Climate Change Adaptation Planning in Latin American and Caribbean Cities

FINAL REPORT: CUSCO, PERU

Kingdom of the Netherlands

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Climate Change Adaptation Planning in Latin American and Caribbean Cities

A report submitted by ICF GHK
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Abbreviations

ACI……………………………………………………………………………..….Adaptive Capacity Index

ANUSPLIN………………………………………..Professional interpolation software for meteorology data

ASAPASC……………………………….………South Zone Sewage and Water Services Association
Asociación de servicios de agua potable y alcantarillado de la zona Sur - Cusco

CENEPRED............................National Centre for Disaster Risk Estimation, Prevention and Reduction
Centro Nacional de Estimación Prevención y Reducción de Riesgo de Desastres

CEPLAN…………………………………………………………..…National Centre for Strategic Planning

CGPA….……………………………………………………………………Guamán Poma de Ayala Centre
Centro Guamán Poma de Ayala

CIAT………………………………………………………………………..Center For Tropical Agriculture

COCIPREDE…..Scientific Committee of Disaster Prevention
Comité Científico de Prevención de Desastres

COPESCO...Special Regional Project Plan
Proyecto Especial Regional Plan

DGCCDRH……………..Directorate General for Climate Change, Desertification and Water Resources
Dirección General de Cambio Climático, Desertificación y Recursos Hídricos

ENSO…………………………………………………………………………..EL Nino/Southern Oscillation

FAO……………………………………………………United Nations Food and Agriculture Organization

FONAM…………………………………………………………………National Fund for the Environment
Fondo Nacional del Ambiente

GEF…………………………………………………………………………Global Environmental Facility

GDP………………………………………………………………………………Gross Domestic Product

GHCN………………………………………………………………..Global Historical Climatology Network

GRCUSCO………………………………………………………………………Cusco Regional Government

HDI……………………………………………………………………………Human Development Index

IGP…………………………………………………………………………...Geophysical Institute of Peru
Instituto Geofísico del Perú

IIAP………………………………………………………………Peruvian Amazon Research Institute
Instituto de Investigaciones de la Amazonía Peruana

IMA…………………………………………………………Water Management and Environment Institute
Instituto de Manejo de Agua y Medio Ambiente

INDECI………………………………………………………………………National Civil Defence Institute
Instituto Nacional de Defensa Civil

INEI…………………………………………………………….National Institute of Informatics and Statistics
Instituto Nacional de Estadística e Informática

INRENA…………………………………………………………….National Institute of Natural Resources
Instituto Nacional de Recursos Naturales

IPCC……………………………………………………………Intergovernmental Panel on Climate Change

ITCZ……………………………………………………………………..…Inter-Tropical Convergence Zone

LAC……………………………………………………………………………..Latin America and the Caribbean

MINAM………………………………………………………………………….....*Ministry of the Environment*
Ministerio del Ambiente

MPC……………………………………………………………………………....Cusco Provincial Municipality
Municipalidad Provincial del Cusco

MEF……………………………………………………………………………..Ministry of Economics and Finance
Ministerio de Economía y Finanzas

ODENA……………………………………………………………………………....National Defense Office
Oficina de Defensa Nacional

PACC……………………………………………………………..…… Climate Change Adaptation Programme
Programa de Adaptación al Cambio Climático

PAT…………………………………………………………………………………Urban Development Plan
Plan de Acondicionamiento Territorial

PCM………………………………………………………………………………..Office of the Council of Ministers
Presidencia del Consejo de Ministros

PENTUR……………………………………………………………………Strategic National Tourism Plan
Plan Estratégico Nacional de Turismo

PPAD…………………………………………………………National Disaster Attention and Prevention Plan
Plan Nacional de Prevención y Atención de Desastres

PRECIS…………………………………………………………..Providing Regional Climates for Impact Studies

PREDES………………………………………………………..........Centre for Disaster Study and Prevention
Centro de Estudios y Prevención de Desastres

PRONAGCC……………………………………National Program for the Management of Climate Change
Programa Nacional para la Gestion del Cambio Climático

R-HYDdronet…..…Regional, Electronic Hydrometeorological Data Network for South America, Central America, And The Caribbean

SEDA………………………………………………………………………… Public Sanitation Services Company
Empresa Pública de Servicios de Saneamiento

SENAMH………………………………………………………… National Meteorology and Hydrology Service
Servicio Nacional de Meteorología e Hidrología

SDC…………………………………………………………..Swiss Agency for Development and Cooperation

SINAGERD………………………………..……………….............National Disaster Risk Management System
Sistema Nacional de Gestión del Riesgo de Desastres

SNIP…………………………………………………………………….....National System of Public Investment
Sistema Nacional de Inversión Pública

SRTM…………………………………………………………………………Shuttle Radar Topography Mission

SUNAT…………………………………………………………………………………………….National Tax Office
Superintendencia Nacional de Aduanas y Administración Tributaria

UBN…………………………………………………………………………………….Unsatisfied Basic Needs

UNEP……………………………………………………………………..United Nations Environment Programme

UNESCO………………………………….....United Nations Educational, Scientific and Cultural Organization

UNSAAC……………………………………………………….…….National University San Antonio Abad del Cusco
Universidad Nacional de San Antonio Abad del Cusco

USDA…………………...………………………………………………United States Department of Agriculture

WCRP………………………………………………………………..….World Climate Research Programme

WMO…………………………………………………………………….....World Meteorological Organization

Glossary

The following glossary is from the United Nations' International Strategy for Disaster Reduction (UNISDR) terminology on disaster risk reduction (2009 version). The terms are defined by a single sentence. The comments paragraph associated with each term is not part of the definition, but is provided to give additional context, qualification and explanation.

