

CLIMATE RISK MANAGEMENT FOR AGRICULTURE IN PERU: FOCUS ON THE REGIONS OF JUNÍN AND PIURA


Prepared by the International Institute for Sustainable Development (IISD)

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CRISIS PREVENTION AND RECOVERY





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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 salt water 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 US\$ 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 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 examines high-risk countries and focusses 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.

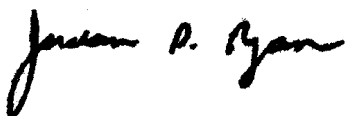
This series is part of a growing body of climate change adaptation resources being developed by UNDP. The Climate Risk Management – Technical Assistance Support Project has formulated a range of climate risk management assessments and strategies that bring together disaster risk reduction and climate 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 a 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 general methodology and analytical framework of the CRM TASP was conceptualized by Maxx Dilley, disaster partnerships advisor, and Alain Lambert, senior policy advisor, with key inputs from Kamal Kishore, programme advisor, Disaster Risk Reduction and Recovery Team, BCPR, in consultation with Bo Lim, senior climate change advisor, Environment and Energy Group, BDP. Within BCPR, the project implementation process has been supervised by Alain Lambert, Rajeev Issar and Ioana Creitaru, who provided regular inputs to ensure in-depth climate risk assessments and identification of tangible risk reduction and adaptation options. From BDP, Mihoko Kumamoto and Jennifer Baumwoll provided their input, comments and oversight to refine the assessment and recommendations. The overall project implementation has benefitted immensely from the strategic guidance provided by Jo Scheuer, coordinator, Disaster Risk Reduction and Recovery Team, BCPR, and Veerle Vandeweerd, director, Environment and Energy Group, BDP.

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

Building upon the CRM TASP general framework to tailor the process to country-level analysis, IISD developed a more detailed methodological framework for assessing climate risks and identifying climate risk management options in seven countries, including Peru. Within IISD, Anne Hammill supervised the overall project implementation. Marius Keller supervised all in-country activities in Peru and is the lead author of the present report.

For their valuable contributions to the project, the project team would like to thank co-author Daniella Echeverria; consultant Dilma Dávila; Hector Yauri Quispe, Irene Trebejo and Grinia Avalos from the National Service of Meteorology and Hydrology of Peru; Gabriella Torres from ÉcoRessources; Maria Elena Gutierrez and María Paz Cigarán from Libélula; Verónica Gálmez, Lorena Mancero and Anelí Gómez Lovatón from Helvetas Swiss Intercooperation; and Griselle Vega of the United Nations Food and Agriculture Organization. The team would also like to thank James Leslie and Jorge Alvarez Lam of UNDP Peru; Laura Avellaneda from the Ministry of Environment; Percy Alvarado, Rafael Campos and Gustave Otárola of the National Institute for Civil Defence; and Sergio Álvarez of the National Centre for Disaster Risk Evaluation, Prevention and Reduction, for serving on the National Directive Committee for the project and for providing support at different levels, as well all the participants of the final review workshop for useful comments and feedback on various drafts of this report.

LIST OF ABBREVIATIONS AND ACRONYMS

BCPR	Bureau for Crisis Prevention and Recovery
BDP	Bureau for Development Policy
CENEPRED	National Centre for Disaster Risk Evaluation, Prevention and Reduction (Centro Nacional de Estimación, Prevención y Reducción del Riesgo de Desastres)
CEPLAN	National Centre for Strategic Planning (Centro Nacional de Planeamiento Estratégico)
CNCC	National Climate Change Council (Comisión Nacional de Cambio Climático)
CRiSTAL	Community-Based Risk Screening Tool – Adaptation and Livelihoods
CRM TASP	Climate Risk Management Technical Assistance Support Project
ENSO	El Niño Southern Oscillation
FAO	United Nations Food and Agriculture Organization
GDP	Gross Domestic Product
GRJ	Regional Government of Junín (Gobierno Regional Junín)
GRP	Regional Government of Piura (Gobierno Regional Piura)
HDI	Human Development Index
IISD	International Institute for Sustainable Development
INDECI	National Institute for Civil Defence (Instituto Nacional de Defensa Civil del Perú)
INEI	National Institute of Statistics and Information (Instituto Nacional de Estadística e Informática)
IPCC	Intergovernmental Panel on Climate Change
MINAM	Ministry of Environment (Ministerio del Ambiente)
PPP	purchasing power parity
SENAMHI	National Service of Meteorology and Hydrology of Peru (Servicio Nacional de Meteorología e Hidrología del Perú)
SINAGERD	National System for Disaster Risk Management (Sistema Nacional de Gestión del Riesgo de Desastres)
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNODC	United Nations Office on Drugs and Crime


EXECUTIVE SUMMARY

This report presents the main results of a climate risk and risk management capacity assessment for Peru, with a thematic focus on the agricultural sector in the regions of Junín and Piura, conducted as part of the Climate Risk Management Technical Assistance Support Project (CRM TASP) of the United Nations Development Programme (UNDP). The combination of scientific and participatory research streams, including literature reviews, community consultations, agroclimatic risk evaluation, policy and capacity assessments, provides a basis for identifying climate risks in the focus sector and regions and prioritizing measures to manage them. A range of national government agencies and consultants were involved in the research.

Peru is a middle-income country that has seen an economic boom over the last decade; however, it still faces enormous development challenges. A huge development gap exists between urban and rural areas, which is mirrored in regional differences between the coastal regions and the highland and Amazon regions. The national development strategy, 'Plan Bicentenario,' aims to reduce poverty; improve education, health, water and sanitation, and governmental effectiveness; increase growth, investment, formal employment and electricity production; reduce deforestation; and extend irrigation, among other things. Peru's agricultural sector is divided into modern, traditional, internal and subsistence-oriented subsectors. Land tenure is fragmented, while competitiveness, profits and investments are low. Barley, cassava, maize, potatoes, rice, wheat, asparagus, onions, grapes, mangoes, plantains, coffee and sugarcane are the most important crops in terms of cultivated area, production quantities and value. The Government aims to grow the sector by 7 percent a year, thereby reducing rural poverty and creating employment. Agriculture is also a key sector in both focus regions, Junín and Piura, employing about one-third of the population in both areas and producing a wide variety of crops across different climatic subregions.

Thanks to complex topography and a wide range of microclimates, the climate ranges from hot and dry on the Pacific coast to temperate in the Andean valleys, cold in the highlands, and hot and humid in the Amazon. Interannual climate variability in Peru is mainly driven by the El Niño Southern Oscillation (ENSO), as well as air movements and water temperatures in and over both the Pacific and Atlantic oceans. Key hazards induced by such phenomena include droughts, floods and frost, as well as cold and heat waves and strong winds. Temperatures have increased by 0.2° C per decade over the last 40 years in most of the territory. Average rainfall has increased on the coast and in the northern Andes and decreased in the northern Amazon. Glaciers are decreasing rapidly, and sea levels are probably rising. National climate projections for 2030 indicate warming trends of about 1.6° C for the northern Andes and Amazon, lower increments for the rest of the Andes, and no significant variation for the central and southern coast and the southern Amazon. For precipitation, reductions of 10 to 20 percent are projected for the Andes, and the coast and Amazon could see increases of similar magnitudes. Regional projections mostly confirm national trends, but inconsistencies and high uncertainties exist. For example, one set of projections for the Mantaro River Basin suggests that temperatures could drop by several degrees in summer. Peru has over 1,100 weather stations, but they are operated by different organizations, geographically concentrated and mostly manually read, and they often only measure rainfall. This limits the measurement of conditions and trends and makes predictions and projections more difficult. Due to Peru's complex topography, localized projections are particularly hard to make, but all the more important.

Every year droughts, frost, floods and landslides claim dozens of lives, affect tens of thousands of people and/or cause millions of dollars of damages, especially in the agricultural sector. El Niño events have had the worst economic effects in the past. Climate change could increase droughts and is likely to lead to more water scarcity because of rapidly decreasing glaciers. However, many other trends are uncertain due to insufficient understanding of complex local climates. Regional agroclimatic studies in the Mantaro and Piura river basins highlight the severity of impacts of El Niño events, droughts and frost on key crops, including maize, potatoes and fruits. The Piura study also suggests that climate change impacts over the next two decades will be varied and will not exceed those imposed by natural climate variability. However, over time, more and more crops will be moving away from optimal growth conditions in terms of temperatures and water availability. Local consultations suggest that while some communities can use sustainable coping strategies to deal with some of these impacts, overall they lack sufficient internal and external capacity to adapt to climate variability and change, not least because of poverty, environmental degradation, and a lack of adequate institutions and governance. The combination of hazards and vulnerability leads to significant climate risks not only for farmers, rural communities and the agricultural sector, but also for the achievement of general development goals, including poverty reduction; access to education, nutrition and water; irrigation and electricity; infrastructure improvements; and growth in agricultural earnings and exports.



SINAGERD is Peru's National System for Disaster Risk Management. Evaluation, prevention and risk reduction are managed by the National Centre for Disaster Risk Evaluation, Prevention and Reduction (CENEPRED), whereas disaster preparedness, response and recovery are the responsibility of the National Institute for Civil Defense (INDECI). The Ministry of Environment (MINAM) is responsible for climate change affairs and coordinates action through the National Committee on Climate Change and its sectoral subcommittees. Climate risks are recognized as a threat to development in national, sectoral and regional development plans, including in the two focus regions Junín and Piura, and in agriculture. Dozens of projects and initiatives to reduce climate risks at different scales are under way across the country and in a wide range of sectors. As a result, Peru has a good basis for integrated climate risk management, but important challenges remain in terms of more in-depth and coherent vulnerability and risk assessments, coordinated identification and prioritization of risk management options, formal coordination mechanisms between the disaster risk management and climate communities, and information collection, processing and accessibility.

To reduce climate risks in agriculture, we recommend efforts to improve agricultural practices, including through the revival of ancestral methods, water management and irrigation, access to markets and financial services, livelihood diversification, climate-proofing of local infrastructure, and the management of information and data on climate and vulnerability. Further research could expand the knowledge of climate risks in agriculture by means of deeper and more comprehensive studies on climate events and trends as well as on physical and socio-economic impacts and risk management options. New threats such as those related to glacial retreat should receive special attention. On the policy level, we recommend the coherent and thorough integration of the climate change adaptation and disaster risk management agendas and structures. The two themes should be fully integrated into sectoral and national strategies, and specific capacity development needs in different sectors and at the regional and local level should be addressed. A comprehensive climate risk management programme to holistically implement these recommendations should be established. While these efforts will be substantial, they will pay off quickly as they help sustain Peru's recent progress in economic and human development.

INTRODUCTION

Climate risk management is the systematic approach and practice of incorporating climate-related events, trends and projections into development decision-making to maximize benefits and minimize potential harm or losses. Climate change is altering the nature of climate risk, increasing uncertainty and forcing us to re-evaluate conventional climate risk management practices. Historical experience with climate hazards may no longer be a sound basis for evaluating risk: observable trends and longer-term, model-generated projections must also be taken into account if development is to be truly sustainable.

Recognizing this shifting reality, UNDP, through its Bureau for Crisis Prevention and Recovery as well as the Environment and Energy Group of its Bureau for Development Policy, designed the CRM TASP to assist countries in identifying climate-related risks and risk management priorities and capacity needs as a basis for policy, planning and programme development. The International Institute for Sustainable Development (IISD) was commissioned to implement the project in seven countries in Africa and the Latin America and Caribbean region, including Peru, in close collaboration with UNDP Country Offices, governments and other partners.

In each country, the main outputs of the project are the prioritization of climate-related risks, a focused risk assessment for a priority sector or area, and the identification of risk management options for that sector or area. This information provides an evidence base for examining the adequacy of the institutional and policy environment for implementing risk management solutions. The present report summarizes the main results of the research conducted in Peru, where the project stakeholders chose agriculture as the focus sector and the regions of Junín and Piura as case studies.

APPROACH AND METHODS

Three key principles guide the implementation of the CRM TASP in each country. First, the project builds on existing climate risk information and aims to fill critical knowledge gaps. Second, the main research phase focuses on one key sector, and potentially case study areas, in order to produce useful and concrete recommendations. Third, with a view to building capacity to identify, prioritize and manage climate risk, IISD works closely with in-country partners, which execute important parts of the research. These principles are put into practice in each country through a generic six-step implementation process (see table 1).

TABLE 1. PROJECT STEPS AND METHODS

PROJECT STEP	PURPOSE	METHODS USED IN PERU
1. Engagement	<ul style="list-style-type: none"> Raise awareness about CRM TASP. Secure country-level ownership and support for the process. 	<ul style="list-style-type: none"> Inception trip, meetings and discussions with key stakeholders.
2. Broad climate risk assessment	<ul style="list-style-type: none"> Understand and synthesize existing data and information on climate risk and risk management options. 	<ul style="list-style-type: none"> Literature review conducted by Torres et al. (2012).
3. Risk prioritization	<ul style="list-style-type: none"> Identify gaps and priorities for climate risk assessment and management, which can be addressed in a focused risk assessment. 	<ul style="list-style-type: none"> National inception workshop with key stakeholders; focus on agriculture in the regions of Junín and Piura determined.
4. Focused climate risk assessment	<ul style="list-style-type: none"> Understand the nature of climate risk for a specific priority sector/ecosystem/social group (agriculture in the regions of Junín and Piura, in the case of Peru). 	<ul style="list-style-type: none"> Agroclimatic risk studies in both regions (Trebejo and Avalos., 2011; Yauri Quispe, 2012). Community consultations based on the CRiSTAL tool (Davila, 2012).
5. Risk prioritization II	<ul style="list-style-type: none"> Identify and prioritize climate risk management options based on the more focused assessment. 	<ul style="list-style-type: none"> National workshop on integrating disaster risk and climate adaptation policy and institutions (MINAM et al., 2011). Regional workshops held by FAO on adaptation and risk reduction in agriculture. Policy and capacity analysis.
6. Reporting & dissemination	<ul style="list-style-type: none"> Elaborate and validate results. Secure country-level ownership of results. 	<ul style="list-style-type: none"> National revision workshop. Publication of final report.

In Peru, the focus areas and sector were chosen with key stakeholders such as INDECI, MINAM, the National Service for Meteorology and Hydrology (SENAMHI), UNDP and IISD during the national inception workshop held in October 2010 in Lima. In view of the project duration and budget and the large number of similar research projects, the stakeholders felt a focus on one or two regions of Peru could produce more useful and specific results than a nationwide study. The departments of Junín and Piura were selected as focus areas because of the combination of a good information base (for example, in terms of regional climate projections), high levels of vulnerability identified in previous studies, and the commitment of regional governments to addressing climate risk. It was suggested that the model applied in this study could later be applied to other regions.

The selection of the focus sector—agriculture—was largely the result of the decision to focus on the two selected regions. Agriculture is a key sector in both regions and is known to be highly vulnerable to climatic risks. Nevertheless, the current knowledge on these risks is rather limited. It was therefore decided that the combination of methodological approaches outlined below could make an important contribution to improving the basis for decision-making in this key sector.



Figure 1. Participants of a national policy workshop on integrating disaster risk management and climate change adaptation in Lima (reprinted with permission from MINAM et al., 2011)

Several research tasks were undertaken. Torres et al. (2012) conducted an initial synthesis study to provide general background on current and future climate risks and impacts. Yauri Quispe (2012) and Trebejo and Avalos (2011) of SENAMHI conducted agroclimatic studies in both focus regions, with a view to understanding climate hazards and vulnerabilities and the resulting risks for agriculture. As a complement, Davila (2012) conducted community consultations in Piura, and we then synthesized the results of similar previous consultations conducted by CARE (2011) in Junín for this report. These local insights provide a qualitative and bottom-up perspective on climate vulnerability and adaptive capacity. Policy and capacity analysis helped shed light on the current institutional structures for climate risk management. A national workshop in November 2011 looked specifically at how the current institutions could be improved, with a view to providing more coherent and effective climate risk management structures. Finally, regional workshops held by the United Nations Food and Agriculture Organization (FAO) in the context of elaborating a national strategy on disaster risk reduction and climate change adaptation for agriculture provided proposals on risk management options in Junín and Piura.

KEY CONCEPTS

In this report, 'climate risk' refers to the probability of harmful consequences or expected losses resulting from the interaction of climate hazards with vulnerable conditions (UNISDR, 2004). 'Climate hazard' refers to a potentially damaging hydrometeorological event or phenomenon that can be characterized by its location, intensity, frequency, duration and probability of occurrence. This report considers both events with an identifiable onset and termination, such as a storm, flood or drought, and more permanent changes, such as a trend or transition from one climatic state to another, as hazards (Lim et al., 2005).

