate and test it at the municipal level pilot application project in Quito. The responsibility and capacity for CRM is disbursed across various institutions in Ecuador. No systematic efforts have been made for collecting, compiling, and analysing climate data and its relationship to socio economic systems. The capacity to assess different thresholds for different aspects of the economy including crops, fisheries and livestock is limited. There is also limited understanding of the exposure of development assets to existing and emerging climate risk both and planned.

b. Prioritization function: As there is no institutional arrangement or capacity to assess climate risk, there is no effort to prioritize development interventions from a CRM perspective.

c. Coordination function: The CRM function is spread across different institutions (refer to Table 5.1).and there is no coordination mechanism in place to synchronise the efforts of different institutions.

TABLE 5.1 INSTITUTIONS RELEVANT FOR CLIMATE RISK MANAGEMENT IN ECUADOR

INSTITUTION	TYPE	RELEVANT OBJECTIVE	ROLE IN CRM
National Climate Change Committee (CNC)	Collegiate body composed of representatives from several Ministries, private sector and institutions	Committee operates through technical multi-sectoral Working Groups; which are leaded by public entities. e.g., CNRH leads the Water Resources and climate change, Ministry of Energy and Mines leads Energy and climate change group	Key for mainstreaming climate change in national institutions.
National Institute of Meteorology and Hydrology (INAMHI)	National Meteorological Agency	Meteorological monitoring, monitoring of water flow in watersheds INAMHI has a secretarial role in the CNC;	Key role for providing climate data and observation, early warning system. Needs capacity development for monitoring equipment and staffing
National Secretary of Planning and Development (SENPLADES)	National Development Planning Agency	In charge of planning and managements of strategies for the development of the country. Formulates sectoral risk management projects.	Key in incorporating climate change into national development agenda Technical expertise in risks and planning.

TABLE 5.1 CONTINUED

INSTITUTION	TYPE	RELEVANT OBJECTIVE	ROLE IN CRM
Ministry of the Environment (MoE)	National Ministry	National Environment Authority, management of protected areas (which host important watersheds) Hosts the Climate Change Unit, focal point for UNFCCC, preparing the SNC and the national strategy on climate change Forms part of the Board of CNRH. Leads the CNC.	Public awareness to increase support for adaptation measures. Policy development and enforcement.
National Secretariat for Risk Management	National Agency	Responsible for risk reduction strategy	
Ministry of Agriculture	National Ministry	Key ministry with food security as one of its priorities	Key user of weather and climate information
National Council of Water Resources (CNRH)	National Authority of Water in Ecuador	Formulation of National Water Resources Plan, regulation of the use of water in governmental projects, the management of irrigation systems and its transfer to users, water quality control and the management of watersheds; establish cost recovery policies. Part of the CNC; is in charge of the Working Group on water resources and climate change.	Improved systemic capacity supports effective water management under conditions of climate change. Policy development and enforcement.
Navy's Oceanographic Institute (INOCAR)	Institute of Excellence	Monitoring of sea level, marine currents and related issues.	Key role in climate data and observation.
International Center for Research on the El Niño Phenomenon (CIIFEN)	International Center of Excellence	Monitoring of ENSO, supporting preparation of agro-climatic risk maps and maps indicating climate risks on infrastructure and related issues	Key role in climate data and observation, early warning system.
Consortium for Provincial Councils of Ecuador (CONCOPE)	National Consortium	Groups all the provincial councils of Ecuador.	Could provide an easy approach to diffuse and incorporate climate risk management practices among provincial councils.

TABLE 5.1 CONTINUED

INSTITUTION	TYPE	RELEVANT OBJECTIVE	ROLE IN CRM
Association of Municipalities of Ecuador (AME)	Association	Federates all the municipal governments of Ecuador. Building and operation of wastewater systems and drinking water treatment and distribution networks.	Could provide an easy approach to diffuse and incorporate climate risk management practices among municipal governments.
National Electrification Council (CONELEC)	National Council	Regulation of energy generation, fixation of tariffs, environmental permits for generation and transmission projects.	Could assist in incorporating climate change and risk concerns into approvals for hydro-energy projects.
Regional Development Corporations (CDR's)		In charge of design, build and operate water and flood control infrastructure in different regions of Ecuador.	For mainstreaming climate risk and change considerations into water and flood control operations
Water Resources Forum (FRH)	A water users association	This Forum has become an important public arena for discussions on water policies	Considering water is a critical issue, could provide inputs from small consumers, peasants and NGOs for climate risk management measures aimed at water sector