Adaptation

The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Comment: This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence. Adaptation can occur in autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Many disaster risk reduction measures can directly contribute to better adaptation.

Capacity

The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions.

Comment: Capacity development is a concept that extends the term of capacity building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment.

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

Comment: This definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Comment: The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

Disaster risk

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Comment: The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.

Exposure

People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Comment: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Comment: In meteorology a forecast refers to a future condition, whereas a warning refers to a potentially dangerous future condition.

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Comment: The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are "… hazards of natural origin and related environmental and technological hazards and risks." Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.

Mitigation

The lessening or limitation of the adverse impacts of hazards and related disasters.

Comment: The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Risk

The combination of the probability of an event and its negative consequences.

Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time.

Source: extracts from UNISDR terminology (2009 version), http://www.unisdr.org/we/inform/terminology

Executive summary

The *Climate Change Adaptation Planning in Latin American and Caribbean Cities* project is designed to inform policy making and climate change adaptation planning in small and medium-sized cities. The focus is on floods and landslides, which are two of the most common climate-related risks in cities across the Latin America and Caribbean region.

Five cities were selected for involvement: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Esteli, Nicaragua and Santos, Brazil. For each city, five main activities were carried out:

1. A climate-related hazard assessment focused on floods and landslides
2. An urban, social and economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. A climate-related vulnerability assessment; and
5. Based on the findings of the four assessments, a combined strategic climate adaptation institutional strengthening and investment plan, intended to complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The figure below graphically shows the process and main activities carried out under the project.

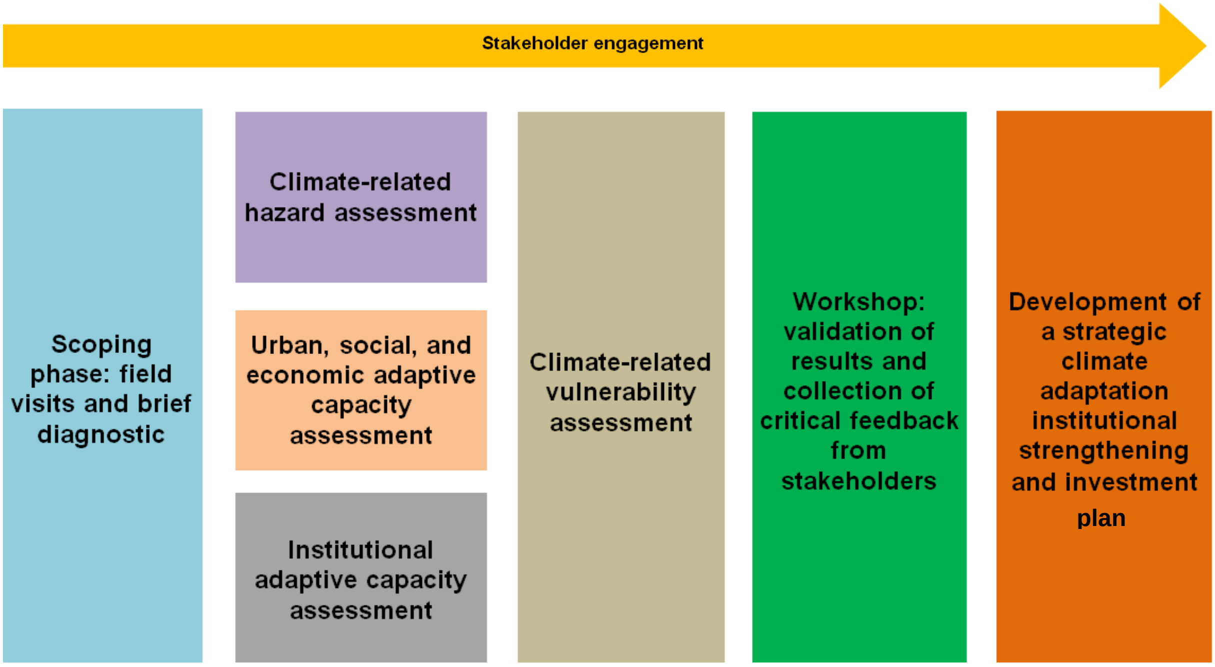


Figure 0.1: The process and main activities of the project

A summary of key findings of this report now follows.