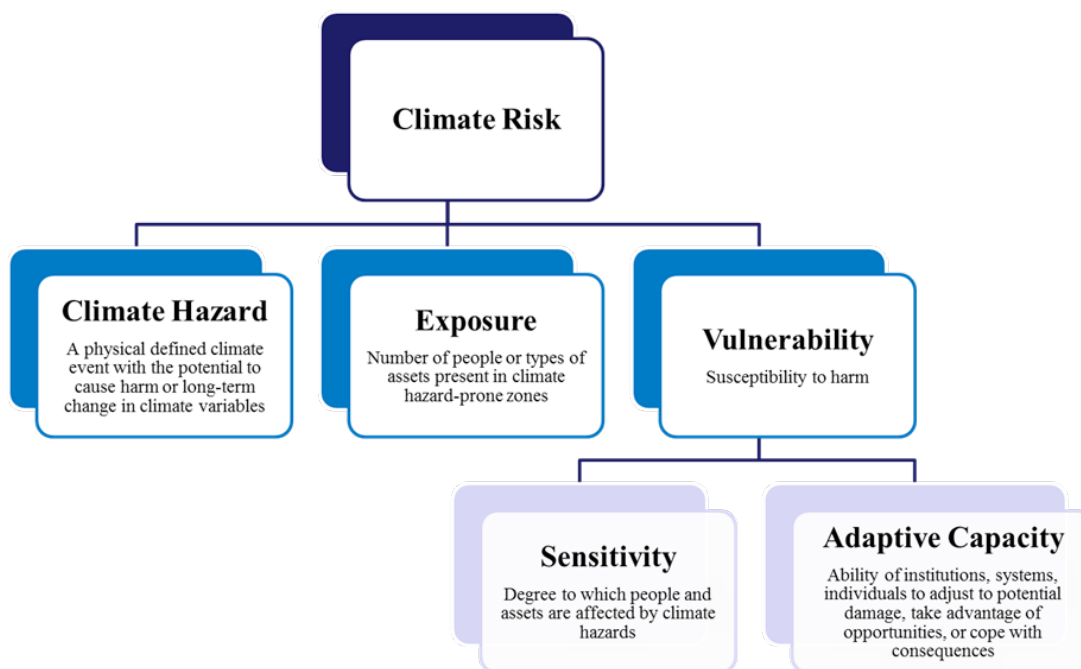


Figure 2. Components of climate risk

'Exposure' is a second element of climate risk. It refers to the presence of people and assets in areas where hazards may occur (Cardona et al., 2012). Finally, 'vulnerability' refers to the potential for a system to be harmed by something, and in the CRM TASP this 'something' is a climate hazard. When assessing vulnerability, we need to recognize the hazard specificity of people's vulnerability; indeed, the factors that make people vulnerable to earthquake are not necessarily the same as those that make people vulnerable to floods (UNDP 2004). We understand vulnerability to be a function of a system's sensitivity and its adaptive capacity, as depicted in Figure 2.

REPORT STRUCTURE

This report has six sections. After this introduction, 'Development Profile' (pp. 14–20) describes the current development conditions, trends and objectives, with a subsection on agriculture and specific attention to the regions of Junín and Piura. This sets the baseline against which climate risks can be assessed. 'Climate Profile' (pp. 21–28), covering climate conditions, variability and change, describes mainly the hazard side of the risk equation. Next, 'Climate Impacts and Risks' (pp. 29–37) provides both an overview for the country and a detailed analysis of climate impacts and risks for the agricultural sector, building on the primary research tasks described above. 'Institutions and Policies for Climate Risk Management' (pp. 38–41) looks at the institutions, policies and initiatives that currently exist to deal with climate impacts and risks. Finally, 'Recommendations for Climate Risk Management' (pp. 42–47) concludes with recommendations for actions to reduce the risk of negative impacts on agriculture, as well as for the changes to institutions and policies necessary to facilitate the implementation of such actions, and for further research.

DEVELOPMENT PROFILE

Although exposure and vulnerability are hazard-specific, the general developmental conditions of a country are a crucial driver of both. Settlement patterns determine who and what is located in or close to hazard-prone areas. Agriculture, for instance, is much more sensitive to climatic conditions than are many other sectors. Factors like incomes or social capital are key elements of adaptive capacity and can explain in part how well people can deal with climate hazards. This section lays the basis for the subsequent risk analysis by summarizing development conditions, trends and challenges, as well as the vision, objectives and priorities for future development. Agricultural conditions, trends and priorities and the regional situations in Piura and Junín are given particular attention.

NATIONAL AND REGIONAL DEVELOPMENT CONDITIONS, TRENDS AND CHALLENGES

Peru is in the western part of South America and is the third-largest country in the region. Its territory spans 1,285,216 km², bordered by Ecuador to the north, Colombia to the northeast, Brazil to the east, Bolivia and Chile to the southeast, and the Pacific Ocean to the west. Peru has 24 regions, which are located within its three natural regions (Pacific coast, Andean plateau and Amazon basin) (SENAMHI, 2009).



Figure 3. Map of Peru (reprinted with permission from United Nations, 2012a)¹

¹ The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Peru is home to an estimated 29.4 million people (UNDP, 2011). In 2007 the capital, Lima, was home to approximately 31 percent of the total population. Fifty-five percent of the country's people lived in the coastal region, 32 percent in the Andes and 14 percent in the Amazon (INEI, 2012). In 2011, an estimated 77.3 percent lived in cities. Recent population growth is estimated at 1.1 percent per year, so that by 2030 the total population is expected to surpass 35 million (UNDP, 2011).

Poverty and human development

Of the Peruvian population, 34.8 percent currently live under the national poverty line, more than in Brazil and Chile but less than in other neighbouring countries. The average income in purchasing power parity (PPP) terms in 2011 was US\$8,629, compared with US\$14,311 in Chile (UNDP, 2011). Poverty figures have dropped by about one-third since 2004, and extreme poverty was almost halved, from 17.1 percent in 2004 to 9.8 percent in 2010. Also in 2010, rural poverty stood at 54.2 percent, much higher than the urban rate of 19.1 percent. In line with this, almost half of the poor live in the Andes, more than one-third in the Amazon basin and only 17.7 percent on the coast (INEI, 2012).

Similarly to its neighbours, Peru has relatively high literacy and school enrolment rates. In 2011, 92.8 percent of all Peruvians were literate. Of children between 6 and 11 years old, 98.5 percent received primary education, and 92.4 percent of all children between 12 and 16 years of age attended secondary school in 2010, a number that has been increasing steadily since 2004 (INEI, 2012). However, only 34.5 percent of the country's population received tertiary education between 2001 and 2010, one of the lowest rates among its neighbours (UNDP, 2011). Furthermore, as is the case for poverty, most indicators are significantly worse in rural regions.

Despite recent improvements in health, Peru still has a high share of people without access to clean water and sanitation, as well as to health centres. The child mortality rate stands at 21 per 1,000 live births, and is higher than in Chile and Brazil. Maternal mortality stands at 98 in 100,000 live births (World Health Organization, 2012). Life expectancy was 74 years in 2011, surpassed in the region only by Chile and Ecuador. Medical assistance and insurance levels have improved recently (INEI, 2012).

Peru ranks 72 out of 146 countries on UNDP's Gender Equity Index. Only 57.6 percent of women over 25 years old have received secondary education, compared with 76.1 percent for men. One-third of students in tertiary education are female. In Congress, less than one-third of seats are held by women (UNDP, 2011). The United Nations Entity for Gender Equality and the Empowerment of Women (2011) reported that in 2011, Peru was among the top three countries in Latin America and the Caribbean where women reported having no say in their household.

UNDP's Human Development Index (HDI) summarizes the developmental state of countries by ranking them according to life expectancy, schooling and income. Peru currently ranks 80, just above Ecuador, Brazil and Colombia (see table 2).

TABLE 2. HUMAN DEVELOPMENT INDEX VALUES AND COMPONENTS FOR PERU AND NEIGHBOURING COUNTRIES (UNDP, 2011)

COUNTRY	HDI RANK (2011)	HDI VALUE (2011)	LIFE EXPECTANCY (YEARS, 2011)	MEDIAN YEARS OF SCHOOLING (2011)	EXPECTED YEARS OF SCHOOLING (2011)	GROSS NATIONAL INCOME PER CAPITA (CONSTANT 2005 PPP USD)
Bolivia	108	0.663	66.6	9.2	13.7	4,054
Brazil	84	0.718	73.5	7.2	13.8	10,162
Chile	44	0.805	79.1	9.7	14.7	13,329
Colombia	87	0.71	73.7	7.3	13.6	8,315
Ecuador	83	0.72	75.6	7.6	14	7,589
Peru	80	0.725	74	8.7	12.9	8,389
<i>South America (Average)</i>	<i>81.67</i>	<i>0.72</i>	<i>73.57</i>	<i>8.17</i>	<i>13.73</i>	<i>8,810</i>

Economy and politics

In 2010 the Peruvian Gross Domestic Product (GDP) was US\$157 billion at market exchange rates, making it the seventh-biggest economy in Latin America (World Bank, 2012). According to figures for 2007, services (excluding commerce) made up the largest share of GDP, at 42.4 percent. Other important sectors included manufacturing (17.3 percent), commercial services (16.2 percent), agriculture (9.3 percent), hydrocarbons and mining (6.5 percent) and construction (6.2 percent). Employment was also highest in non-commercial services (44 percent), while agriculture employed 22.6 percent of all economically active people, commerce 17.8 percent, and manufacturing 8.9 percent (CEPLAN, 2010, 2011).

The Peruvian economy has grown rapidly in recent years. Between 2006 and 2010, annual growth rates oscillated between 7.7 and 9.8 percent, with the sole exception being 2009, when the economy grew by only 0.9 percent, due to the global economic crisis (World Bank, 2011). As a result of this boom, construction has grown by 15.6 percent per year from 2005 to 2008. Commercial services, other services, manufacturing and agriculture also grew at high rates, while mining saw its highest growth rates between 1995 and 2005 (CEPLAN, 2010).

According to the United Nations Office on Drugs and Crime, Peru's homicide rate is among the lowest in South America. However, the country is one of the main suppliers of coca leaves, along with Bolivia and Colombia, and much of this production is linked to cocaine markets. In an effort to control coca production and trade, the Peruvian Government has reduced the amount of land under coca cultivation from 120,000 ha in 1989 to less than 60,000 ha in 2005. Terrorist attacks, common in the 1980s, have virtually ceased (UNODC, 2010; World Bank, 2011).

Environment

Environmental conservation remains a challenge. Peru lost 150,000 ha of forest per year between 1990 and 2000 (MINAG, 2008). According to MINAM (2010a), the major contributors to deforestation are cattle breeding and agricultural expansion. The country is also losing its glaciers. In the last 35 years, glacier surface decreased by 22 percent (Vargas, 2009).

Conditions in the focus regions of Junín and Piura

The two focus regions of the CRM TASP, Junín and Piura, are similar in size (44,197 km² and 35,892 km², respectively), and both cover multiple geographic and climatic regions. Piura is situated on the northern Pacific coast and reaches into the Andes and the Amazon. Junín lies in the middle of the country and also spreads from the lower highlands up into the Andes and down into the Amazon forest (see figure 3). Each region has one major river, the Mantaro in Junín and the Piura in Piura. Both are crucial for agriculture, mining, hydroelectricity and human consumption (MINAM, 2010a).

Junín was home to 1,273,000 people in 2007, of which 67.3 percent lived in urban areas and 34.3 percent remained below the poverty line, with 10 percent in extreme poverty (GRJ, 2011). Piura, on the other hand, counted 1,630,000 inhabitants in 2005, of which approximately 75 percent lived in urban areas.

NATIONAL AND REGIONAL DEVELOPMENT VISIONS, OBJECTIVES AND PRIORITIES

Peru's 'Plan Bicentenario' (CEPLAN, 2011) lays out a strategic vision for the year 2021 of a democratic, modern, decentralized, transparent, participatory, efficient, competitive and ethical state that is based on the rule of law, private investment, technological development, innovation and sustainable use of natural resources and pursues the eradication of poverty. Table 3 outlines the plan's strategic themes and objectives, as well as some sample indicators.

TABLE 3. STRATEGIC THEMES, OBJECTIVES AND SAMPLE PROGRESS INDICATORS OF THE 'PLAN BICENTENARIO' (CEPLAN, 2011)

STRATEGIC THEME		OBJECTIVES	SAMPLE INDICATORS (FOR 2021)
1.	Fundamental rights and dignity for all	Access to an efficient and autonomous justice system, to lead towards reduction in inequality and poverty.	<ul style="list-style-type: none"> • Reduce extreme poverty from 34.8% to 10%. • Increase female representation in high governmental positions from 26% to 50%.
2.	Opportunity and access to public services	Improved access to education, health, water, sewage, electricity, telecommunications, settlements and public safety.	<ul style="list-style-type: none"> • Increase average years of education from 11.4 to 13.5. • Decrease chronic child malnutrition from 18.3% to 5%.* • Increase water, sewage and electricity access from 68.6%, 53.3% and 74.1% to 85%, 79% and 95%, respectively.
3.	State and good governance	Transparency and efficiency within public administration; increased public participation in democratic processes; strengthened national, subnational and international cooperation; and investments in national security.	<ul style="list-style-type: none"> • Improve ranking in the World Bank's governmental effectiveness and regulatory quality index from 46.4 and 62.3 to 84.8 and 92.8, respectively. • Achieve parallel ranking with Latin America's leading countries in the corruption perception index. • Double the number of bilateral agreements, treaties, and memorandums of understanding a year. • Decrease coca leaf cultivation by one-third.
4.	Economy, competition and employment	Public and private investment in job creation and innovation to lead towards economic growth.	<ul style="list-style-type: none"> • Increase GDP per capita to US\$10,000. • Increase the investment rate to 24%. • Increase the percentage of wage earners in the economically active population from 42.7% to 60%.
5.	Regional development and infrastructure	Reduced inequality among regions through investments in economic infrastructure and adequate production.	<ul style="list-style-type: none"> • Invest US\$28 billion in infrastructure development for electricity generation and access.
6.	Natural resources and environment	Streamlined natural resource management throughout public administration.	<ul style="list-style-type: none"> • Halt deforestation by 2021. Increase total surface area under technical irrigation from 2% to 27%.

* The Ministry of Health proposes a goal of 16.7% for 2021.

Peru's objectives are largely in line with the United Nations' Millennium Development Goals (United Nations, 2012b). For example, Peru seeks to improve its social indicators by decreasing poverty to 10 percent and extreme poverty to 5 percent and by increasing the quality of education so that 70 percent of second graders have a good comprehension of reading and mathematics. Furthermore, in its health sector it aims to lower child mortality rates to 15 for every 1,000 live births and maternal mortality to 46 for every 100,000 live births; decrease child chronic malnutrition to 16.7 percent; establish universal health care; and improve access to drinking water, drainage and electrical services to 85 percent, 79 percent and 95 percent, respectively. In terms of environmental goals, it seeks to place 75 percent of its tropical forest under public resource management, eradicate deforestation in the Amazon region and mainstream resource management in its development strategies.

Regional development strategies

The Regional Government of Junín (GRJ, 2011) has outlined several short-term development goals to be reached by 2014, and a medium-term vision for 2021 with four pillars: social, economic, environmental and institutional. The regional government seeks to achieve economic growth that promotes social inclusion and human development. Its objectives include improving social conditions so as to reduce poverty to 40 percent by 2015; investing 0.012 percent of regional GDP in infrastructure in order to increase economic production; promoting natural resource management, including reducing vulnerability to natural hazards in 11 districts; and strengthening the decentralization process to maximize efficiency and effectiveness levels (11 public institutions will benefit from this process by 2015).

The Regional Government of Piura (GRP, 2007) in its 2007 'Plan Bicentenario,' set similar objectives, to be achieved by 2011. It seeks to streamline decentralization and place social justice and inclusion within its development goals. By taking advantage of its well-endowed natural resources, the regional government seeks to promote agricultural and fishing exports as well as tourism. In addition, it seeks to strengthen competitiveness, promote job creation and increase income generation in the region. The Regional Government of Piura highlights the importance of private-public partnerships in promoting its strategic pillars, namely natural resource management, capacity development, good governance, economic development and social development.