Source: Based on information from 'Adaptation to Climate Change through Effective Water Governance in Ecuador' Government of Ecuador, United Nations Development Programme Project Document. 2008

A coordination mechanism for climate information could serve the interests of several government and non-government development stakeholders that are sensitive to climate risks. These include the provincial and municipal authorities, regional development corporations and watershed-management authorities, all in charge of water-related infrastructure investments and/or of the care of key watersheds, and other institutions that group provincial/local governments such as the Consortium for Provincial Governments of Ecuador (CONCOPE). CONCOPE comprises of all the provincial councils of Ecuador and the Association of Municipalities of Ecuador (AME). It also consolidates funds created to manage environmental and water management projects. Other possible users and key interests related to climate risk management include:

- i Banana Exporters Association: Climate information would help in creating production estimates and appropriate marketing strategies;
- ii Banana company: Concerned about flooding and identify mitigation measures they can undertake to protect plantations and facilities;
- iii Ministry of Fisheries: Interested in incorporating climate risk management into fisheries resources management involving artisanal fishermen;
- iv University of Guayaquil, Faculty of Science: Climate effects on the Ecuadorian coast + focus on biological aspects;
- v Environmental Studies: Interest in risk management for watersheds;
- vi Coastal Environmental Association: Climate effects on ecosystems;
- vii Oceanographic Institute of the Navy: Ocean-Atmosphere Interaction and the effects in the coastal zone;
- viii Department of Planning: Sectoral Risk management;
- ix National Council of Electricity: Energy offer based on seasonal forecasts;
- x Ministry of Information: Cross cutting information for all the strategic areas;

xi Coastal Infrastructure Agency: Contingency planning for the coastal areas;

xii Provincial unit of Guayas: Climate information to be applied for contingency plans at the provincial level;

xiii University of Sta. Elena: To include CRM tools and approaches in academic programmes;

xiv Environment Department: Environmental Management;

xv Red Cross in Guayas: Improve preparedness and response;

xvi FAO Country Office: To support CRM initiatives in the agriculture sector.

c. Information management function:

In terms of priority the climate-sensitive sectors are agriculture, health, water resources, energy and tourism. While some progress has been made in climate information services it is not adequate. The sector for agriculture for example needs specific information systems considering that more than 85 percent of crops in Ecuador are adversely affected by climate risk, making it the most vulnerable sector.

The constraints faced by the existing climate information system include the lack of credibility of INAMHI among users, inadequate observation, monitoring and forecasting capacity, limited understanding of user-specific requirements. Limitations in further developing and improving the climate risk information include:

i. Lack of interest on the part of the central and provincial governments in allocating development budget for disaster prevention and preparedness;

ii. Lack of an accountable system for encouraging and mandating use of available scientific information for appropriate risk reduction measures;

iii. The lack of synergy among national institutions to share climate and relevant information at national level. For example, lack of collaboration between municipal governments and ministries with access to different pieces of climate information to facilitate informed decision-making for risk reduction;

iv. Lack of initiative from the financial and economic sector to engage with stakeholders in developing risk management practices;

v. Low priority and resulting limited progress in climate related state projects like watershed management which can help mitigate the impacts of climate-related risks especially on agriculture and other climate-sensitive sectors;

vi. Limited tools for assessment and risk reduction challenge the process of identifying and addressing risks;

vii. Limited capacity (capabilities, resources and knowledge) of local governments interested in risk management;

viii. The absence of an efficient communication system on extreme climate events to disseminate information in easy-to-understand language for stakeholders including communities;

ix. Lack of an accessible and active database of large, medium and small disasters for potential vulnerability studies, to identify risks at the local scale. The small disasters that go unnoticed by media have a cumulative effect in losses much larger than an adverse event of considerable magnitude;

x. Difficulty in accessing national climate data base for previous studies on infrastructure risks because of the high level of uncertainty and high cost of meteorological data;

xi. Lack of resources for training qualified researchers in higher education institutes for careers related to meteorology, hydrology and oceanography;

xii. Limited involvement of relevant sectors and their coordination to implement local government planning;

xiii. Lack of initiative to develop risk management tools for anticipatory planning and addressing different climate risk scenarios;

xiv. Lack of the culture of prevention of damage and proper maintenance for vulnerable physical and social infrastructure.

A survey conducted in different regions of Ecuador[36] to analyze the poor or non-existent response to climate hazards revealed that lack of easy to understand climate information prevented better reaction by the community in extreme climate events. 15 to 20 percent of damage observed in flooded areas was directly or indirectly related to information and/or communication failures. Reasons ranged from limited access to information, misrepresentation or misinterpretation of technical information by the media and other institutions and limited understanding of unfamiliar technical language and jargons by communities. More than 50 to 60 percent of the population was not aware of climate forecasts and/or do not know what they mean, and if they fairly understand it, they do not know how to apply it to reduce risk.