Understanding the problem of flooding and landslides

Climate-related flood and landslide hazard risks

High in the Andes Mountains at 3,400 meters above sea level, Cusco sits in a valley within the upper basin of the Huatanay River. The city is located at the confluence of the Huatanay and Saphy rivers, and is marked by irregular topography, seismic activity, and the presence of small river micro-basins and water streams. The combination of these characteristics, together with accelerated and largely unplanned urban expansion, expose Cusco to a wide variety of natural disasters, including earthquakes, landslides, and floods.

Floods have been the most frequently reported weather-related disasters in Cusco, with 111 flood-related events recorded from 1970 through 2011. There have also been a total of 39 landslides reported over the 41 year period. The Cusco area is threatened by flooding from both overland flow and riverine flooding. Flooding in the city is seasonally marked: it regularly occurs during the rainy season. During this period, stream levels are high from the increased precipitation and as a result of the warm temperatures melting the Andes snow and glacial ice. Within the city, the overflow of small river micro-basins is caused by either long periods of rains or short intense storm events. In turn, this results in the flooding of streets and houses, which is exacerbated by the lack of an efficient drainage system in many areas. Furthermore, when floods cause the Huatanay River and its tributaries to overflow, Cusco faces water pollution caused by wastewater discharge and littering, thus threatening the preservation of the urban area's natural environment.

Landslides also represent a hazard for much of the population of Cusco, particularly those inhabiting steep slopes of the Andes towards the north, east and west of the central part of the city. Earthquakes and landslides are interrelated, as historically the former could trigger the latter. Cusco is located in an area of deep seismic activity where the Nazca and American Continental plates meet: seismic activity can contribute to slope movement and stability, thus unleashing landslides. However, it is important to underline that although landslides in Cusco have been traditionally related to seismic activity and the location of geologic faults, recent developments illustrate that climatologic events also have an influence upon them: the most recent landslides have been triggered by heavy precipitation events or sustained periods of rain.

Although there is a degree of uncertainty associated with the climate projections undertaken during the assessment, the results indicate that by the 2040s, the rainy season may be intensified and extended by a few months, which would slightly increase precipitation. This would thus also result in an increased possibility of floods and landslides. However, projections also suggest that there could be a reduction in the intensity of rainfall during precipitation events: i.e., there could be more frequent, yet less severe rainfall events, which might ultimately moderate the possibility of floods and landslides.

The aforementioned uncertainty is further complicated by Cusco's variable terrain, which can lead to large differences in precipitation received in one location versus another. The findings presented here should be carefully applied to the municipal planning within the context of this uncertainty. Concerning floods, the analysis performed reveals that the areas identified as prone to flood events are projected to continue to cause concern to Cusco in the 2040s. The change in landslide hazard is less clear; some regions may experience an increase in activity while others experience a decrease.

Urban development and exposure to disaster risk and climate change

The urban area of Cusco is marked by a long-run expansion and settlement pattern, dating back to the Inca period and followed by the Spanish occupation. This process had a significant impact in shaping Cusco's current urban structure and layout: due to its geographical location in a valley, Cusco has grown following a linear, horizontal and low-density pattern, covering in this fashion all available space. Nowadays, the urban area is spread across five of the province's districts: Cusco (including the historic centre), Santiago, San Sebastián, San Jerónimo and Wanchaq.

With a population of 407,488 in 2011 (INEI, 2011), Cusco is still going through an important phase of urban expansion. As an important economic centre, it is a hub for in-migration, attracting people from the surrounding region and the rest of Peru, and mostly from rural areas. Within the department of Cusco, there is a marked division between the largely urban province of Cusco and other provinces: the widening development gap between the urban and rural areas generates a continuous flow of in-migration.

The formation of new urban areas in Cusco is not following urban plans and development control regulations, and a large percentage of households lack basic services: it is estimated that informal growth has accounted for approximately 80 percent of the total urban expansion in recent years (MPC, 2006). A considerable group of newly-arrived migrants locate in areas not designated for habitation, for example, archaeological, ecological protection, forestry, agricultural and hazard risk areas. Areas at greater risk have been identified in the north-west slopes, in Pichu, Ayahuico, and the Saphy River basin. San Sebastian district is at high risk from landslides, while the Wanchaq district, where middle-class residents predominate, is the only area where no risk has been identified. Overall, the Urban Planning Unit of MPC estimates that up to 40 percent of Cusco's population is located in risk areas, this rising to up to 60 percent of the population in the city's northwest neighborhoods.

A close look at social and economic variables in Cusco allows the determining of poverty disparities amongst the five districts that compose the city: poverty is only negligible in Wanchaq, as all other districts experience poverty rates of above 25 percent. Cusco is also marked by a particular form of urban morphology present throughout the city, and which intertwines with poverty: the low-income urban fabric is characterized by adobe or quincha dwellings. Adobe and quincha are local construction materials derived from mud, which have been used by low-income groups since the Inca period. Adobe remains nowadays as the predominant material used by low-income households that informally settle in the periphery of Cusco (Tarque et al, 2009). According to the 2005 INEI census, around 80 percent of the building stock in Cusco is made of adobe (ibid). Adobe dwellings are the most vulnerable buildings in Cusco (Benavente et al, 2004).