THE AGRICULTURAL SECTOR

Six percent, or 7.6 million ha, of Peru's total territory is used for agriculture. Most of the agricultural activity takes place in the Andes and the Amazon. In contrast, the coast has less dedicated land for agriculture, but has good transportation and production infrastructure, and it has the highest levels of production mostly destined for exports. Land holdings in Peru are fragmented because of the country's topography. Approximately 84 percent of agricultural lands are in parcels of 10 ha or less, which account for approximately 50 percent of Peru's land tenures (MINAG, 2008).

Agriculture contributed 9.3 percent of GDP in 2007 and employed 22.6 percent of the economically active population (CEPLAN, 2010; 2011). The share of the rural population involved in agriculture is much higher. The World Bank (2012) estimates the share at 50 percent for 2008. The same sources estimate that 7 percent of all exports were agricultural goods. The agricultural sector has had an average growth of 4.2 percent between 2001 and 2010 (Banco Central de Reserva del Perú, 2012). Total agricultural exports earned the country US\$2.6 billion in foreign exchange earnings in 2009 (FAO, 2012b). Coffee, asparagus, chillies and fruits have contributed the largest shares of export revenue (FAO, 2012a). Table 4 shows the harvested area, production and estimated production value for selected key crops.

TABLE 4. HARVESTED AREA, PRODUCTION AND VALUE FOR SELECTED KEY CROPS IN PERU, 2010 (SOURCE: FAO, 2012A)

CROP	HARVESTED AREA (HA)	PRODUCTION (T)	VALUE (1,000 USD)*
Asparagus	30,896	335,209	238,334
Barley	154,005	216,193	67,517
Cassava	105,408	1,240,120	177,213
Coffee, green	349,633	264,605	474,701
Grapes	15,000	280,468	162,139
Maize (all types)	543,748	1,949,381	751,608
Mangoes, mangosteens, guavas	25,230	454,330	129,802
Plantains	156,114	2,007,280	280,016
Onions (dry)	21,568	724,042	211,710
Potatoes	289,873	3,814,370	836,491
Rice (paddy)	288,659	2,831,370	648,950
Sugar cane	76,983	9,660,900	195,150
Wheat	154,285	219,454	83,853

**This value has been estimated by multiplying production quantities by 2009 prices per ton.*

Livestock production in 2007 was dominated by poultry (41 percent) and cattle (31 percent). Pork contributed 7 percent, and camelidos 2 percent (MINAG, 2008).

Based on the different technological and infrastructure levels and access to credit and markets, Peru's agriculture sector can be categorized into four subsectors: modern, traditional, internal market production and subsistence agriculture. Table 5 describes the key features of each subsector.

TABLE 5. AGRICULTURAL SUBSECTORS (INFORMATION FROM MINAG, 2008; INSTITUTO NACIONAL DE INNOVACIÓN AGRARIA, 2012)

AGRICULTURAL SUBSECTOR	SIZE, LOCATION AND OWNERSHIP	CROPS AND LIVESTOCK	OTHER FEATURES
Modern	Approximately 45,000 ha, primarily on the coast; medium-sized land owners and agroindustries	Asparagus, paprika, citrus fruits, artichokes, mangoes, poultry, pork	Crops mainly for exports; livestock for internal markets; modern technology
Traditional	1.2 million ha across the country; small land owners	Rice, cotton, sugar cane, maize, coffee, potatoes, cattle	Lack of appropriate technology; dependency on middlemen for credit and market access
Internal market production	Mainly in the Andean and Amazon regions	Vegetables, quinoa, kichiwa, tara, camu-camu, pijuayo, palm heart, sacha inchi, medicinal and aromatic plants, guinea pigs	Heavy dependency on governmental support for technology
Subsistence	Only about 400 families, in extreme poverty, on marginal lands of approximately 0.5 ha on average	Various	Income generation depends on other activities and on public support

The development of the sector is low compared with other countries such as Colombia and Chile, which have had better export growth rates (Instituto Nacional de Innovación Agraria, 2012). According to the Ministry of Agriculture (2008), this is because the high share of small landholdings prevents the exploitation of economies of scale and the introduction of new technologies such as efficient harvesting and irrigation. Public and private investment in agriculture is generally low in Peru. As a result, the sector is uncompetitive, and yields and profits are low. Other issues relate to unsustainable use of natural resources, including land, water and forests, in particular by large agroindustries.

Agriculture in the focus regions

Agriculture contributed 8.3 percent to Junín's GDP in 2006 (Agrojunin, 2008). Thirty-six percent of the region's population was involved in agriculture in 2010, down from 49.6 percent in 2006. Regional agricultural production was worth about US\$390 million in 2011 (INEI, 2012). Major crops in the region include potatoes, vegetables, grains, cereals, cattle ranching and coffee. In the highlands, wheat, barley, maca and cattle ranching dominate, while in the Amazon basin key crops include citrus, coffee and other fruits (Agrojunin, 2008). Rain-fed agriculture makes up 88.4 percent of the area (GRJ, 2008). Livestock production in the region includes cattle, fish farming, guinea pigs and snails. The Mantaro River basin is the largest in central Peru and is of major importance for the agriculture sector in Junín. Current research and development in the region is promoting crops such as potatoes, artichokes, maca, aromatic herbs and native fruits of the jungle, for industry and commercial use (Agrojunin, 2008).

In Piura, agriculture contributed 12 percent to GDP in 2005, while fishing and aquaculture added another 3 percent (GRP, 2007). There, 31.7 percent of the population was actively involved in agriculture in 2010 (INEI, 2012). Most agricultural production takes place along the coast (Consejo Nacional del Ambiente, 2001). The main crops in Piura include rice, plantains, cotton, mangoes, limes, corn, coffee, bananas and cocoa (Banco Central de Reserva del Perú, 2012; INEI, 2012). Total production was worth about US\$254 million in 2011 (INEI, 2012). The regional government identifies high poverty rates, the lack of territorial planning, negative impacts from mining activities, deficient road networks, and climate hazards as obstacles to agricultural development. It aims to boost production of mangoes and organic bananas, as well as cotton, cocoa and tamarind (GRP, 2007).

Government objectives for agriculture

The Ministry of Agriculture seeks to turn Peru into the leading agricultural country on South America's Pacific coast by 2015, taking into account sustainable natural resource management, competitiveness and equity as well as modernization and decentralization. It hopes to boost rural development. Specific strategic goals include: generating US\$12 million in GDP, growing the agricultural

sector by 7 percent per year, generating US\$4.5 million in export earnings, creating 400,000 new jobs directly in agriculture and another 200,000 through indirect effects, making accessible some US\$2,370 million for investments, and reducing rural poverty by 35 percent. Specific strategic themes relate to water supply management, market access, agricultural information, financial services and insurance for small farmers, agrarian innovation, and rural development (MINAG, 2008).

Key messages: Development profile

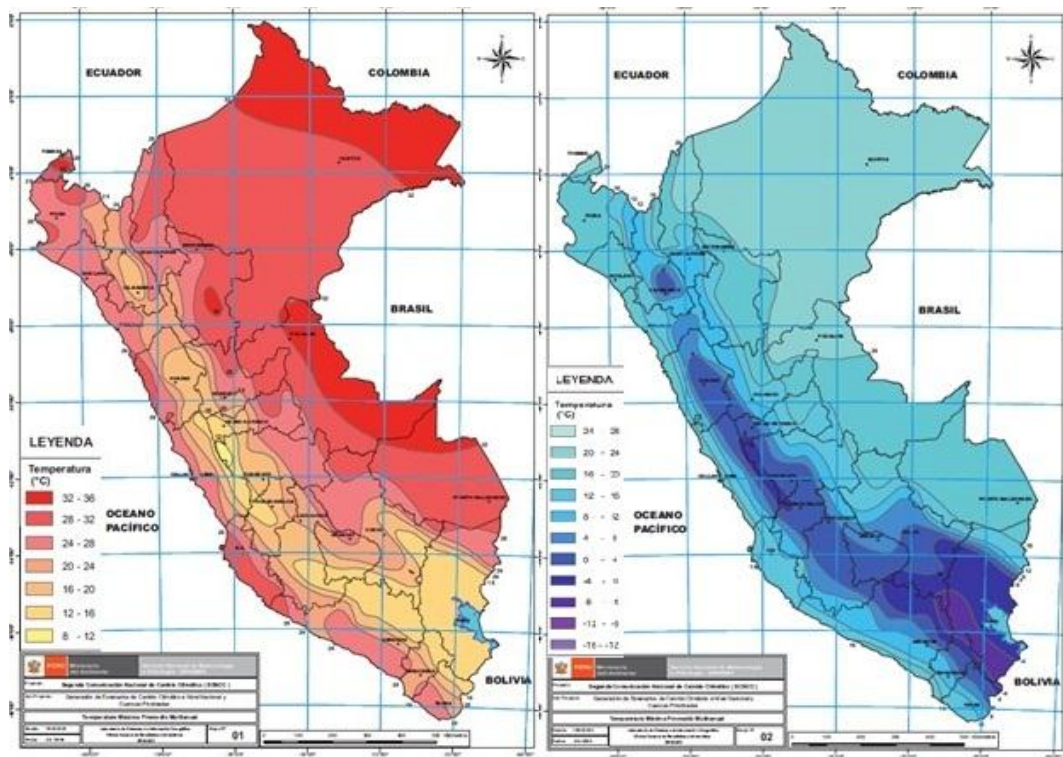
- Peru is a middle-income country and has seen an economic boom over the last decade, which has been fuelled by various sectors, including construction, services, manufacturing, agriculture and mining. However, it still faces enormous development challenges, and there is a huge gap between the urban and the rural areas, which is mirrored in regional differences between the coastal regions and the highland and Amazon regions.
- The national development strategy, 'Plan Bicentenario,' lays out a vision for a democratic, modern, decentralized, transparent, participatory, efficient, competitive and ethical state that is based on the rule of law, private investment, technological development, innovation and sustainable use of natural resources and pursues the eradication of poverty.
- Peru's agricultural sector is divided into modern, traditional, internal and subsistence-oriented subsectors. Land tenure is fragmented, and competitiveness, profits and investments are low. Barley, cassava, maize, potatoes, rice, wheat, asparagus, onions, grapes, mangoes, plantains, coffee and sugar cane are the most important crops in terms of cultivated area, production quantities and value.
- The Peruvian Government aims to grow the agricultural sector by 7 percent a year, thereby reducing rural poverty and creating employment.
- Agriculture is a key sector in both focus regions, Junín and Piura, giving employment to about a third of the population in both areas and producing a wide variety of crops across different climatic subregions.

CLIMATE PROFILE

Because of its complex topography, Peru hosts a wide variety of climates, ranging from hot and dry on the Pacific coast to temperate in the Andean valleys, cold in the highlands, and hot and humid in the Amazon. Maximum temperatures average up to 36° C in the Amazon and on the coast, and up to 24° C in the highlands. Minimum average values are around 20° C in the low areas and can be as low as –12° C in the Andes. Rainfall varies widely, too. Most of the coast accumulates less than 200 mm annually, and in some areas almost no rain falls at all. On the other hand, the Amazon receives abundant precipitation of up to 2,800 mm per year on average (Sistema Nacional de Defensa Civil, 2003). The rainy season typically lasts from September to April.

The regional climates of the two focus areas of this report reflect the same diversity. Average annual maximum temperatures in Piura are around 31° C in the lower watershed and drop to 14.7° C on the Andean plateau. Average minima range from 19.5° C down to 6.7° C. Rainfall is low on the coast, but reaches 600 to 1,100 mm in the highlands (Yauri Quispe, 2012). The region of Junín also encompasses a range of microclimates, as the area spans from the Pacific slope to the Andes and the Amazon. In the Mantaro Valley, around the regional capital, Huancayo, mean temperatures oscillate between 4° C and 19.5° C throughout the year, and annual average rainfall is about 680 mm (Trebejo and Avalos, 2011).

The following maps show average maximum and minimum temperatures as well as rainfall quantities across Peru.



Figures 4 and 5. Annual average maximum and minimum temperatures (reprinted with permission from SENAMHI, 2009)

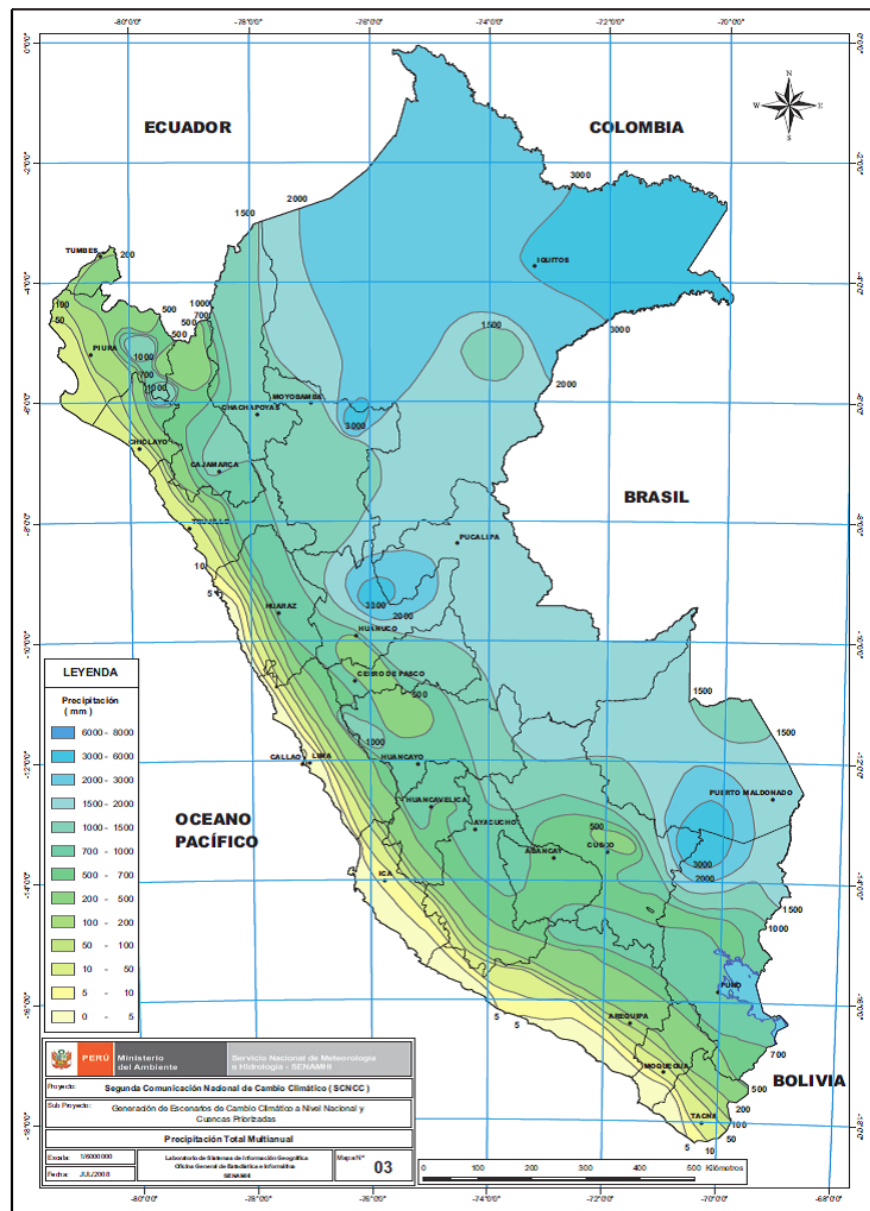


Figure 6. Annual average rainfall (reprinted with permission from SENAMHI, 2009)

CURRENT CLIMATE VARIABILITY AND EXTREMES

Important deviations from the average climate have been observed in Peru, including in the form of climate hazards such as droughts, cold spells and floods.

Typical intra-annual climate patterns involving significant variation in temperatures and rainfall are observed in all areas of Peru. In the Mantaro Valley, the highest maximum temperatures occur in November, and the lowest minimum temperatures in June and July (Trebejo and Avalos, 2011). In Piura, on the other hand, the highest temperatures are observed in February and August, and the lowest in August and November for the lower and higher areas, respectively (Yauri Quispe, 2012). The range between the lowest and highest monthly values for minimum and maximum temperatures reaches 7° C in some areas. As for the national level, most precipitation falls between September and April in Piura and Junín.