After the 2012 floods in the coastal region of Ecuador, an assessment of the weaknesses and strengths of the current institutional framework to adequately cope with the region's regular climate related disasters was carried out. One of the main conclusions of that study was the critical deficiency of adequate and timely information to support decision making before, during and after the emergency. The need for specific information, written in easy to-understand language and easy to access at any time for decision makers and disaster managers was expressed.

Broadly, the available climate knowledge is unable to reach and guide people and institutions for appropriately guiding development activities.

There is a need to invest in climate monitoring. For example, the changes in glaciers do not always result in a decrease of snow cover. Certain La Niña events result in building up the glacial cover. Hence observation systems are critical, as inadequate information guiding adaptation practices now could lead to maladaptation later, systematic observation for slow onset phenomena would help understand the changes, and develop evidence-based policy leading to suitable adaptation measures. Thus there is a need for greater emphasis and funding for scientific monitoring.

d. Climate risk reduction function: Past and existing climate knowledge and El Nino forecast makes it is possible to reduce climate risk. However, lack of policy and institutional mechanism constraints the climate risk efforts in Ecuador.

KEY MESSAGES (CURRENT CLIMATE RISK MANAGEMENT)

- Most of the government efforts in CRM is diffused among large number of stakeholder institutions.
- CRM is undertaken in three different domains –development, disaster reduction and climate change adaptation–. There is a need to synchronise these three domains to have a holistic CRM Process.
- The climate risk assessment system is very weak with several capacity gaps.
- There is no institutional arrangements to coordinate CRM assessments, prioritization, coordination and information management for risk reduction efforts.
- The investment in CRM is less than 1 percent of the development budget of Ecuador resource allocation.
- Climate information systems need to be strengthened despite availability of application of ENSO forecasts. Its prerequisites are policy, institutional mechanism and capacity engagements.

RECOMMENDATIONS FOR CLIMATE RISK MANAGEMENT

In light of the capacity gaps for developing and implementing climate risk management options in Ecuador, the following recommendations are proposed. In addition to building institutional and informational systems and capacities the CRM TASP recommends priority interventions in the sectors of agriculture and infrastructure owing to their role in the future development planning of Ecuador and their sensitivity to climate risks.

From a development perspective, the proposed approach towards CRM options is to prioritise CRM in agriculture and infrastructure (high climate-sensitive sector), promote agroforestry-based livestock system (a moderately climate-sensitive sector), with gradual shift to non-farm occupations (least climate-sensitive sector), while ensuring it is socially acceptable, environmentally sustainable, and economically viable for Ecuador.

INVESTMENTS IN AND INSTITUTIONALIZATION OF CLIMATE RISK MANAGEMENT

There is a need to strengthened investments in and institutionalization of CRM system for proactive risk reduction actions in Ecuador. This would include the following:

a. Mobilize adequate and appropriate financial investment for climate risk reduction, which should be seen as an investment in securing and integrating marginalized population groups (like small farmers, urban slum dwellers etc.) into mainstream development processes. Currently the Government of Ecuador (GoE) allocates less than 1 percent of its development budget for CRM (2011).

b. Build and coordinate an institutional mechanism with capacities for CRM. The National Secretariat for Risk Management should facilitate this process and climate sensitive sectors and ministries such as Ministry of Agriculture, Ministry of Infrastructure and National Climate Change Committee (CNC) should be involved in establishing and integrating CRM in the functioning of the climate sensitive sectors. A policy mechanism to institutionalise this system is also required.

c. Undertake needs assessment to build capacities of the key institutions involved. While, the regional and local institutions have limited capacities, the active and unique civil society organizations could be used as an alternative to institutional forums for introducing CRM measures and enhancing use of climate information at the local and community level.

d. Establish alliances among institutions to share risk reduction knowledge for decision making in a multi-sector context. Multi-stakeholder dialogue will also benefit local governments with responsibility for management of the land and watersheds.

e. Establish an inter-institutional communication network to enhance dialogue and create a specialized network to disseminate and coordinate common activities on risk management among national institutions. This could be virtual so that even the most remote municipalities will have access to it.

f. Develop training programs to improve integration of environmental, disaster and climate risk concerns for sustainable development. Promote professional courses on climate related areas through masters and doctorate degrees, for officials involved in key development sectors. Engineering and social sciences could add curriculum on making use of available climate information at masters and PhD levels.

g. Develop and apply training methodologies for using CRM tools such as maps, land use planning, and others. The goal is to incorporate them into planning and management of strategic sectors of development like agriculture and infrastructure, especially roads, irrigation etc.

h. Identify municipalities with variable local climate risk scenarios and propose risk management strategies with community participation to serve as inputs for the local development plan. This initiative could be used as a successful case in CRM and replicated and/or offer lessons for the rest of the country.