The city is currently horizontally expanding towards the northwest and southeast peripheral suburban areas. At the same time, due to the fact that land in central areas is increasingly becoming expensive and scarce, a vertical urban growth model has also emerged, notably in the denser districts of Wanchaq, Santiago and Cusco. Recognizing the urban planning challenges that the city of Cusco faces, the MPC has developed planning instruments in order to attempt to orient growth in a more sustainable pattern. The “2006-2016 Cusco Territorial Planning Map” and the “2006-2011 Cusco Province Urban Development Plan” present a general overview of the social, economic and environmental issues in the Cusco region. In addition to identifying risk areas in each district, perhaps more significantly they present a tendency, and probable scenarios for urban expansion.

The analysis undertaken in the assessment phase illustrated that there is a manifest geography of vulnerability in Cusco. Combining the sensitivity of settlements with the adaptive capacity of dwellings allowed identifying what are the most vulnerable districts amongst the five districts making up Cusco:

- The sensitivity of the settlements within each district was ranked based upon two metrics: percentage of households with adobe and the density of the urban population. The percentage of adobe households was used as a proxy to suggest the proportion of housing that are less able to withstand landslides and may suffer more damage during a flood. The density of the urban population suggests the amount of the population that might be affected by the hazard and/or areas more prone to affect population if the hazard were to occur (either directly or indirectly).
- The adaptive capacity within the settlements was based upon two metrics: poverty levels and households with unsatisfied basic needs (UBN). These metrics were used based upon the assumption that settlements that rank high will be less capable of responding to and/or protecting against the hazard.

The vulnerability analysis to floods and landslides performed concluded that Wanchaq, Cusco and San Jerónimo present medium levels of vulnerability, while Santiago and San Sebastián are marked by high levels of vulnerability.

Institutional vulnerability issues

Peru’s Disaster Risk Management (DRM) legal framework has recently been through significant changes. In 2011, Law 29 664 was published, creating a National System of Disaster Risk Management (Sistema Nacional de Gestión del Riesgo de Desastres – SINAGRED). The law divides Peru’s DRM scheme into two main components: the National Civil Defence System (Instituto Nacional de Defensa Civil – INDECI) is the government organ responsible for coordination and response when a disaster occurs, while the National Centre for Disaster Risk Estimation, Prevention and Reduction (Centro Nacional de Estimación Prevención y Reducción de Riesgo de Desastres – CENEPRED) is in charge of preparedness and reconstruction efforts.

As part of SINAGRED, regional and local governments are responsible for establishing work groups, integrated by senior government officials, to develop and execute DRM strategies. Under the law, presidents of regional governments and local mayors are the apex authority in charge of supervising, leading and executing disaster risk management processes. As such, in Cusco the MPC leads the actions in the DRM system. Within the Provincial Municipality, the Committee of Civil Defence, part of the Office of Civil Defence, is the leading government organ in terms of disaster preparedness and relief. It is chaired by Cusco’s Provincial mayor. The Committee is a permanent government organ responsible for preserving the physical and material integrity of the population in the event of a disaster. It leads institutional coordination when emergencies and disasters occur, and has acted as the local operative cell of INDECI for the past 30 years.

Although Cusco's local DRM system benefits from this sound structure, challenges persist. The city's devolved governance system can complicate the coordination of DRM strategies: each district has its own mayor, civil defense and planning unit, which has resulted in an uneven application of risk management strategies across the entire urban conurbation. In order to take full advantage of the localised and democratic nature of municipal governance in Cusco, greater collaboration and coordination is required across all districts.

Most importantly, a core challenge faced by municipal institutions in Cusco is the need to reconcile economic growth with reduction in risk and vulnerability. As a start, joining the agendas of tourism and city level climate change adaptation would strengthen both sectors of activity: population growth, in-migration and tourism are leading causes of uncontrolled building and construction activity in the city, placing increasing pressure on already stressed public services and infrastructure. It will be a daunting challenge for city officials to balance socio-environmental risk with economic priorities and the promotion of an expanding city that serves as a commercial and regional hub. Unless this balance is achieved, the potential for disaster and loss remains high, with no clear strategy for long term growth and planning at the city level.

Further, the institutional assessment identified as a challenge the existence of a gap between policy initiatives for planning and adaptation, and the capacity of government agencies to implement, regulate, and enforce these measures. The centralised nature of Peru's government facilitates national planning but the strength of climate change institutions at the national level has also resulted in weak local adaptation capacity as municipal governments await direction and budgetary resources from above. Cusco is also characterized by a low level of institutional capacity, resources, and flexible management systems. Implementation of procedures and regulations that require technical and human resources is poor due to a lack of funding and capacity, and will need to be improved to deal with increased risks associated with climate change.