Interannual climate variability in Peru has largely been driven by the El Niño Southern Oscillation (ENSO), a climate pattern characterized by changes in ocean surface temperatures and pressure in the tropical eastern Pacific. Warm deviations are called El Niño, and cold deviations are called La Niña. ENSO periods occur every three to eight years. The most intense phase typically lasts about one year. During strong El Niño events, the ocean off the Peruvian coast heats up by several degrees, and the sea level rises as warmer water expands. Temperatures and precipitation increase on the coast, while dry air over the Andes prevents wet air from reaching the highlands, thus provoking droughts in the mountains. La Niña events, on the other hand, lead to approximately inverse conditions, especially in terms of temperatures. La Niña phases occur between El Niño events (SENAMHI, 2005). Some climate events are also linked to other regional and global climate phenomena, including air movements and water temperatures over both the Atlantic and Pacific oceans (Trebejo and Avalos, 2011; Sanabria, 2011).

In meteorological terms, drought relates to an abnormal lack of rainfall over a given period, which can translate into hydrological drought, i.e. low water levels and flows, for example in rivers. El Niño appears to be the main driver of droughts, typically influencing the southern and central highlands as well as, to some extent, the Amazon (MINAM, 2010a). Droughts can also be brought about by anti-cyclonic movements over the western Pacific in the case of the Mantaro Valley, and by abnormally warm temperatures in the Atlantic Ocean in the case of the Amazon basin. In agricultural terms, drought relates to a lack of humidity in soils. Avellaneda Huamán et al. (2006) elaborated figure 7 based on precipitation and evapotranspiration to visualize areas with water deficits, which are particularly prone to drought.



Figure 7. Areas prone to agricultural drought (reprinted with permission from Avellaneda Huamán et al., 2006)

Floods and flood-related landslides usually occur in the rainy season, mostly between November and April. They tend to occur particularly along major rivers and lakes. Due to increased sedimentation, the amount of rainfall needed to cause inundations has decreased. During El Niño years, the probability of floods in northern areas increases (Avellaneda Huamán et al., 2006). In La Niña years, increasing run-off has been observed in watersheds across the country (Sanabria, 2011).

Avellaneda Huamán et al. (2006) define “frost” as a period during which the temperature remains below 0° C. Since soils tend to be colder than the air at the height of weather stations, measured temperatures of up to 1° C to 3° C can coincide with frost conditions for agriculture. Frost is a regular phenomenon in the highlands, particularly in the southern half of the country (Avellaneda Huamán et al., 2006). As figure 8 shows, the observed number of frost days per year (vertical axis) is closely related to altitude above sea level (horizontal axis): below 2,500 m, there are almost no frost days, while at 4,500 m, frost becomes nearly permanent.

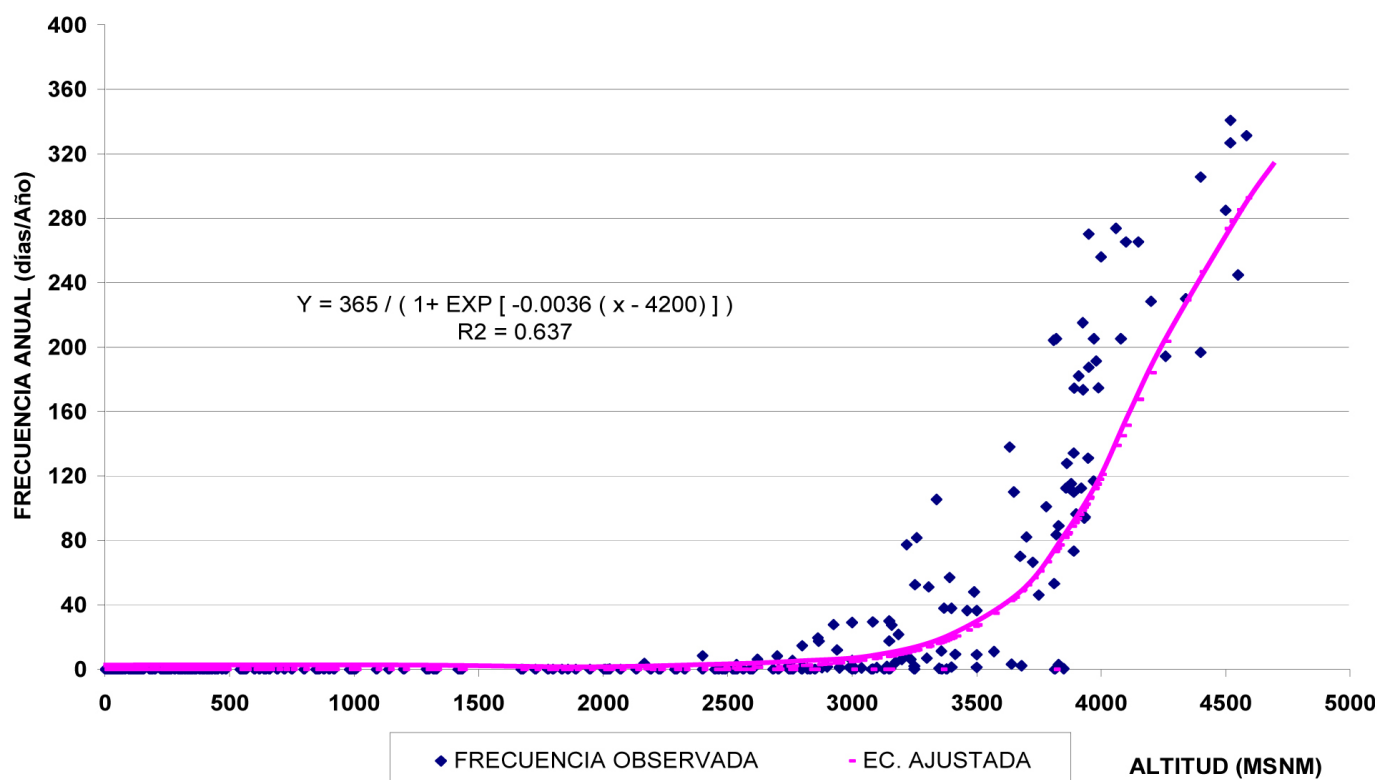


Figure 8. Number of frost days at different altitudes. The x-axis represents altitude, and the y-axis represents number of days per year. (Reprinted with permission from Huamani 2007)

In addition to frost, waves of dry and cold polar winds blow from west to east during the winter months, particularly in July, causing temperatures to drop to 15° C in the Peruvian Amazon, and also cooling the southern mountain slopes. While such cold waves occur every year, high-intensity events only occur every four to six years. On the other hand, heat waves have been observed on Peru’s northern coast, sometimes but not always in the context of El Niño events. The entire coast is also subject to strong polar winds from the south in the winter months (Sanabria, 2011). Finally, various types of air-mass movements occur in Peru. They have different names, such as *huaycos* and *aluviones*, depending on which type of material they consist of. Air-mass movements occur mainly in hilly and mountainous territory, often in the context of heavy rains (Avellaneda Huamán et al., 2006).

OBSERVABLE CHANGES IN CLIMATE

A temperature increase of 0.2° C per decade has been observed over the four decades from 1965 to 2006 over most of the Peruvian territory (SENAMHI, 2009). There are also a few instances of observed temperature reductions. For example, minimum temperatures in parts of the central Mantaro River basin have decreased (Trebejo and Avalos, 2011). Nevertheless, the general warming trend is unequivocal.

Rainfall trends, however, are more varied. On the coast and in the northern Andes, significant increases in annual average precipitation have been observed (SENAMHI, 2009). In the medium and upper Piura river basin, for example, annual rainfall has increased by 10 to 19 percent between the 1971–2000 and 2001–2010 periods. Most of this increase accumulates in summer and autumn (Yauri Quispe, 2012). Rainfall averages have decreased, however, in the northern Amazon. In other regions, no consistent precipitation changes have been observed (SENAMHI, 2009), although individual stations still measure important variations. For example, two weather stations in the Mantaro River basin, in the central region of Junín, report rainfall reductions of 23 mm and 27 mm per decade from 1971 to 2010. Most of this change has been concentrated in the summer months (Trebejo and Avalos, 2011).

Climate variability is changing, too. Rainfall intensity is reported to have increased on the coast and in the northern Andes, and decreased in the central highlands. The number of cold days and nights is generally diminishing, but frost days are increasing in some parts and decreasing in others. No trend has been identified for droughts (SENAMHI, 2009).

Peru has experienced a rapid decline in glacier volume since measurements began in 1860. Over the past 35 years alone, the surface area has decreased by 22 percent, which is equivalent to a retreat of 20 m per year (Vargas, 2009). The surface of glaciers in the Huaytapallana mountain range, a key source of water for the Mantaro River basin, has decreased by almost 60 percent between 1976 and 2006 (Instituto Geofísico del Perú, 2010). Sea levels have been rising in South America over the last century by at least 1 mm per year, with rates probably increasing in recent decades (Magrin et al., 2007). SENAMHI (2005) reports measurements for three sites in Peru that confirm the increasing trend. However, climate variability, mostly related to El Niño, has largely overshadowed the long-term trend. For example, observations for the station of Paita, in the Piura region, show short-term fluctuations with a range of over 40 cm. The strong El Niño event of 1998 alone caused sea levels to rise by around 30 cm, a value that exceeds the estimated annualized long-term increase at the Paita station by a factor of more than 10.

PROJECTED CLIMATE TRENDS

SENAMHI (2009) presented national and subnational climate scenarios using different time horizons, climate models and the A1, A2 and B2 emissions scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC).² Recent national projections for the average climate from 2025 to 2035 are based on the A2 scenario and use the Climatic Community System Model along with the Regional Atmospheric Modelling System. According to these projections, temperatures will increase by around 1.6° C in the northern Andean highlands and the Amazon in comparison with the 1971–2000 baseline period. The rest of the Andes are expected to experience a more moderate temperature rise, while not much variation from the current climate is expected for much of the coast and the southern Amazon. On the northern coast and in the Amazon, warming is most pronounced in spring, whereas in the Andes, the highest increments are expected for fall. Figure 9 shows the projected increases in maximum temperatures by 2030. For precipitation, reductions of 10 to 20 percent are projected for the Andes, and the coast and Amazon could see increases of similar magnitude.

² As per the IPCC's 2001 'Special Report on Emissions Scenarios,' the B2 scenarios assume some degree of emissions mitigation through more efficient energy use and better-positioned solutions. The outcome of these processes would be lower generation, and therefore concentrations, of atmospheric greenhouse gas emissions. The A1 scenario family is based on rapid economic growth but also on the fast introduction of clean technologies. This leads to initially higher emissions, but rapid decline in the second half of the 21st Century. The A2 scenario assumes that economic growth will be slower, globalization lower and population growth steadily high. The outcome of this scenario is the generation of atmospheric greenhouse gas concentrations that far exceed current levels (United Nations Economic Commission for Latin America and the Caribbean, 2010).

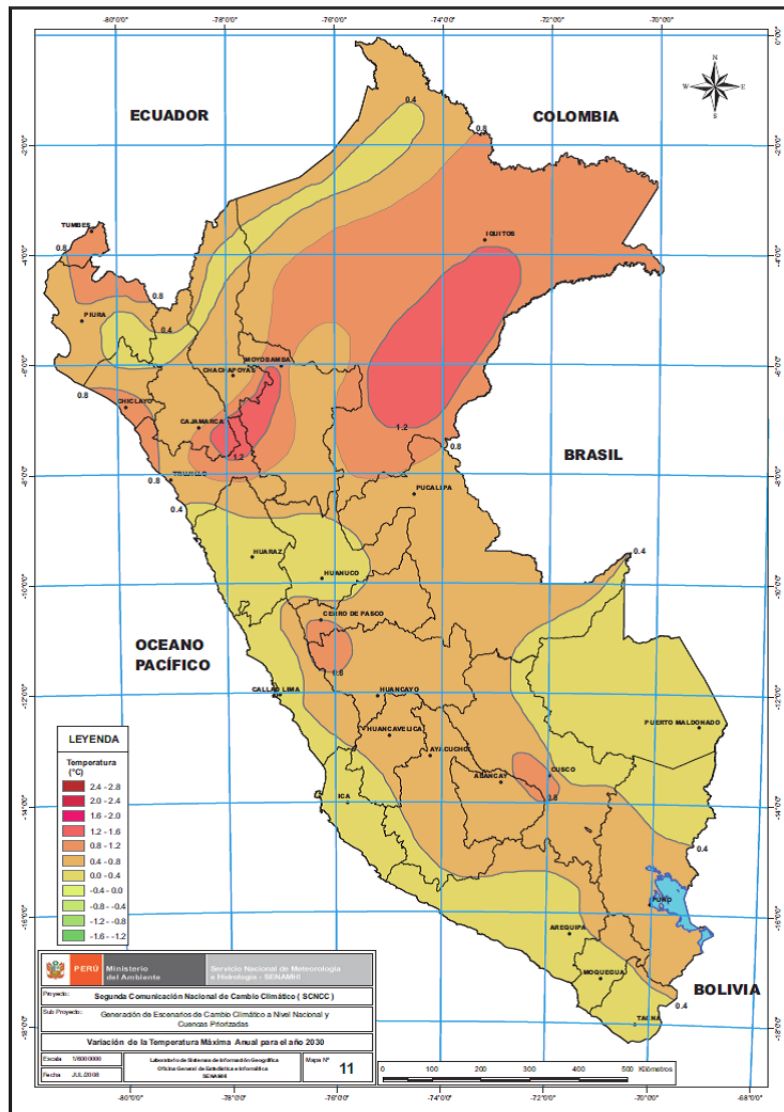


Figure 9. Projected increase in maximum temperature by 2030 (reprinted with permission from SENAMHI, 2009)

In addition to national scenarios, SENAMHI developed regional projections for a number of watersheds, including the Piura and Mantaro rivers (MINAM, 2010a). For Piura, IPCC scenarios A2 and B2 were applied, using downscaled rainfall projections from the above-mentioned models that were used at the national scale, along with temperature projections from the global circulation models ECHAM4, CCSM, CCSR/NIES and CCCma. For the period from 2030 to 2040, maximum temperatures could change between -0.1°C and $+2^{\circ}\text{C}$ compared with the period from 1990 to 2005. Minimum temperatures are expected to increase, but within a smaller range. Precipitation could increase in the entire basin. In the lower basin, the increment is expected to accrue solely during the winter season.

For the Mantaro River basin, in the Junín region, SENAMHI elaborated two scenarios for two time horizons. The first set looks at the 2045 to 2055 period, takes the 1990s as a baseline, and uses IPCC's A1 and B2 scenarios along with the CCSM2 and RegCM2 climate models. Its results are surprising, as they project a reduction in maximum temperatures on the order of 3°C for the summer

months (January to March), with reductions of up to 5° C for the western part of the valley. Minimum temperatures could decrease by 4° C in the western part and increase slightly on the eastern side of the basin, also from January to March. No results for other months are presented. For rainfall, results are reported for the September to April season. They project changes ranging from –20 to +100 percent for different emission scenarios and areas of the watershed. The second set develops projections for the end of the 21st Century, using climate data from 1971 to 2000 as a baseline and applying the A1B scenario with the MRI/JMA_TL959L60 climate model. These projections predict an increase in temperatures of 3° C to 3.5° C in the north of the basin, and 2.3° C to 3.4° C in the centre and south. Increases in minimum temperatures are slightly lower. Expected rainfall changes are largely in the range of +/-10%, except for a possible 35 percent reduction in the high altitudes in the winter months (MINAM, 2010a).

No national projections for sea level rise are available, but McSweeney et al. (2009) apply a regional adjustment for South America to the global projections by Meehl et al. (2007), and they expect a 0.18 m to 0.43 m increase by the 2090s according to the most optimistic scenarios, and 0.23 m to 0.56 m for the A2 scenario. Projections for Peru for the year 2050 are in the range of 0.15 m to 0.21 m (SENAMHI, 2005). Rapid glacial retreat in the Andes is certain to continue. According to MINAM (2010a), glaciers situated below 5,500 metres above sea level are expected to disappear in coming years. Between 2170 and 2250, glaciers in Peru could disappear altogether.

Regional projections suggest that the frequency of extreme events in the region will increase (Magrin et al. (2007). For example, the number of consecutive dry days may increase in most areas of South America. However, national projections for Peru say that extreme rainfall could decrease (MINAM, 2010a). No clear link between anthropogenic climate change and ENSO has been established. Changes have been observed in the intensity of El Niño events and the location of the surface temperature abnormality since 1970, but these changes have not been conclusively linked to human-induced global warming (Trenberth and Hoar, 1997; Lee and McPhaden, 2010; McPhaden et al., 2011).