CRM FOR THE AGRICULTURE SECTOR

a. Delineate risk zones for food production using climate risk assessment results, water management, agronomic practices, and building on existing agro-climatic zones.

b. Implement crop relocation and/or de-concentration of food crop production as per the decentralized assessment of areas based on the variables of productive and conducive for crop growth, current and future climate trends and their vulnerability to climate shocks.

c. Develop a climate information decision-support tool using existing forecasting capacities. Ecuador can have high climate predictability by using ENSO parameters and other advances in climate prediction. Climate information can be generated at different timescales for application in food production.

   For example, an El Niño forecast, with lead time of 9-12 months, can inform the exploitation of normally water-logged marginal lands for agriculture. The forecast could also inform water resource management planning for the longer dry season. An El Nino forecast can also inform crop planning. For example, with early onset and late withdrawal of the wet season due to El Nino, planting and, hence, harvest could be advanced, freeing land for one additional crop. Seasonal forecasts can inform rice production projections. Absence of robust decision support tools has led to under-estimation of domestic food production and over-estimation of import requirements, causing depression of domestic food prices and subsequent losses to farmers. In some years, domestic food production was over-estimated and import requirements under-estimated, which led to food price increases that harmed net food consumers in both urban and rural areas.

d. Use climate information to anticipate inter-annual and intra-seasonal variability. Farmers could also consider crop diversification. Heavy rain and strong winds constrain the scaling up of these initiatives into commercially viable enterprises. Through contract farming, supported by insurance instruments, climate information could shift farming from subsistence to market-oriented farming. It could also help build food and/or fodder reserves during the normal or above-normal seasons, for use during below normal years.

e. Link weather/climate information with broader input and output related information, like markets, seeds for alternate crops, pest and diseases etc. for meeting challenges of seasonal and inter-annual climate fluctuations in agriculture production.

f. Incorporate climate risk management measures into supply chain management. The first step would be an assessment of climate impact pathways and non-climate risks, such as credit, fertilizer, and seeds availability, and the role of market price in affecting a farmer's decision, through feedback pathways. Managing climate risk within the supply chain framework could pave the way for addressing production and market risks holistically.

CRM FOR THE INFRASTRUCTURE SECTOR

The adaptation assessment matrix for infrastructure (Table 6.1) identifies some CRM options to manage the potential impacts of climate variability and extremes in Ecuador. Overall, this requires capacity development of the Ministry of Infrastructure to continually assess and priorities specific threats to infrastructure assets in the country and to implement adaptive measures.

TABLE 6.1: ADAPTATION ASSESSMENT MATRIX FOR INFRASTRUCTURE

CLIMATE	IMPACT	OPTIONS AND CONSTRAINTS
1. Rising Sea-Level and Associated Storm Surges		
Submergence	-Some roads may be submerged -Embankments may become dikes -Construction in deltas and rivers poses problems	Engineering Options: Seawalls or realignment works offer the lowest cost long term solution. Where sea level inundates an existing road the acquisition of land problems may arise. Re-planting of mangroves, where physically possible, provide a cost effective means to protect against wind and wave erosion.
Rising level of water tables in coastal zones	Reduction in the effectiveness of drainage which will lead to a reduction in the bearing capacity of the soils which become saturated	Water table levels are expected to changes in coastal areas in line with sea level changes. Drainage system capacity should be checked where sea level changes result in roads being located near a sea shore.
2. Lack of water: Drought and its Consequences		
Lowering of water table	Settlement of road subgrade (compressible soils) leading to distortion of the road surface	The lack of clay sub-soils steep terrain means the overall risk is low.
Drying of subgrade	-Transverse instability - Non uniform deformation of the subgrade causing distortion of the road surface	The lack of clay sub-soils steep terrain means the overall risk is low.
Insufficient moisture to sustain the vegetative cover	Erosion	The feasibility of replanting with drought tolerant species is dependent on the availability of land being made available over a wide enough area to have an impact. Bio-Engineering (e.g. matting/ erosion control blankets) may become expensive when applied at larger scales, but also provide wider benefits (see below for further details)
Forest and bush fires	Increased erosion due to reduced ground cover.	Re-planting with fire tolerant species in suitable habitat areas may be constrained by the availability of land. This hazard is not expected to be a significant risk in the immediate future.
Drying of materials in fill	Shrinkage problem No uniform deformation in the case of fills on slopes Problem of connections with engineering structures Surface drying (skin effect) making the soil erodable	This hazard is not expected to be a significant risk in the immediate future.