Despite the institutional weaknesses discussed, there are emerging opportunities and a variety of positive steps to build on, including the on-going work on climate adaptation at the local level. There is considerable capacity in Cusco to take further action to not only increase resilience but also to operationalize planning in order to reduce vulnerability, climate-related and otherwise. Efforts towards improving the availability of information on risk and response measures to risk managers and at risk populations appear to have resulted in a much greater impact in increasing overall risk identification and planning capacity in the city.

Strategic climate adaptation investment and institutional strengthening plan

The findings of the assessments provide a basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sectoral plans and planning instruments in Cusco. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Cusco in March 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be linked or incorporated into existing priorities, sectoral plans and planning instruments, and form part of an overall climate change adaptation strategy for Cusco.

Cusco has taken significant steps in enhancing its institutional capabilities in disaster risk reduction. The World Bank has supported such efforts through various programs. The Cusco Regional Development Project, which includes disaster risk management as a core component, aims at conciliating environmental risks and concerns with tourism policy. The project could act as a first step in merging the climate change and local economic development agendas, and thus mainstream climate change adaptation as a main policy consideration. Framing adaptation in line with overall development priorities can prove to be crucial. If adaptation is mainstreamed within the existing institutional structures and developing objectives, including poverty reduction, exposure to climate hazards can be significantly reduced.

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Cusco. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process. Finally, a set of specific actions that can be undertaken to implement climate change adaptation measures are proposed.

The planning themes that create the foundation for a climate change adaptation strategy to help Cusco build its resilience against floods and landslides, both now and in the future, are:

(i) Coordinated risk management and planning across all districts of Cusco; (ii) capacity building in national and city level government institutions engaged in climate change planning and risk management; (iii) mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing; (iv) improved budgetary resources and climate financing for long-term recovery and building resilience against climate change hazards; (v) cross-scale integration of risk management practices; and (vi) a shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance.

An integrated strategic plan requires the use of both structural and non-structural measures. Our proposed measures thus follow a “no-regrets” approach, and they include, *inter alia*: additional financing for the public investment project (Proyecto de Inversion Publica – PIP) for the head waters of the Saphy river; enhance the implementation of zoning and land use planning instruments; improve data collection; improved waste management measures and incorporation of risk management into solid waste projects; work towards establishing integrated approaches to reducing risks; and improved efforts into linking tourism and adaptation priorities.

The timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments and action. The main challenge for policy- and discussion-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term risks and embraces uncertainty. The ability and willingness of key actors to address climate change impacts will be of utmost importance.

1 Introduction

1.1 About the project

An ICF GHK consortium was commissioned in May 2012 by the World Bank's regional Urban and Disaster Risk Management Unit for Latin America and the Caribbean (LAC) (LCSDU) to carry out second phase activities for the initiative *Climate Change Adaptation Planning in Latin American and Caribbean Cities*. This initiative started in April 2010 and will be completed in 2013.

The wider initiative seeks both to build and to strengthen capacities for adaptation to climate change in LAC cities. The primary focus is cities in the region less likely to have had access to climate change (CC) adaptation training, finance, or knowledge networks. In practice, this implies a focus on medium and small-sized cities, as larger cities have more human and financial resources to draw on.

Five medium-sized cities were therefore selected: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Esteli, Nicaragua and Santos, Brazil.[1] The first phase involved an initial institutional mapping and rapid diagnostic for the initiative. The second phase assignment's objective is to inform policy making and adaptation planning at the city level by incorporating local and international technical knowledge, tools and expertise into existing planning structures to better respond to the adverse effects of climate change.

The emphasis is on floods and landslides, which are two of the most common climate-related risks in cities across the LAC region. Poorly planned and managed urban development and spatial expansion also contributes to flood and landslide hazard risks. **The ultimate goal is to strengthen local adaptive capacity and to increase urban resilience through mainstreaming climate change adaptation into current planning systems.**

For each involved city, there were four main activities specified for the second phase:

1. A climate-related risks assessment focused on floods and landslides
2. A socio-economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. Based on the findings of the three assessments, a combined strategic climate adaptation institutional strengthening and investment plan, which will complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The outputs from the above-mentioned activities in this assessments report constitute a critical input for the main output of the overall initiative in its third phase: a regional Guidebook for city officials on urban adaptation to climate change.

1.1 Outline of the report

This report is divided into the following sections:

- ***Climate-related hazard assessment.*** This section first provides an assessment of current coastal and inland flood risk and landslide risk for Cusco. It then considers how climate change may impact these existing flood and landslide hazards in the future.
- ***Urban, social and economic adaptive capacity assessment.*** The section assesses how vulnerability to climate-related hazards is linked to topographical, human settlement and urban development characteristics: the location and condition of settlements and the materials used in their construction have a direct impact in the level of exposure they

[1] The selection of the pilot cities was based on the following: a) survey results from Phase 1 of the project; b) diversity of geographic region and climate; c) recommendations provided by World Bank staff leading operational activities across LAC, ensuring the cities' political willingness, interest, and commitment to working with the initiative; d) prevalence of floods and/or landslides as major climate change-related risks; and e) availability of climate risk-related data.

have for landslide and flood risk. Studying these variables allows assessment of how the urban development trajectory of Cusco impacts upon climate change vulnerability in the city.