STATUS OF CLIMATE AND HAZARD INFORMATION

Peruvian decision-makers can rely on a wealth of climate data and information. As this section shows, there are numerous studies, maps and data sources on current conditions, climate hazards, observed trends and projections at both national and subnational levels. Nevertheless, shortcomings exist. Although Peru has over 1,100 weather stations, with much data reaching back five decades or more, they are managed by different entities, and the information is not collected centrally. SENAMHI manages 781 stations, and 388 others are independently managed. The geographic distribution of stations is skewed towards the coast and the highlands, whereas the Amazon region has low coverage. Most measurements are taken manually, reducing the reliability and continuity of data. Also, many stations only measure rainfall. Given Peru's complex topography and many microclimates, these shortcomings place significant limitations on the ability to measure climate conditions and feed prediction mechanisms, including early-warning systems.

It is also more difficult to measure trends and to make projections for the future climate, as these depend on a solid basis of past climate data. In addition, such future projections are limited by the current inability of global circulation models to depict hydrological cycles at regional scales (Magrin et al., 2007). Regional climate models, on the other hand, have not been used extensively in South America, as they are still being tested and developed. Furthermore, even if broad regional trends can be projected with some certainty, the local climate may differ markedly from regional averages. This is especially true for mountain areas, where changes in atmospheric circulation can induce large variability at the local scale (Christensen et al., 2007). This can result in inconsistencies such as those observed between different projections for the Mantaro River basin reported above, as well as generally large uncertainty ranges, especially for rainfall and extreme events.

Key messages: Climate profile

- Peru has a complex topography and a wide range of microclimates, ranging from hot and dry on the Pacific coast to temperate in the Andean valleys, cold in the highlands, and hot and humid in the Amazon.
- Interannual climate variability in Peru is mainly driven by ENSO, as well as air movements and water temperatures in and over both the Pacific and Atlantic oceans. Key hazards induced by such phenomena include droughts, floods and frost, as well as cold and heat waves and strong winds.
- Temperatures have increased by 0.2° C per decade over the last 40 years in most of the territory. Average rainfall has increased on the coast and in the northern Andes and decreased in the northern Amazon. Glaciers are decreasing rapidly, and sea levels are probably rising.
- Climate projections suggest that most of these trends will continue in the coming decades. By 2030 the northern Andes and Amazon could warm by another 1.6° C. Projected increments are lower for the rest of the Andes, and no significant variation is expected for the central and southern coast and the southern Amazon. For precipitation, reductions of 10 to 20 percent are projected for the Andes, and the coast and Amazon could see increases of similar magnitude.
- Regional projections mostly confirm national trends, but inconsistencies and high uncertainties exist. For example, one set of projections for the Mantaro River basin suggests that temperatures could drop by several degrees in summer.
- Peru has over 1,100 weather stations, but they are operated by different organizations, geographically concentrated and mostly manually read, and they often only measure rainfall. This limits the measurement of conditions and trends and makes predictions and projections more difficult. Due to Peru's complex topography, localized projections are particularly hard to make—but all the more important.

CLIMATE IMPACTS AND RISKS

Peru only ranks 62 in Germanwatch's global climate risk index (Harmeling, 2011), down from 47 a year earlier. Nevertheless, the statistics show that extreme weather has had severe impacts on lives and livelihoods. According to records for the period from 1991 to 2010, every year an average of 93.75 people were killed and economic assets worth US\$154 million in purchasing power parity terms were destroyed. The major threats are droughts, floods, landslides and frosts. All except the last of these are often related to the ENSO phenomenon.

Table 6 presents records of human and economic impacts of some of the major climate disasters that have occurred in Peru over the last two decades. These numbers are incomplete, especially for slow-onset disasters such as droughts, and sometimes contradict information from other databases. Information on economic impacts is almost nonexistent in the database. Detailed information about impacts on specific sectors, such as agriculture, or on regions, is hard to come by except for some individual events. Trends cannot be identified with certainty because record-keeping has most probably improved. Nevertheless, the records make for impressive evidence of the frequency and magnitude of climate impacts. Every year several disasters hit, with dozens of casualties, tens of thousands of affected people and, to the extent that they have been recorded, millions of dollars of damages.

TABLE 6. RECORDED IMPACTS OF MAJOR CLIMATE DISASTERS IN PERU (CRED, 2011)

EVENT	YEAR	KILLED	AFFECTED	ECONOMIC DAMAGES (MILLION USD)
Flood	1992	-	30,000	
Drought	1992	-	1,100,000	250
Flood	1993	80	219,000	-
Floods (2 events)	1994	88	101,130	50
Landslide	1995	20	-	-
Landslide	1997	300	30,000	-
Landslides (2 events)	1998	45	2,607	-
Floods (2 events)	1999	74	491,200	-
Landslide	1999	40	1,200	-
Flood	2000	22	50	-
Landslide	2000	11	-	-
Floods (3 events)	2001	15	66,310	-
Landslide	2001	20	150	
Flood	2002	13	2,169	-
Drought	2002	-	21,500	-
Flood	2003	18	60,012	-
Cold wave	2003	339	1,839,888	-
Landslide	2004	11	76	-
Cold wave	2004	90	2,137,467	-
Flood	2006	-	15,325	-
Flood	2007	17	47,714	-
Cold wave	2007	67	884,572	-
Flood	2008	40	450,012	-
Cold wave	2009	274	24,262	-
Floods (2 events)	2009/10	178	316,308	-
Landslides (4 events)	2009	145	1,315	-
Landslide	2010	68	1,054	-
Cold waves (2 events)	2011	409	71,000	-

The disaster statistics displayed above do not contain much information about economic damages. Yet it is generally acknowledged that the worst impacts in economic terms have occurred during extreme phases of the ENSO phenomenon, which have manifested themselves through hazards such as droughts, floods and landslides as well as higher ocean temperatures. In the recent past, the worst episodes occurred in 1982–1983 and 1997–1998. Economic damages associated with ENSO-related climate events in these years have been estimated at US\$2.3 billion and US\$2 billion, respectively (MINAM, 2010a; Guerrero and Remigio, 2009). These events appear to have impacted national economic growth rates significantly, as figure 10 shows.

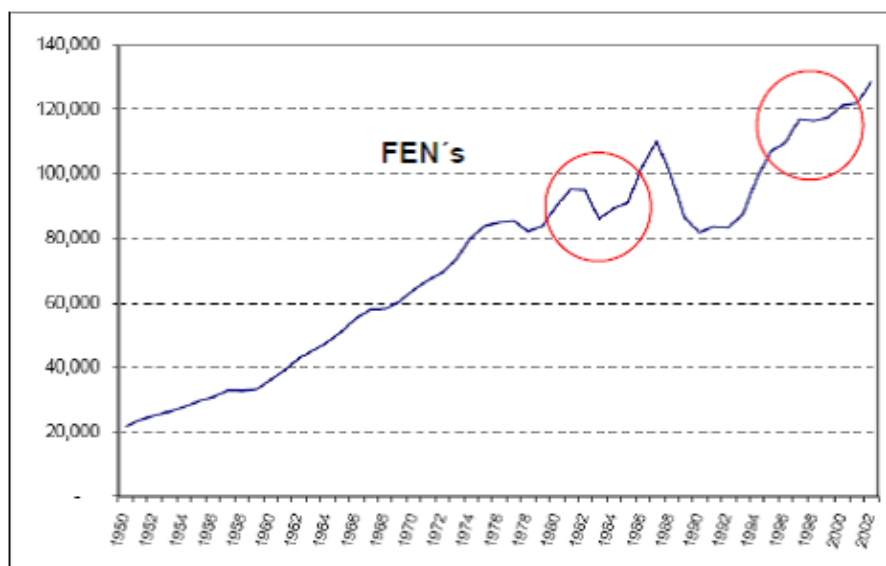


Figure 10. Trends in economic output (in million USD) and ENSO years; “FEN’S” = El Niño phenomenon (reprinted with permission from Avellaneda Huamán et al, 2006)

In agriculture, the damage caused by climate hazards over the period from 1995 to 2007 has been estimated at US\$390 million per year. The two El Niño events mentioned above and a drought in 2003–2004³ had the worst impacts. The country lost 73,047 ha of agricultural production, reducing the production of several key crops by between 38 and 97 percent. The fisheries sector lost 13.4 percent of its output in 1998 due to ENSO. The cost for the rehabilitation and reconstruction of infrastructure after the same event was estimated at US\$685 million (Vargas, 2009). Other hazards affect agriculture, too. Quispe et al. (2006, in Sanabria, 2011) also reports on a cold wave that left 260,505 head of livestock dead.

Impacts of projected climate change

Climate change can both alter the characteristics of current hazards and present new threats. It appears more likely than not that more frequent and/or more intense impacts of the type described above could occur.

The steady melting of Andean glaciers is the most certain and undisputed risk driver. Ninety-five percent of the Peruvian population depends on water sources that originate in the Andean highlands (MINAM, 2010a). Over the past 35 years, 22 percent of the total glacier surface has disappeared (Vargas, 2009). This trend is certain to continue, as temperatures will keep on rising. According to current estimates, glaciers below 5,500 m above sea level will disappear in the coming years, and all glaciers could disappear within about 200 years (MINAM, 2010a). This will have profound effects on water supply. According to results reported by MINAM (2010a), the water run-off from glaciers is likely to peak sometime between 2030 and 2050, meaning that the full negative effects of glacial retreat on water scarcity will only be felt in the longer run.

However, there are important regional variations. In addition, climate change can affect the water supply through changes in rainfall patterns and evaporation rates. According to projections, most of the Pacific coast, where the population and economic assets are concentrated, could experience reductions in water availability of 6 percent on average by the 2020s. The Amazon might also see its

³ This event is not visible in the disaster statistics presented above, as the dataset for this event contains no impact numbers.

run-off reduced; however, water is currently abundant in this region. Water run-off in the Lake Titicaca basin is expected to increase until 2020, but will afterwards drop as well (MINAM, 2010a).

Many sectors, including hydroelectricity and agriculture, depend on water and will therefore be affected by these scenarios. Agriculture accounts for 80 percent of total water demand and is also directly affected by changing temperature and rainfall patterns. Climate sensitivity varies significantly by crop, but no specific future impacts have been quantified in the literature reviewed for this study. Vargas (2009) looked at overall economic impacts, which can probably mostly be associated with impacts on agriculture. Based on a statistical model, she estimates that by 2030 an increase in temperatures of 1° C and a higher variability of rainfall could reduce economic growth by 0.18 to 0.78 percentage points. By 2050, total output could drop 23.4 percent below its potential without climate change. Note, however, that these results rely solely on past relationships between climate and output and may not constitute accurate predictions.

CLIMATE RISKS TO PRIORITY CROPS IN THE MANTARO RIVER BASIN

As part of the CRM TASP, SENAMHI conducted agroclimatic studies in the regions of Piura and Junín. The study for the Junín region was led by Trebejo and Avalos (2011) and focused on the effects on key crops in the region's most important watershed, the Mantaro River basin, and the risks posed by the two local priority hazards, frost and drought, to those crops. Its methodology considered both the frequency and intensity of the hazards and factors of vulnerability such as seed use, soil management, technology, and the presence of irrigation and drainage systems.

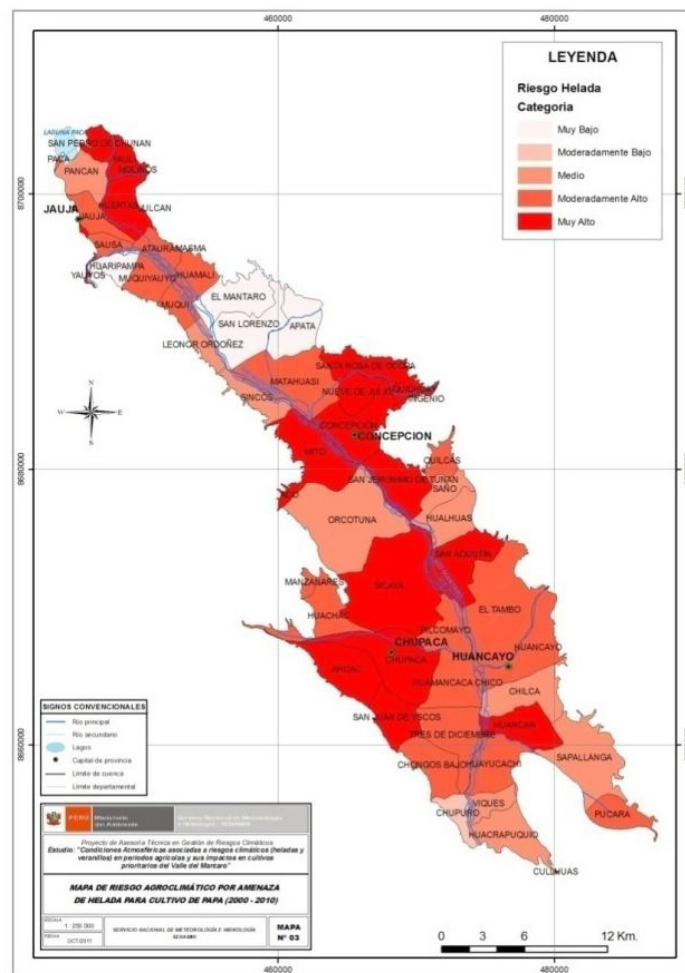
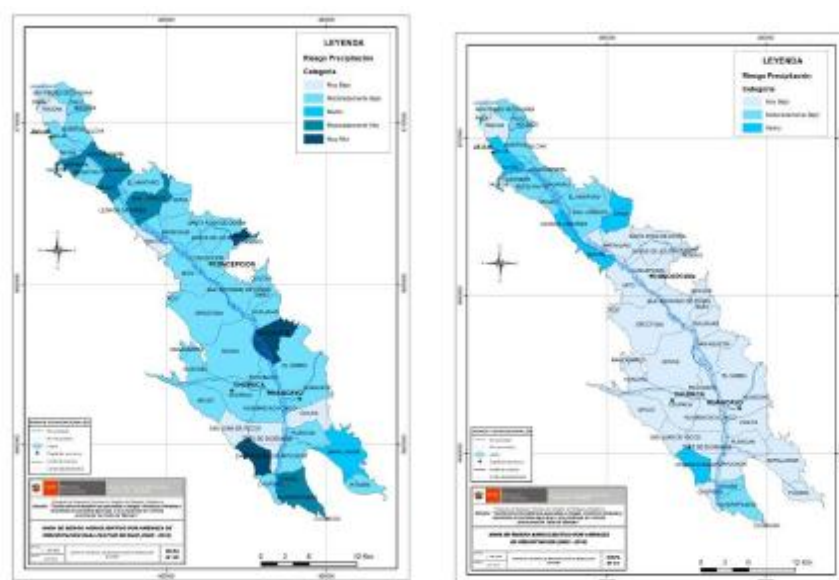


Figure 11. Frost-related agroclimatic risk for potatoes and maize in the Mantaro Valley (originally published in Trebejo and Avalos, 2011)

The Mantaro River basin is heavily exposed to frost. Vulnerability factors, such as dry soils with little water or heat-retention capacity, facilitate negative impacts. The impact of frost on crop production depends on the phenological phase during which the plant is hit. A relatively strong frost event occurred in early 2007, right during the grain-formation period of maize and when potatoes were in their growth and tuberization phase. As a result, potato and maize yields dropped across the valley by an average of 12.8 percent and 13.5 percent, respectively. Figure 11 shows a frost-risk map for those two key crops in the watershed. Darker shades of red indicate higher risk. The fact that higher risk is not associated only with higher altitude and consequently lower temperatures highlights the importance of local vulnerability factors. One of the key factors is the water-retention capacity of soils, as more humid soils are better at absorbing and storing heat.

Frost events have become less frequent in the Mantaro basin from 1965 to 2011, although interannual variability is very high (Trebejo and Avalos, 2011). Taking into account climate scenarios, general warming trends may render frost events less probable. However, some climate scenarios for the Mantaro basin point towards decreasing temperatures (see 'Climate Profile,' pp. 21–28). Furthermore, climate variability may increase. Indeed, frost events have increased over the past decades in other parts of the country. Impacts will crucially depend on how vulnerability evolves, as well.