TABLE 6.1 CONTINUED

3. Presence of a Large Amount of Water		
More runoff water	Gully erosion More severe floods Water build-up Overflow and mud /debris Landslides and slips of the slopes of fill or cut slopes	Engineering Options: Additional culverts and higher bridges are effective but expensive. The effectiveness of bio remediation systems to reduce runoff will be limited by the soil profile and steep terrain commonly found in Ecuador For engineering solutions to be effective adequate routine maintenance must be performed continuously. It is unlikely land and cost constraints will restrict using only bio-retention systems. Re-vegetation can be a community-based activity that provides income to villages along the roads, if coupled with maintenance contracts. Potential land ownership issues may arise.
Raising of water tables and of penetration of greater volumes of water infiltration affecting the subsurface moisture content	Reduced pavement failure and increased risk of pavement failure due to water saturation. Subsidence and collapse caused by natural or manmade underground cavities Collapse of fill	Engineering Options: The effectiveness of bioremediation systems to reduce runoff will be limited by the soil profile and steep terrain commonly found in Ecuador. Poor maintenance will render higher number of culverts ineffective. Bio-retention systems may have to be built in areas outside the ROW, which could be problematic due to land ownership issues. Re-vegetation can be a community-based activity that provides income to villages along the roads, if coupled with maintenance contracts. Potential land ownership issues may arise.
4. Increase in Wind Strength		
Increased wind (particularly for coast) Fallen trees Dune advance Wind erosion	Inadequate strength of vertical signing, particularly poles and gantries	Re-planting of mangroves and coastal forests in suitable habitat areas provides wider benefits and is relatively inexpensive. However, it does not provide complete protection as some risk areas may not be suitable for mangrove re-planting.

Adapted from World Bank: Road climate resilient road project 2009-2011

STRENGTHENED INFORMATION AND COMMUNICATION MANAGEMENT FOR CRM:

a. Develop a user-relevant climate information system involving assessment of users' information requirements and tailoring information to address specific requirements; characterising and packaging uncertainties associated with climate information of different time-scales; orientation of climate information to facilitate its application in a risk management framework and demonstration of economic benefits of using climate information and adopting the CRM framework.

b. Improve current national capacities on climate data processing, analysis, modeling and the generation of information and forecast services including its sectoral applications in four strategic sectors: agriculture, health, water resources and energy.

c. Strengthen the capacity of governmental institutions such as planning secretary, ministries, and other sectoral institutions to identify their climate information requirement and apply climate information in their respective sectors.

d. Strengthen research capacity to link existing climate information and make use of it for operational purposes. It should be built as a priority among both information providers (INAMHI and other centers) and information users (planning agency and sectors).

e. Develop GIS capabilities for hydro meteorological information in INAMHI to share climate information tailor-made as per user requirements to enable use by various users.

f. Improve the current climate information communication systems and coordination between INAMHI and national agencies and authorities.

g. Create a documentation centre to systematize the information on disasters in the country. Aid the research on autonomous adaptation in various regions of Ecuador and identify and systematize traditional knowledge and skills for predicting and managing climate risks.

AREA SPECIFIC RECOMMENDATIONS

a. There is useable information (especially on ENSO) already available for coastal regions, which can be used beyond its direct application for El Niño projections. Capacities should be built in the coastal regions to facilitate its use.

b. For the Andes-Sierra region, which has highly variable climate, research outputs are available to assess the patterns in linking climate variability with Northern Oscillations and other factors. But the state of knowledge and research capacity to link it to operational forecasting is not adequate. Thus focus should be on generating useable information and facilitating its use.

c. In highlands, with very likely climate change impacts, there is a need to analyze and screen current development projects for their exposure and vulnerability to climate risks.

d. In the Amazon, where the climate is not as variable, it is prudent to observe the changes, reduce deforestation and review urbanization stresses related to oil extraction, to develop suitable adaptation measures.

e. Ecuador's has high spatial variability due to unique characteristics including climate influences like ocean currents, Northern Oscillations and ENSO and the topography. This makes it essential to develop a dense and well-established observation systems for climate information. This is especially relevant for existing and planned development investments in the power and water sector. Decision-making in the absence of such systems has exposed these high-value assets to the vagaries of climate in Ecuador.

NOTES:

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