- ***Institutional adaptive capacity assessment.*** The institutional assessment focuses on the disaster risk management and urban planning structures and capacities of institutions and stakeholders in Cusco and how they take into account and incorporate climate change adaptation.
- ***Climate-related vulnerability and risk assessment.*** Using the information from the three previous assessments, this section synthesizes information on landslide and flood vulnerabilities, focusing on physical risk, urban, social and economic conditions and institutional arrangements to create maps that identify the most vulnerable areas and populations within the city exposed to flood and landslide hazards. The analysis considers the exposure, sensitivity, and adaptive capacity of settlements and critical infrastructures to flood and landslide hazards, and provides an informative screening of which settlements and critical infrastructures are more likely to be affected by and be vulnerable to landslides and floods some 30 years into the future (i.e., the 2040s).
- ***Strategic climate adaptation investment and institutional strengthening plan.*** The *Climate-related vulnerability assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sector plans and planning instruments in Cusco. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The above-mentioned assessment approach is broadly consistent with the Urban Risk Assessment (URA) tool developed by the World Bank, but at the same time incorporates aspects that can add a dynamic element to the analysis. [2]

Assessments in the URA tool are associated with three levels of complexity (primary, secondary, and tertiary). The primary level provides an 'entry point' to assess the challenges posed by climate-related hazards. The secondary level provides a more 'refined' analyses to identify and map the most vulnerable areas and populations exposed to climate-related hazards and to consider how hazards may change in the future. Finally, the tertiary level undertakes specific probabilistic risk assessments and makes use of advanced risk management tools.

Progression from the primary to the tertiary level in any city or town is dependent upon the availability of what can be significant amounts of data, the technical capabilities of relevant staff and actors, and the ability and willingness of politicians, officials and others to commit what can amount to not inconsiderable financial resources and time to conducting assessments – and to building policy, strategy and action plans on the basis of findings. Box 1 below elaborates on our experience for the case of Cusco.

Box 1 Using the URA for Assessment in Cusco

The Terms of Reference for the phase two activities described above derives from the World Bank's Urban Risk Assessment tool. As will be seen in the sections of this report which follow, we were able to apply the URA approach to guide and create our assessments for each city, in a process which saw good collaboration with local governments and other stakeholders.

Some provisos are nonetheless required. The URA is avowedly a flexible tool, as it needs to be. In Cusco, data availability and time and resource constraints meant the following adaptations to the 'pure' URA approach:

1. **Climate-related risks assessment for floods and landslides**: It was possible to assess present-day current flood and landslide hazard levels, which are well-understood and the subject of much study for the city. After much discussion, local-level precipitation data was made

[2] World Bank (2011) *Urban Risk Assessment: An Approach for Understanding Disaster and Climate Risk in Cities*. Urban Development and Local Government Unit; Finance, Economics and Urban Department, The World Bank.

available which allowed consideration of the likely impacts of climate change and, consequently, a projection of changes in hazard levels for a period of some 30 years in the future. Full assessment of the risk levels for the flooding and landslide hazards, both currently and for the future, was not possible as the financial and demographic data necessary was not readily available to us. In addition, the prediction for future changes in hazard levels on account of climate change is broad-brush rather than detailed, as this level of detail requires such efforts as hydrologic/hydraulic modelling under future scenarios. This certainly does not preclude future elaboration of risk levels (i.e. detailed risk assessment) in the future on the part of government authorities and other stakeholders in Cusco. The findings of our analysis based on simpler approaches can in fact provide guidance regarding the best use of funds for conducting such a vulnerability and risk analysis (e.g., which hazards are likely to worsen, are there potential hotspots where hazards may get even worse, amongst others.). The first assessment in this report is therefore titled – and more correctly seen as – a climate-related hazard assessment.