Figures 12 and 13. Drought-related risk for maize (left) and potato (right) production in the Mantaro Valley from 2000 to 2010 (originally published in Trebejo and Avalos, 2011)

'Veranillos'—meteorological droughts defined as periods of at least 10 days with no more than 1 mm of daily rainfall, which occur during the rainy season—can affect crops during critical stages of their development. The most critical phase for key crops in the Mantaro River basin is December to March. From 1965 to 2011, on average about one event per year occurred. The longest drought lasted 23 days. Trebejo and Avalos (2011) analysed one 11-day event in January 2001 in terms of its impact on maize and potato productivity. They found that potato production fell by 3.8 percent, whereas maize production dropped by 8.4 percent on average across the valley. This difference in resilience between maize and potatoes is also shown in the maps displayed in figures 12 and 13 above, which represent drought risks for the 2000 to 2010 period. Darker shades of blue indicate a higher risk of crop yield reductions. As for the event described above, drought risk for maize is higher.

No clear tendency can be detected in the intensity (in terms of number of days) of such events, although the frequency appears to increase. General regional climate trends could render the occurrence of droughts more probable in the future. However, precipitation trends are not uniform across the watershed. According to projections, summer and autumn precipitation could decrease in the northern and central areas and increase in the southern part; in winter, rainfall could decrease in high altitudes; and in spring, it could increase in most of the area (MINAM, 2010a). No specific trends for consecutive dry days have been identified. As for frost, vulnerability will play a key role in defining future climate risk.

The Mantaro River valley has been the focus of other studies on climate risk, many of which are summarized in a book by the Geophysical Institute of Peru (Instituto Geofísico del Perú, 2010). Among other things, they mention the increased occurrence of plant pests and diseases and higher evapotranspiration rates, both resulting from temperature rise, as important additional risks to agriculture. The threats from glacial retreat are also highlighted, as glaciers in the Huaytapallana mountain range, which are one of the main sources of water for the area, lost almost 60 percent of their surface between 1976 and 2006, and continue to shrink.

CLIMATE RISKS TO PRIORITY CROPS IN THE PIURA RIVER BASIN

For the Piura River basin, Yauri Quispe (2012) conducted a study of the impacts of climate variability and change on key crops in different parts of the watershed. He developed statistical production functions to identify the relevant climate parameters for yields of maize (different types), wheat, rice, cotton, mangoes and lemons.

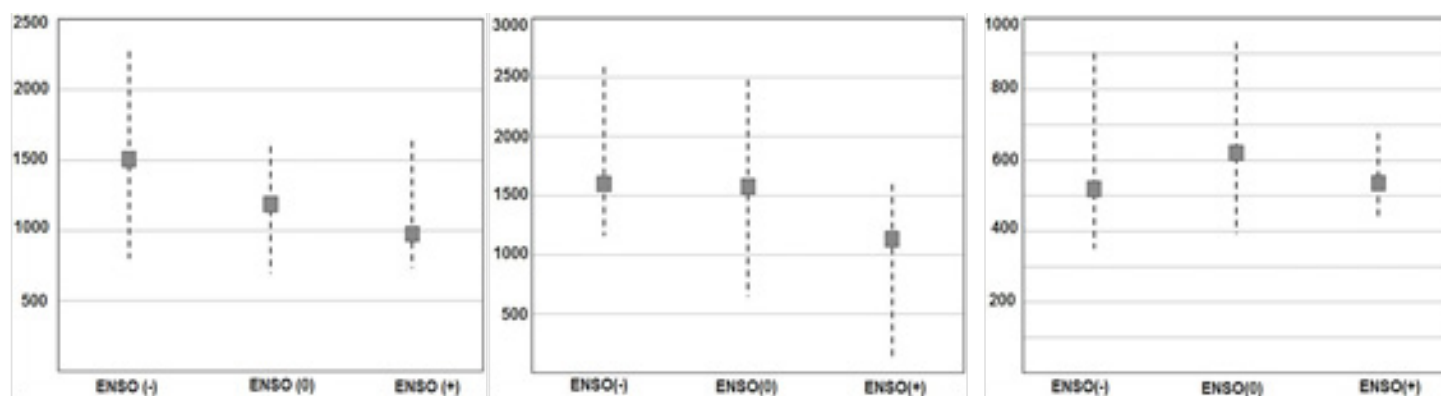


Figure 14. Variation of mango, cotton and rice yields in ENSO phases (originally published in Yauri Quispe, 2012)

In a first step, Yauri Quispe (2012) identified variations in yields for ENSO events for rice, cotton and mangoes. Figure 14 shows average yields in kg/ha for mangoes (left), cotton (centre) and rice (right) over the period from 1950 to 2010, for negative, neutral and positive ENSO phases. The graphs show that positive ENSO phases are associated with reductions of 20 percent or more in yields for the three crops, while negative ENSO phases, that is, La Niña events, boost mango production, hardly affect cotton yields and reduce rice yields by about 20 percent. Note, however, that the yield variation ranges shown in figure 14 are large. Positive ENSO phases affect rice and cotton mainly during the period from January to March, while mangoes are most sensitive to temperature variation between June and August. The study notes that factors of climate variability other than those associated with ENSO explain more of the yield variation for rice and cotton.

Yauri Quispe (2012) also developed crop-production functions to estimate potential impacts of future climate change.⁴ As a first step he chose an econometric model for each crop that best simulated past interannual variations in crop yields. Then he applied projected climate trends to the model in order to estimate the impacts of climate change on two key crops grown in the upper watershed: white maize and wheat, and five crops grown in the lower watershed: rice, cotton, yellow maize, mangoes and lemons.

The two highland crops are grown without irrigation. Yields for white maize have increased by about 40 percent over the last 10 years, to reach about 1000 kg/ha in 2010. For wheat, there has been a smaller increase, of about 10 percent over the last decade, and production per hectare averaged about 800 kg in 2010. Due to limited past data, projections for these highland crops were only made for the year 2015. For both crops the models suggest that climate change could increase yields in the short term, probably because of increasing rainfall and warmer temperatures. For white maize, the projected increase is less than 10 percent, while for wheat it is above 10 percent, when extrapolating from past trends of yield increases. Past trends suggest that yields will also increase in the absence of climatic changes, as a result of technological progress.

For lowland crops, which are irrigated, Yauri Quispe (2012) was able to project yields up to the year 2030, thanks to longer records. For rice, yields have almost doubled since 1971, to reach about 9,000 kg/ha in 2010. If this trend continues, yields in 2030 will reach nearly 12,000 kg/ha. Climate change is not expected to affect rice much by 2030 according to the model, although climate trends

⁴ The underlying climate scenarios are the regional projections for Piura presented earlier in this report.

are thought to be suitable for rice production. For cotton, the yields have increased from about 1,300 kg/ha in 1970 to 1,800 kg/ha in 2010, although with much higher interannual variation. Climate change could reduce production compared with the baseline scenario by some 300 kg/ha, probably because optimal minimum and maximum temperatures will be exceeded. Yellow maize production increased from about 3,100 kg/ha to about 4,200 kg/ha between 1971 and 2010, and climate change is not expected to alter trends significantly by 2030.

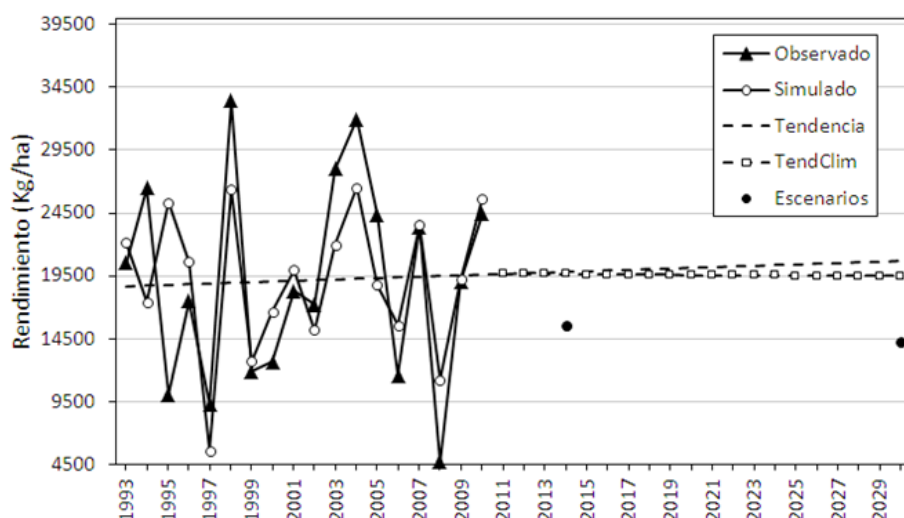


Figure 15. Observed, simulated and projected mango yields in the lower Piura watershed (originally published in Yauri Quispe, 2012)

Production of mangoes and lemons, on the other hand, has not seen any increases since the beginning of the data series in 1993 and 1987, respectively, although interannual variation is very high. For mangoes, which currently have a production of almost 20,000 kg/ha, climate change could reduce yields by almost 25 percent by 2030. Figure 15 shows observed and simulated past mango production values for 1993 to 2010, along with projections based on the tendency of observed and simulated values and projected production for the climate scenarios for 2014 and 2030. The reductions shown in these scenarios are likely due to the warming trend, which will cause minimum temperatures to exceed the optimal range for mangoes, especially in the flowering period. A temperature anomaly in 2008 of just +0.9° C led to a 75 percent decline in productivity (see figure 15), highlighting the sensitivity of mango production to variations in climatic conditions. Lemon production has also varied sharply across the recorded period, as it is similarly vulnerable to anomalies in the winter minimum temperature. The trend line for lemon yields has been slightly decreasing over the past 24 years, and climate change could slightly accelerate this decreasing trend.

The models suggest that the dominant drivers of crop yields remain technological progress and climate variability. Nevertheless, climate change could have a significant impact by 2030 on crops such as wheat and mangoes, and could even boost production of maize in the highlands. The results presented here should, however, be interpreted with caution, as they rely solely on the past statistical relationship between annual average climate conditions and output, and do not take into account important factors such as soil conditions or other climate impacts such as seasonal variability, pests and diseases, and changes in the cultivation cycle.

Neither do the models look at the actual water demand of key crops or seasonal water availability under climate change conditions. Since, in the Piura River basin, more than 94.3 percent of water is used for agriculture, and the watershed is already under water stress today, this is of critical importance. While projections indicate an overall increase in rainfall, water scarcity is still expected to be exacerbated due to higher temperatures and the corresponding rise in evapotranspiration, which means that crops will need more water in the future to grow optimally (SENAMHI, 2005). Furthermore, the more profound impacts of climate change may only occur beyond the time horizon of the above-mentioned model results, which is 2030. Many crops are near a point where additional increases in temperature will reduce their growth potential. Water scarcity could also become more severe with a continued temperature increase beyond 2030.

LOCAL CLIMATE VULNERABILITY AND ADAPTIVE CAPACITY

To complement the quantitative perspective of the two agro-climatic studies presented above, we held community consultations in Piura and synthesized the results of previous consultations in Junín. Capturing the local perspective allows for unique insights into the wider impacts of climate variability and change on communities' livelihoods and into the way people cope with such impacts.

Junín

CARE (2011) conducted local consultations based on the Climate Vulnerability and Capacity Analysis (www.careclimatechange.org/cvca) and CRISTAL⁵ tools in the Shullcas micro-watershed, which is part of the Mantaro River basin. The Shullcas River depends heavily on water from the Huaytapallana Glacier, whose size is decreasing rapidly and which represents the main water source for 10 settlements along the river as well as Huancayo, the capital of Junín. Apart from human consumption, water is used for the production of crops such as potatoes, peas, fava beans, maize, wheat, barley and tubers, as well as livestock, fish farms and energy. The Mantaro River basin is also known as the food basket of the Peruvian capital, Lima.

The consultations show that although they are aware of certain environmental changes, consulted communities do not yet feel the impacts of melting glaciers or the widespread loss of wetlands. However, many people perceive that extreme events such as droughts, frost, floods and landslides have increased, with important impacts such as loss of livestock and crops, loss of agrobiodiversity (such as potato varieties), changing crop cycles, the appearance of pests and diseases that affect both crops and livestock, and the ebbing of water springs and sources, which changes irrigation schedules, and can cause conflicts over water.

Common response strategies include shortening crop cycles, with associated shifts in varieties, as well as displacing crops to higher altitudes where there is more humidity—a generally beneficial factor in the context of both droughts and frost. While such changes in altitude zones can alleviate negative impacts, there is also a risk of increased habitat degradation. Women and older adults were identified as particularly vulnerable to climate impacts, as they are responsible for families and older adults, and both these groups have lower mobility. Younger children were seen as particularly vulnerable to cold temperatures because, for example, they contract respiratory illnesses more easily.

The lack of governance of natural resources such as water and forests; the absence of institutional structures to coordinate risk management initiatives; low local disaster response capacity; the lack of access by the local population to information on current and future climate risk drivers, such as glacial retreat, and their consequences; and the lack of risk management plans and policies all compound the high levels of vulnerability among the rural population (CARE, 2011).

Piura

In the highlands of the region of Piura, Davila (2012) held consultations as part of the CRM TASP. Five communities were consulted in the municipality of Centro Poblado Menor in the district of Huarmaca, and in another two communities in the Salitral district. Participants identified droughts, landslides and strong winds as the main hazards, along with the key direct and indirect impacts presented in table 7.

⁵ CRISTAL stands for Community-Based Risk Screening Tool – Adaptation and Livelihoods. For more information see www.iisd.org/cristaltool.

TABLE 7. CLIMATE HAZARDS AND IMPACTS IN THE UPPER PIURA WATERSHED (DATA SOURCE: DAVILA, 2012)

HAZARD	DIRECT IMPACTS	INDIRECT IMPACTS
Drought	<ul style="list-style-type: none">• Loss of soil fertility, crops and trees• Weakening and illness of livestock• Diseases Water scarcity	<ul style="list-style-type: none">• Food scarcity• Loss of employment, income and savings• Reduction in school enrollment• Social conflicts
Landslides*	<ul style="list-style-type: none">• Loss of life• Loss of soil fertility, land, crops and trees• Interruption of transport links• Infrastructure damage	<ul style="list-style-type: none">• Food scarcity• Loss of incomes and savings• Reduction in school enrollment
Strong winds	<ul style="list-style-type: none">• Loss of crops and trees• Damage to housing• Human and animal diseases	<ul style="list-style-type: none">• Loss of incomes and savings• Unemployment

* Huaycos (mudslides) and avalanches were summarized under landslides.

People have developed many ways to cope with climate impacts, intervening at different stages of the impact chain, and some of these coping strategies are more sustainable than others. Sustainable strategies to deal with loss of soil fertility, crops, and livestock, and the associated impacts on food availability, incomes and employment, include the diversification of crops, incomes, and fertilizers; rainwater harvesting and water storage; and increased use of groundwater. In two sites, tree loss is countered with reforestation programmes. Livestock is being vaccinated against diseases. Some improved roof designs and relocation are being used to protect houses from extreme events.

However, for many impacts no sustainable coping strategies appear to be available. Health impacts are alleviated, but not prevented, by traditional medicines and the use of local health centres. Migration and day labour is a way out in times of significant climate stress. Often, communities are forced to ration food and sell valuable assets such as livestock, which can render them even more vulnerable to future climate events. As a result, it appears adaptive capacity depends on the climate hazards and their impacts, varies between consulted communities, and is to a large extent dependent on external support. The lack of sufficient local organization, for example for emergency response, was identified as a major deficiency in achieving greater risk management capacity.

CLIMATE THREATS TO DEVELOPMENT OUTCOMES

Agricultural production in the regions of Junín and Piura, and the communities whose livelihoods depend on it, face significant climate risks as a result of high exposure to climate extremes and change and the sensitivity of key crops to climatic variation and of livelihoods to those crops, as well as the generally low adaptive capacity resulting from underinvestment and low infrastructural and technological development; weak access to markets and finance; lack of territorial planning, appropriate institutions or governance; unsustainable use of natural resources; and poverty.

The analysis above highlights that climate variability, mainly in the form of changes in rainfall and temperatures in the context of ENSO events, should be the predominant concern over the next few decades, as gradual climate changes will not exceed the variations caused by even moderate climate variability. Climate extremes can lead to temporary water scarcity or excess, reduce crop yields and destroy critical infrastructure, such as irrigation systems or roads that are needed for market access.

Yet climate change is a looming threat that should not be ignored. Glaciers are melting rapidly and will eventually lead to quickly decreasing water availability and less stable water flows in many areas. Increasing temperatures will increase evapotranspiration, exacerbating water scarcity even in areas where average rainfall is expected to increase. Even though some crops are expected to benefit from warmer temperatures and sometimes higher precipitation in the short term, the optimal temperature range may be exceeded for more and more crops in the medium to long term, affecting yields and agricultural biodiversity.