2. **Socio-economic adaptive capacity assessment**: in Cusco, the reasonably good availability of data meant that it was possible, within the time frame, to conduct socio-economic assessment, and ascertain the exposure and sensitivity of urban residents to current and future flood and landslide hazards. We attempted to add to and 'thicken' the URA approach with more detailed consideration of the dynamics of both urban and economic growth, change and development for Cusco, within its broader 'metropolitan' and regional spatial contexts. Adding this dimension makes assessment more dynamic (i.e., 'adaptive') – accordingly, we have re-titled this assessment to emphasize these urban and economic aspects.
3. **Institutional adaptive capacity assessment**: the real willingness of stakeholders to share their experience in planning, primarily for urban development and disaster risk, rather than climate change itself, permitted a full assessment within the time frame. Our assessment attempted to incorporate the dimension of how institutions in Cusco had changed over time, notably in the past decade, again to stress the element of dynamism that has (or may have) inhered to the institutions under study.
4. **Climate-related vulnerability and risk assessment**: to compensate for the limitations on risk assessment, we developed a wider vulnerability assessment than originally intended. This is based on the findings of the three preceding assessments, and identifies and maps, to the degree possible, the most vulnerable neighborhoods, populations and infrastructures within the city that are exposed to floods and landslide hazards both currently and in the future. This should be seen as an overview of vulnerability, rather than a full assessment: this vulnerability 'screening' could usefully be complemented by fuller and more detailed vulnerability analysis on the part of local stakeholders in the future. The assessment concludes with a section on risk information, which suggests studies and data collection activities to continue the development of pertinent risk information for Cusco.
5. **Combined strategic climate adaptation investment and institutional strengthening plan**: In a workshop in March 2013 in Cusco, there was enthusiastic participation by stakeholders in discussing initial assessment findings and suggesting future strategy and concrete measures for adapting to current and future flood and landslide hazard risks. This interaction forms the basis for the plan as outlined in this report. It should be emphasized that, by design, this plan has no particular institutional affiliation or 'official' status – it, and the assessment and analysis upon which it is founded, now stands as a contribution offered to a debate that is already occurring on climate change adaptation in Cusco. Again, stakeholders in Cusco will be able to adopt and elaborate the measures proposed as they see necessary.

1.2 Context and study area

Cusco is located within a unique setting. Its urban expansion and layout are closely linked to its history, as well as its natural environment. Peruvian pre-Hispanic societies were hugely innovative in that they managed to successfully adapt to the irregular topography of the Andes. Cusco started to emerge as an urban area from the 13th Century, and became the capital of the Inca Empire (Carazas Aedo, 2001).

The city's location on a valley surrounded by mountains shaped its urban structure. The Inca city was constituted by uniform square blocks and the presence of squares. Local construction materials, such as *adobe*[3], were typically used (Carazas Aedo, 2001). With the arrival of the Spanish, the city was transformed. Nonetheless, the Spanish urban layout was similar to the one present in the Inca city, as many of its elements were similar: squares, uniform blocks, and streets. This superposition of different urban layers constitutes Cusco's identity and uniqueness.

Due to its distinctive urban history, Cusco was declared a UNESCO World Heritage Site in 1983. Historic preservation constitutes a major asset, but also a challenge as the city expands. Tourism is a major economic activity in the city, and there is a specialized government agency – COPESCO – which promotes tourism economic development policy and associated investments. As it will be seen further on in this report, Cusco's urban, social and economic structure, as well as the construction techniques present in the region, have an impact in the exposure of the city to climate-related events.

Cusco simultaneously denotes a region (or department), province and city. Cusco Department is one of Peru's 25 regional administrations (this designation covers the national territory, with the exclusion of Lima Province). Cusco also forms a province within the department. Defined as a city, Cusco's urban area had a population of 407,488 in 2011 (INEI, 2011). The urban area is spread across five of the province's districts: Cusco (including the historic centre), Santiago, San Sebastián, San Jerónimo and Wanchaq (Figure 1.1).

Due to the city's complex administrative configuration, urban boundaries are not clearly defined in jurisdictional terms (Figure 1.2). The Cusco Provincial Municipality (MPC) is responsible for urban planning and local development. At the same time, each district has the specific role of approving District Urban Plans. The MPC leads the urban development process, taking into consideration the initiatives stemming from district municipalities.

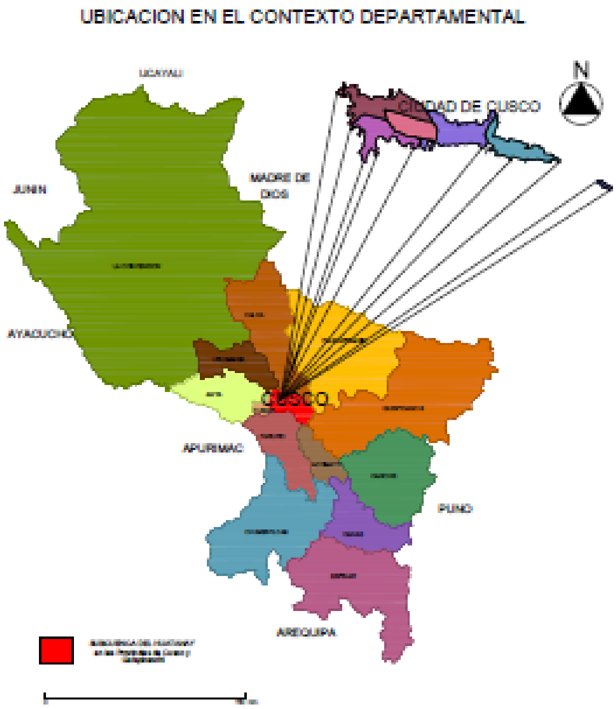


Figure 1.1 The Province and City of Cusco within the Cusco Department, Source: Municipalidad Provincial del Cusco.

While there is much discussion about Cusco's regional sphere of influence as a city, there is broad agreement amongst our informants that the city of (or urban) Cusco – as the study area for this project – can be specified as the urban neighborhoods (or zones) in the five districts mentioned above, and presented in the graphic below. These zones are identifiable through the national census statistics.