Farmers, the agricultural sector as a whole, and the society and economy at large are all affected by current and future climate impacts. Some of those impacts, and their effects, are summarized below.

The direct biophysical impacts of climate change on crop yields and infrastructure also have indirect impacts on farmers, rural communities and the agricultural sector as a whole:

- **Incomes** from agriculture could fall throughout the value chain due to lower yields, higher production costs, infrastructure damage and lower reliability of supply.
- **Food insecurity** could increase as a result of lower crop yields as well as higher food prices. Impacts could be felt directly in the city of Lima, which receives much of its food supply from the Mantaro Valley.
- **Exports** could decrease, and the need for **imports** of affected crops could increase.

Not only are such impacts a major concern to farmers and the agricultural sector, but they can put the achievement of several key national and sectoral development objectives at risk:

- The rapid **reduction of extreme poverty** envisaged in the 'Plan Bicentenario' is more difficult.
- **Increasing school enrollment** may be more difficult, as farmer parents pull children out of school because of scarce financial means and to support crop production.
- Reducing **malnutrition** can become more challenging if crop yields decrease.
- **Increasing access to water, irrigation and electricity** will be more challenging under rising water scarcity.
- More money will have to be invested in **infrastructure** due to repeated and severe damage in the context of extreme climate events.
- The **sectoral goals for agriculture** of the Ministry of Agriculture, including the planned 7 percent sectoral growth per year, increased export earnings and job creation, and reduction in rural poverty, are more difficult to achieve as a whole.
- The **objectives of the regional governments** of Junín and Piura also relate to boosting agricultural production and exports and may suffer from similar obstacles due to the climate impacts identified above.

Other goals may be threatened indirectly as a result of unsustainable coping strategies, such as agricultural expansion into previously forested areas, or conflicts over scarce natural resources such as land and water, which could affect institutional stability. The Peruvian Government needs to take these issues on and channel its current economic boom into a more climate-resilient development path if it is to avoid a backlash fuelled by the interaction of climate hazards and conditions of vulnerability.

Key messages: Climate impacts and risks

- Every year droughts, frost, floods and landslides claim dozens of lives, affect tens of thousands of people and/or cause millions of dollars of damages, especially in the agricultural sector. El Niño events have had the worst economic effects in the past.
- Regional agroclimatic studies in the Mantaro and Piura river basins highlight the severity of impacts of El Niño events, droughts and frost on key crops including maize, potatoes and fruits. The Piura study also suggests that climate change impacts over the next two decades will vary and will not exceed those imposed by natural climate variability. However, over time, more crops will move away from optimal growth conditions in terms of temperatures and water availability.
- Local consultations suggest that, while some sustainable coping strategies exist to deal with such impacts, communities lack sufficient internal and external capacity to adapt to climate variability and change, not least because of poverty, environmental degradation, and a lack of adequate institutions and governance.
- The combination of hazards and vulnerability leads to significant climate risks not only for farmers, rural communities and the agricultural sector, but also for the achievement of general development goals, including poverty reduction; access to education, nutrition and water; irrigation and electricity; infrastructure improvements; and growth in agricultural earnings and exports.

INSTITUTIONS AND POLICIES FOR CLIMATE RISK MANAGEMENT

As in most countries, climate risk management is currently addressed from two main angles: disaster risk management and climate change adaptation. In addition, climate risk considerations have recently been mainstreamed into important national and sectoral policy documents. This section looks at current institutional and policy arrangements for climate change adaptation and disaster risk reduction, as well as key actions, followed by an analysis of current national risk management capacity. It draws mainly on the results of a national workshop on the integration of climate risk management institutions and policies (MINAM et al., 2011).

DISASTER RISK MANAGEMENT

Peru has recently renewed its legal and institutional structure for disaster risk management. The new National System for Disaster Risk Management (SINAGERD) aims to provide an inter-institutional, synergic, decentralized, cross-cutting and participatory framework with the following overarching objectives:

- Identify and reduce the risks associated with various hazards or minimize their negative effects.
- Avoid the creation of new risks.
- Conduct disaster preparedness and management by establishing norms, policy guidelines, processes and tools for disaster risk management.

Two agencies form the core of SINAGERD. The National Institute for Civil Defense (INDECI) is responsible for coordinating disaster preparedness, response and recovery and leads the formulation of a 'National Plan for Disaster Prevention and Attention'. The National Centre for Disaster Risk Evaluation, Prevention and Reduction (CENEPRED), on the other hand, is a new organism for the coordination, facilitation and supervision of the National Disaster Risk Management Policy. As such, it deals with the underlying aspects of vulnerability and the fundamental drivers of climate risk. Both INDECI and CENEPRED report to the Presidency of the Council of Ministers, which is the directive entity for SINAGERD as a whole.

In 2007 the Ministry of Economy and Finance introduced mandatory risk analysis for the formulation and evaluation of all public investment projects, with a view to both protecting these investments from hazards and avoiding the creation of new vulnerabilities. Furthermore, in 2011 the Government assigned 63 million soles (around US\$23 million) to a strategic budgetary programme for vulnerability reduction and emergency disaster response.

Peru is also a member of the Andean Committee for Disaster Prevention and Relief, which unites several ministries in Colombia, Ecuador, Bolivia and Peru with the aim of reducing the risks and impacts of natural and man-made disasters in the Andean region through mutual assistance, cooperation, coordination and promotion of policies, strategies, plans and activities in disaster prevention, mitigation, preparation, response, rehabilitation and reconstruction (Comité Andino para la Prevención y Atención de Desastres, 2012).

CLIMATE CHANGE

The General Directorate for Climate Change, Desertification and Water Resources of MINAM is in charge of climate change policy and presides over the inter-institutional National Climate Change Council (CNCC), which was created in 1993 for the implementation of Peru's obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The CNCC has subcommittees for different themes, including for adaptation, Reducing Emissions from Deforestation and Forest Degradation, mitigation, the Clean Development Mechanism, research and technology, finance, international negotiations, and education and communication (MINAM, 2010b).

The CNCC also coordinated the elaboration of the 'National Climate Change Strategy' in 2003, which defines Peru's vision on climate change mitigation and adaptation. The strategy lays out 11 strategic objectives: research, policies and projects related to adaptive capacity development, participation in international negotiations, mitigation policies and actions, knowledge dissemination, promotion of poverty reduction projects with adaptation and mitigation co-benefits, appropriate technology use, civil society participation, forest ecosystems management, seeking of just compensation from polluters, and management of fragile ecosystems,

particularly in high mountains. Each objective is divided into several sub-objectives. The 'National Climate Change Strategy' is currently undergoing review.

Peru's 'Second National Communication to the UNFCCC' (MINAM, 2010a) proposes guidelines for a national adaptation strategy based on vulnerability studies and existing adaptation actions, which will complement the more generic guidelines of the 'National Climate Change Strategy'. In addition, MINAM has recently elaborated the 'Action Plan on Adaptation and Mitigation' (MINAM, 2010b). Its thematic axis on adaptation proposes, among other things, to elaborate climate scenarios at the regional and watershed levels, promote risk and vulnerability studies and cost analyses, and promote actions to reduce vulnerability at different scales and for ecosystems. A separate strategic theme is dedicated to the integration of adaptation with disaster risk management.

Since 2002 the Government has promoted the elaboration of regional strategies on climate change. Four regions, including Junín, have approved one, and in four others, including Piura, proposals for a regional strategy exist. Regional technical committees accompany and promote the implementation of these strategies. Piura already has an adaptation strategy for the Piura River watershed. The regional government of Junín has a technical committee on climate change, vulnerability and adaptation, which aims to implement political proposals and climate change strategies and to develop preventive and adaptive measures.

The Andean Community plans to elaborate a regional strategy on climate change for Bolivia, Peru, Ecuador and Colombia (Comunidad Andina, 2011), but so far, it has only elaborated a scoping paper (Comunidad Andina, 2007).

RECOGNITION OF CLIMATE RISK MANAGEMENT IN KEY POLICY DOCUMENTS

Climate change adaptation and risk reduction are referred to in key policy documents of the national Government. The 'Plan Bicentenario', the national development strategy (CEPLAN, 2011), mentions climate change in several of its strategic axes, including governance, economy and competitiveness, and natural resources and environment. Under the last, adaptation is also mentioned as an explicit strategic objective.

Promoted by the Ministry of Agriculture, in 2008 an inter-institutional working group on food security and climate change started to work on a sectoral vision for agriculture and climate change with a view to identifying vulnerabilities, adaptation options and ways to mainstream climate concerns into sectoral strategies. These efforts are now pursued with the elaboration of the 'National Plan on Risk Management and Adaptation to the Adverse Effects of Climate Change in the Agrarian Sector for the Period 2012 to 2021', which integrates both disaster risk management and climate change adaptation into agriculture.

Piura's 'Plan on Concerted Regional Development 2007–2011' has six strategic themes, including risk management and adaptation technologies (MINAM et al, 2011). In addition, in the regional strategic plan for agriculture, adaptation of crops to changing climate conditions is mentioned as an element of sustainable agricultural development (Yauri Quispe, 2012).

CLIMATE RISK MANAGEMENT ACTIVITIES

Because of its long history of extreme events, Peru has been involved in numerous disaster risk reduction activities. One of the biggest initiatives is the Disaster Preparedness Programme of the European Community Humanitarian Aid Office. Its current action plan includes initiatives on capacity development, early-warning systems, resilient communities and education led by UNDP, FAO, the United Nations International Strategy for Disaster Reduction and other agencies in several parts of the country (INDECI, 2012).

The 'Second National Communication' (MINAM, 2010a) lists 63 ongoing adaptation initiatives in Peru. These projects range from capacity development to research and implementation, are being implemented across the country, and address many different climate risks. The water sector has received particular attention, along with agriculture and ecosystems. The Andes and the dry areas on the northern coast have attracted more projects than other areas. Several projects have taken a watershed approach. Furthermore, many capacity development initiatives involve the national as well as a number of regional governments. Peru is also involved in many regional or global projects, the former often being shared with other Andean countries, including Bolivia, Ecuador and Colombia.

Among the largest projects is the Regional Project for Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes, which seeks to implement measures to meet the anticipated consequences of the catastrophic glacial retreat induced by climate change through design and implementation of strategic pilot adaptation measures. One of the main focus regions is Junín. Another big initiative is the Adaptation to Climate Change Programme, which focuses on building capacities and promoting adaptation action in the regions of Cusco and Apurímac, with a view to reducing the vulnerability of the poor, supporting local livelihoods and reducing climate-induced migration. Piura is currently the focus region of UNDP's Territorial Approach to Climate Change project, which seeks to improve resilience to climate change and reduce the carbon footprint in subnational territories in developing and transition countries (Adaptation Partnership, 2011).

ASSESSMENT OF CLIMATE RISK MANAGEMENT CAPACITY

Based on the World Resources Institute's National Adaptive Capacity Framework (World Resources Institute, 2009), we have conducted a short desk-based capacity assessment on climate risk management. The framework evaluates capacities based on the availability, systematization and mainstreaming of and capacity to conduct risk assessments; the existence of explicit risk management priorities and a process to revise these priorities; the existence of coordination processes and bodies; the sound management of information; the identification of risks for priority areas; and the evaluation of adaptation options as well as their implementation.

Assessment. A wide range of assessments on climate vulnerability, impacts and risks have been carried out to date in Peru. A synthesis study conducted as part of the CRM TASP (Torres et al., 2012) identified assessments on past risks by hazard, especially on ENSO impacts, and a range of sectoral assessments on future climate risks for water, biodiversity and the Amazon, agriculture and fisheries, services, energy and transportation. The study also identified macroeconomic assessments. Nevertheless, important knowledge gaps remain, both in terms of coherence and depth. Few quantitative risk evaluations exist, either regarding climate hazards or in terms of vulnerability. Little is known, for example, about how current and future climate variability and change will affect key crops such as potatoes. It is necessary to calculate return periods for hazards, how they impact different sectors physically and economically, who is affected, and the importance of different risk factors. It is also important to conduct integrated studies on both current and future climate risks using innovative combinations of methodologies, as well as evaluations that provide targeted information to decision-makers. The two regional case studies presented in this report are a small step in this direction.

Prioritization. Peru has made significant efforts to identify key actions to reduce vulnerabilities. Its 'Action Plan on Adaptation and Mitigation' (MINAM, 2010b) identifies a range of actions that are complementary to ongoing initiatives and that require funding. Financial resources have been made available to put such actions into practice. According to MINAM (2010b), approximately US\$58 million in public investments has been made in climate change. There are, however, important limitations. No identification of actions similar to the one in climate change adaptation has taken place within the disaster risk management community. Furthermore, vulnerabilities across sectors and social groups have also not been prioritized, with regard to either current or future risks. Strategic documents and plans remain vague in terms of specific actions needed, a situation that mirrors the lack of detailed and comprehensive risk assessments in many sectors. No formalized and permanent identification and prioritization process exists, even though bodies such as the inter-institutional CNCC could take on such a function. It is also necessary for climate change adaptation and disaster risk management to be more thoroughly integrated to make sure priorities are coherently chosen.

Coordination. Vertical and horizontal processes and bodies for coordinating action on climate risk reduction exist to some extent. Within disaster risk management, the two main agencies, INDECI and CENEPRED, both report to the Presidency of the Council Members, and their activities can thus be coordinated from above. INDECI has a long-established network of disaster management agencies at regional and local levels. MINAM chairs the CNCC, with all its subsectoral committees, and supports regional governments in the elaboration of regional climate change strategies. For the agricultural sector, the 'National Plan on Risk Management and Adaptation to the Adverse Effects of Climate Change in the Agrarian Sector for the Period 2012–2021' is currently in elaboration. Challenges remain, however, in terms of improving and formalizing coordination between the disaster risk management, climate change adaptation and sectoral bodies. Although the communities mention each other in some of their respective plans and laws, no formal mechanisms exist. Even between INDECI and CENEPRED, responsibilities are not clearly defined, and formal and direct coordination is not operationalized.

Information management. Despite a wealth of information and documents, timely, accurate and complete information on both hazards and vulnerabilities in Peru remains difficult to access. It appears that even within institutions, different departments are not always aware of the knowledge that exists in other departments. The challenges range from coordinated data collection to processing and public access. In a complex and crowded institutional environment like Peru, it is crucial to improve this situation, as otherwise there is an important risk of duplicating efforts, making wrong short- and long-term predictions, and, most of all, of making wrong decisions at multiple scales. There should be a centralized database and an agency with sufficient funding that is responsible for gathering, processing and publishing vulnerability and risk information.

Climate risk reduction. The last element considered in the 'National Adaptive Capacity Framework' is the climate risk reduction function, which captures elements of the previous functions but focuses more precisely on the identification of specific risks to given priorities, the evaluation of adaptation and risk reduction options, and their selection and implementation. As noted above, risk and vulnerability evaluations exist for various sectors and areas, but more in-depth and comprehensive analysis is required as a basis for the identification and prioritization of adequate risk management options. Inter-institutional coordination needs improvement, in particular between the disaster risk management and climate change adaptation communities. Information management needs to be strengthened with respect to data collection, processing and access. Public funds are available to a good extent, and many adaptation and risk reduction measures have been and are being implemented. Nevertheless, these actions could be more coherent and targeted if the increasing climate risk challenges are to be met.

Key messages: Institutions and policies for climate risk management

- SINAGERD is Peru's disaster management system. Evaluation, prevention and risk reduction are managed by CENEPRED, whereas disaster preparedness, response and recovery are under INDECI's responsibility. MINAM is responsible for climate change affairs and coordinates action through the National Committee on Climate Change and its sectoral subcommittees.
- Climate risks are recognized as a threat to development in national, sectoral and regional development plans, including in the two focus regions, Junín and Piura, and in agriculture.
- Dozens of projects and initiatives to reduce climate risks at different scales are under way across the country and in a wide range of sectors.
- Peru has a good basis for integrated climate risk management, but important challenges remain in terms of more in-depth and coherent vulnerability and risk assessments, coordinated identification and prioritization of risk management options, formal coordination mechanisms between the disaster risk management and climate communities, and information collection, processing and accessibility.

RECOMMENDATIONS FOR CLIMATE RISK MANAGEMENT

Every year, Peru is hit by multiple extreme events such as droughts, floods, cold waves and frost, which lead to dozens of casualties, tens of thousands of affected people, and, to the extent that they have been recorded, millions of dollars of damages. Climate change, which manifests itself in Peru through rising temperatures, changing rainfall patterns and rapid glacial retreat, could increase the frequency and intensity of extreme events and will gradually exacerbate other stressors, such as water scarcity. Due to low technological development and investment levels, the agricultural sector is particularly sensitive to climate hazards. Despite a booming economy, the rural population involved in agriculture largely lacks the capacity to adapt to climate variability and change. However, through reducing vulnerability and increasing adaptive capacity, climate risk can be minimized. This section outlines key recommendations for specific actions on the ground, with a focus on the two case study areas, avenues for further research as well as adjustments in policies and institutions to facilitate action and research.

PRIORITY ACTIONS

The following recommendations for on-the-ground action for managing agricultural climate risks, especially in the regions of Junín and Piura, with a view to reducing the negative impacts of current hazards such as droughts, frost and floods as well as changing climatic conditions, draw mainly on the results of the two regional agroclimatic studies presented above (Trebejo and Avalos, 2011; Yauri Quispe, 2012), on regional workshops held by FAO (forthcoming), and on general recommendations for agriculture from the 'Second National Communication' (MINAM, 2010a). They are summarized under four headings: agricultural practices and ancestral knowledge, water management, finance and markets, and data and information management.

Agricultural practices and ancestral knowledge

Changes in agricultural practices can reduce the risk of crop losses and consequent implications for income and food security. Many lessons can be learned from traditional adaptation and coping mechanisms.

- **Water and irrigation.** These are obvious tools in fighting drought, but they can be used to reduce frost risk, too. In general, healthy, compact and humid soils are protected much better from frost, since they lose warmth less quickly. Irrigating land can therefore reduce sensitivity to frost. Also, placing water pools or tanks between or around crops can help to temper the climate and prevent the temperature of the soil from dropping below freezing (Trebejo and Avalos, 2011).
- **Organic fertilizers.** Techniques such as leaving crop residues on the soil improve soil conservation and keep it warmer and more humid than under current practices. Similarly, using organic fertilizer can help crops recover after frost, although the effect depends on what stage of crop growth the frost happened at (Trebejo and Avalos, 2011).
- **Diversification of crops.** This traditional practice helps reduce the risk of widespread losses, as different crops are impacted asymmetrically by different hazards owing to variations in sensitivity and cultivation periods. For the Mantaro River basin, Trebejo and Avalos (2011) propose combining maize with beans, as well as diversifying into artichokes. Given the general trend towards higher temperatures and higher evapotranspiration, retreating glaciers, and possibly increased climate variability, crop varieties that use less water and have shorter crop cycles should be preferred.
- **Topographical planning.** Valley plains and bends tend to accumulate cold air, which increases risk. Frost risk can be reduced by cultivating sensitive crops on slopes and terraces with high solar irradiation (Trebejo and Avalos, 2011).

Water management

Water is the main transmission channel for climate impacts on agriculture, as many hazards are associated with excess or scarcity of water. As a result, improved water management is a key component of reducing agricultural climate risk. We propose the following measures:

- **Irrigation.** Irrigation reduces climate sensitivity and is especially important in the Peruvian context. Current hazards such as droughts and frost can be reduced with proper irrigation (see above). Furthermore, irrigation reduces potential negative impacts in the future; for example, the risk of increased evapotranspiration due to higher temperatures and, most of all, the threat of disappearing glaciers and the consequent lack of a relatively constant water run-off in rivers. As a result,

MINAM (2010a) proposes to increase irrigation, especially in poor areas where adequate systems are inaccessible for the population. Specifically, it is planning a programme for 100 technical irrigation modules in areas with extreme rural poverty across the country, at altitudes of more than 2,500 m above sea level. It also mentions that maintenance of existing irrigation infrastructure should be improved.

- **Dams and reservoirs.** These are a necessary complement to irrigation systems, as they help to manage variation in water flow, which could increase in the future. MINAM (2010a) suggests the construction of small dams as well as reservoirs, especially in the highlands. In the context of retreating glaciers and increased rainfall variability, small rainwater-fed reservoirs in rural areas are particularly suited to reducing risks related to recurrent hydrological droughts. Small reservoirs can be managed within coherent social groups such as communities or families, thus reducing the risk of conflicts over scarce water resources.
- **Groundwater use.** Local governments and community organizations also need to be supported in exploiting groundwater more, and in more efficient ways. This will involve drilling additional wells as well as educating users on how to use the water efficiently (MINAM, 2010a).
- **Reforestation of watersheds.** Trees protect the water catchment area, as they improve water retention and can smooth water run-off, which helps to fight droughts, floods and the risks associated with decreasing glaciers. Trees can also create a more temperate microclimate and reduce frost risk.

Finance and markets

As per the characterization of the agricultural sector in 'Development Profile' (pp. 13–20), much of the agricultural sector of Peru not only lacks appropriate technology, but also depends on middlemen for credit and market access. Improving market access and financial services could improve incomes and facilitate investments in technology and risk management measures such as those recommended above. Furthermore, farmers need to get access to insurance as a way to transfer and pool risks. MINAM (2010a) proposes a disaster insurance mechanism for agriculture, and adaptation initiatives such as UNDP's Territorial Approach to Climate Change project propose the introduction of weather-based insurance mechanisms (Adaptation Learning Mechanism, 2012).

Data monitoring and information management

The 'Climate Profile' (pp. 21–28) and 'Institutions and Policies for Climate Risk Management' (pp. 38–41) sections of this report revealed important deficiencies in climate data monitoring and information management. Although important efforts have been undertaken, these appear to be concentrated in a few regions and to involve little coordination across institutions. Improvements in this regard should start with an extension of weather and hydrological stations to areas with low coverage, which include both Junín and Piura. Emerging risks, such as alterations in river run-off or glacier lake outburst floods in the context of rapid glacial retreat, should receive particular attention. Data collection should be automated and coordinated to avoid redundancies and inconsistencies. Raw and processed data should be made available to the public for free and in useful formats, including through comprehensive and integrated early-warning systems for droughts, floods and other key hazards, and in the form of medium- to long-term climate projections. Such efforts will allow farmers and other stakeholders to make better short- and long-term decisions to prevent and prepare for climate disasters.

Information management for vulnerability and impact data should also be improved. Along with climate information, it is important to collect relevant socio-economic and agricultural data so as to produce useful advice and support planning and research. Along these lines, MINAM (2010a) proposes the establishment of a virtual platform, the Agricultural Information System, which will make available systematic, integrated and standardized information to help evaluate the impacts of climate variability and change on agricultural activity. The costs are estimated at US\$1.7 million. It is important that such efforts complement rather than undermine local knowledge on climate prediction (Trebejo and Avalos, 2011). As for climate data, coordination among agencies is crucial.

Non-agricultural strategies

Some of the proposed strategies that can help reduce climate risks in rural areas are not related to agriculture itself. In addition to crop diversification, the risks of income loss and food insecurity can be reduced through diversified incomes. This strategy is, however, limited by geographic constraints in many cases. Also, infrastructure, including houses and roads, needs to be protected

from extreme events. For houses, this can involve improved roof design and, if needed, relocation of buildings. Finally, improving local organizational capacity for emergency response and disaster prevention in vulnerable communities should be a priority.

Summary of key climate risk management actions

Table 8 summarizes the climate risk management actions identified above along the same key themes. It also identifies the main expected benefits in terms of climate risk reduction, as well as priority regions.

TABLE 8. PRIORITIZED CLIMATE RISK MANAGEMENT ACTIONS FOR AGRICULTURE

THEME	RISK MANAGEMENT ACTION	EXPECTED BENEFITS	PRIORITY REGION(S)
Agricultural practices and ancestral knowledge	Water and irrigation (e.g. placing water pools/tanks between/around crops)	Reduced sensitivity of soil to drought, frost and glacial retreat	Dry and cold areas
	Use of organic fertilizers and crop residues	Reduced sensitivity of soil to drought and frost	Dry and cold areas
	Crop diversification and intercropping	Reduced livelihood sensitivity to multiple hazards	Everywhere
	Topographical planning (e.g. considering variations in exposure at different altitudes/locations)	Reduced exposure to frost and other hazards	Highland valleys
Water management	Irrigation (extension and maintenance of existing infrastructure)	Reduced sensitivity to droughts, frost and glacial retreat	Dry and cold areas
	Water storage, e.g. through dams or small rain-fed reservoirs	Reduced sensitivity to droughts, frost, floods and glacial retreat	Highlands
	Groundwater use (wells and capacity development)	Reduced sensitivity to water scarcity (e.g. from droughts and glacial retreat)	Highlands
	Reforestation in water catchments and for a better microclimate	Reduced sensitivity to water excess and scarcity, and to temperature variations	Water catchment areas
Finance and markets	Access to markets and financial services to facilitate investment	Improved incomes and investment, and therefore better adaptive capacity	Small and medium farmers
	Agricultural insurance to transfer and pool risk	Risk transfer and pooling	Small and medium farmers
Data monitoring and information management	Improved collection, processing and access to data and information on climate hazards and risks	Improved adaptive capacity, better decision-making	Everywhere
Non-agricultural strategies	Livelihood diversification	Less income sensitivity to climate impacts on agriculture	Smallholder farmers

GOVERNANCE

The priority actions and research needs identified here require adequate institutions and policies at the national level to enable and facilitate their implementation. The recommendations stemming from the conclusions of the previous section, along with suggestions on the integration of climate risk management policy from a workshop held as part of CRM TASP (MINAM et al., 2011) and inputs from MINAM (2010a), can be summarized under the following three themes: integration of climate change adaptation

and disaster risk management institutions and policies, mainstreaming of climate risk into key public policy documents, and capacity development. A final paragraph proposes the formulation of a national programme to promote a coherent and holistic approach to climate risk management.

As outlined in the previous section, while coordination processes have been elaborated within both the climate change adaptation and disaster risk management agencies, there is a need for improved and formalized coordination between the two areas. Although both communities mention the other field in their respective plans and laws, no formal collaboration mechanisms exist. Furthermore, responsibilities between INDECI and CENEPRED are not clearly defined, and formal and direct coordination is not operationalized.

A policy workshop held in November 2011 as part of the CRM TASP resulted in the following recommendations for improving coordination at the national level, among others:

- The Presidency of the Council of Ministries needs to have a stronger role in leading and coordinating activities between CENEPRED and INDECI, the two main disaster risk management institutions. The role of the two organizations needs to be specified more clearly.
- The Ministry for Economy and Finance needs to coherently prioritize public spending on risk reduction and adaptation and incorporate adaptation into public spending decisions, which already contain an analysis of current risks.
- CEPLAN, the National Centre for Strategic Planning, needs to integrate adaptation and risk reduction coherently and consistently into its national and sectoral strategic planning.
- Sectoral strategies should integrate adaptation and risk reduction. The current elaboration of the 'National Plan on Risk Management and Adaptation to the Adverse Effects of Climate Change in the Agrarian Sector for the Period 2012–2021' is a prime example of this.
- MINAM needs to integrate disaster risk management more thoroughly as part of the ongoing revision of the 'National Climate Change Strategy' and in the upcoming 'Third National Communication to the UNFCCC'.
- CENEPRED and INDECI should take part in the National Commission on Climate Change (CNCC).

Similar processes can be developed at the regional and local levels. For example, the development strategies of regional governments should mainstream adaptation and risk reduction at the same time. The same is true for watershed plans and private sector planning. Disaster risk agencies such as the Red Cross should start to take into account the future evolution of climate risks. Universities play a role, too, with respect to integrated climate risk analysis.

An inter-institutional dialogue should be stimulated and formalized between the disaster risk management and climate change adaptation communities to coordinate work and deliberate on options for further integration of the two areas, possibly leading to more radical solutions, such as the formal merging of agencies.

As pointed out above, certain considerations for climate risk are already mainstreamed into national and sectoral policy documents. In agriculture, the 'National Plan on Risk Management and Adaptation to the Adverse Effects of Climate Change in the Agrarian Sector for the Period 2012–2021' is currently in elaboration. It is important, however, that adaptation and risk reduction be incorporated into not only separate strategies but the main sectoral policy documents, that is, into the agricultural strategy itself. Furthermore, the same processes should be promoted at regional and local levels.

Peru has relatively good capacities to deal with climate risks. Many government institutions have benefited from capacity development programmes and have a good staff base, both in quantitative and qualitative terms. Many initiatives are still ongoing (Adaptation Partnership, 2011), and the CRM TASP has also contributed to building further capacities in the two focus regions of Junín and Piura and at the national level. Future capacity development should focus more specifically on the regional and local level and on specific sectoral needs. For example, the capacity to assess specific risks in agriculture still appears to be limited.

Towards a comprehensive climate risk management programme

This report has shown the need both to step up efforts to manage climate risk and to coordinate better among different institutions, policies and actions in order to do so effectively and efficiently. It is therefore recommended that a comprehensive climate risk management programme be formulated that integrates the recommendations made above through the following key elements:

- Integration of disaster risk management and climate change adaptation approaches with each other and into sectoral and national development planning with a view to delivering comprehensive and coherent solutions in terms of actions, policies and research. This will require better coordination among existing bodies, and possibly a reform of the current complex structure, with simplified and overarching protocols and mechanisms that allow for effective coordination, prioritization and implementation of policies and actions.
- Sector- and region-specific risk assessments and management programmes, following the recommendations made in this report, for the two watersheds, but tailored to the respective needs of vulnerable areas and sectors. Even for well-studied sectors such as agriculture, enormous knowledge gaps exist. Many regions and watersheds have hardly been studied at all. These should be identified and prioritized for future assessments.
- Improvement of data collection and information management, including the provision of free access to a centralized system of climate data and risk information and the establishment of an integrated early-warning system, as per the suggestions made in 'Priority Actions' (pp. 42–44).
- Capacity development for key institutions involved in climate risk management, especially at regional and local levels.

The proposed climate risk management programme should be closely connected to the many existing initiatives, plans, programmes and agencies in the area. For example, activities should aim to establish synergies with programmes such as the Disaster Preparedness Programme of the European Community Humanitarian Aid Office, and any policy recommendations should be mainstreamed into documents like the 'Action Plan on Adaptation and Mitigation.'

FURTHER RESEARCH

Although the analysis presented has identified a number of key climatic risks for the agricultural sector, more detailed and comprehensive assessments are needed. As the 'Institutions and Policies for Climate Risk Management' section (pp. 41–45) notes, few quantitative risk evaluations exist, either regarding climate hazards or in terms of vulnerability, both for agriculture and other sectors. On the climate side, return periods for extreme events should be calculated, and better regional and local climate projections should be elaborated. This will in large part depend on the advances made regarding improved collection and processing of present climate data, but will also require investments in human resources and equipment. Emerging hazards should receive particular attention. Sea level rise, for example, has received little attention so far. Potential impacts related to glacial retreat, such as changes in river run-off and glacial-lake outburst floods, have been studied in various research projects, yet given the likely scale of the threat, more comprehensive investigations are needed in terms of territorial coverage and different risk factors and risk management solutions. As climatic and hydrological projections evolve and improve, risk studies must be updated continuously.

On the vulnerability side, impacts of current and future climate phenomena should be studied more thoroughly. In agriculture, for example, studies such as the two agroclimatic assessments presented in this report could cover more areas and crops and more comprehensively quantify impacts on yields. For future risks, crop modelling for key cultures such as potatoes and maize could yield much better insights. It would be useful to add economic evaluations to impact studies in order to compare the cost of adaptation options with the avoided cost of climate risks. It is also important to conduct integrated studies on both current and future climate risks using innovative combinations of methodologies, as well as evaluations that provide targeted information to decision-makers.

On the agronomic side, research should focus on varieties and crops that are more resistant to the main climate hazards in each region, as well as to plagues and diseases in general. It should also look at technological innovations and agricultural practices, such as changes in the crop calendar, and how they can reduce climate risk.

Key messages: Recommendations for climate risk management

- To reduce climate risks in agriculture, we recommend efforts to improve agricultural practices, including by means of reviving ancestral methods, improving water management and irrigation, providing access to markets and financial services, diversifying livelihoods, climate-proofing local infrastructure, and managing information and data on climate and vulnerability.
- A comprehensive climate risk management programme to holistically implement these recommendations should be established.
- On the policy level, we recommend coherent and thorough integration of climate change adaptation and disaster risk management agendas and structures. The two themes should be fully integrated into sectoral and national strategies, and specific capacity development needs in different sectors and at the regional and local level should be addressed.
- Further research could improve knowledge of climate risks in agriculture by means of deeper and more comprehensive studies on climate events and trends, as well as on physical and socio-economic impacts and risk management options. New threats such as those related to glacial retreat should receive special attention.

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