[3] *Adobe is* a local construction material derived from mud.

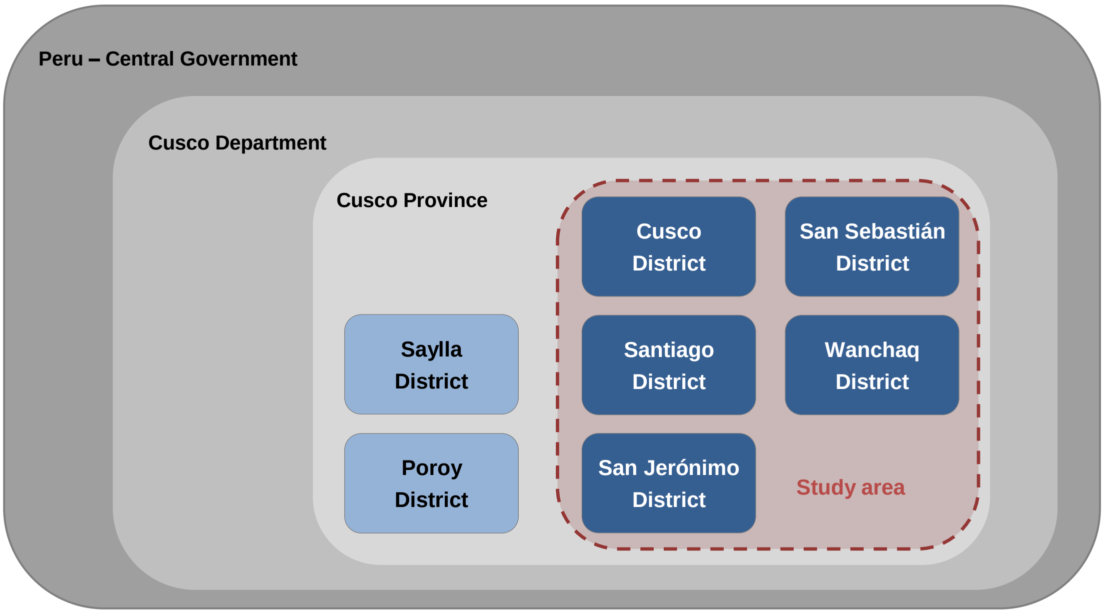


Figure 1.2 Cusco administrative organization

2 Climate-related hazard assessment: floods and landslides

2.1 Introduction

The city area of Cusco, as defined above, sits high in the Andes Mountains. It is situated in a valley within the upper basin of the Huatanay River at 3,400 m above sea level. Irregular topography, seismic activity, and streams that overflow as a result of long periods of rains or short intense storm events expose Cusco to a wide variety of natural disasters, including earthquakes, landslides, and floods. When floods cause the Huatanay River and its tributaries to overflow, the city faces water pollution caused by wastewater discharge, littering in the river beds, urban sprawl, and inappropriate development of productive economic activities. Tourism is a major contributor to the economy of Cusco and is highly vulnerable to these natural disasters.

Figure 2.1 provides a collection of approximate locations where past landslides and floods were reported by the media from 1970 to 2011 (collected in the DesInventar database). However, the data used to support this map may not be complete as the figure identifies areas prone to landslides and floods different from those recognized in interviews and communications with local stakeholders. The figure suggests a high concentration of floods in the upper basin, particularly in the region influenced by the Saphy River. However,, stakeholders suggest that the lower basin also tends to be prone to flooding.

Figure 2.1 Approximate location of floods and landslides reported in the city of Cusco based on the analysis of DesInventar Database (1970s-2011) and placed over a Google earth image. The date of the image is 2008. Most of the data reported in DesInventar have been collected from reports in the media.

All of this information (i.e., maps, stakeholder interviews and communication), suggests that flooding is an endemic problem in Cusco. The figure also shows landslides reported in the upper basin. However, from interviews with local stakeholders, the landslides in the Santiago and San Jeronimo districts in the southwest of Cusco are of greatest concern.

Two hazards are considered in this chapter: inland flooding and landslides. Each hazard is discussed and draws from available information and data. This chapter divides the analysis into the following sections:

- **Methodology (Section 2.2):** a discussion of the approach for analysing how climate change may impact floods and landslides.
- **Physical description (Section 2.3)**: an overview of physical characteristics in Cusco that are relevant to floods and landslides, and the meteorological drivers of events associated with floods and landslides.

- **Floods (Section 2.4)**: a general description of floods relevant to Cusco, a summary of prior events, and a description of the tools used to inform flood disaster management and municipal planning.
- **Landslides (Section 2.5)**: a general description of landslides relevant to Cusco, a summary of prior events, and landslide hazard maps, and a description of the tools used to inform landslide disaster management and municipal planning.
- **Future hazards (Section 2.6)**: an overview of future changes of climate and the potential impact on future landslide and flood events relevant to Cusco, including a section describing gaps and limitations.

2.2 Methodology

This analysis utilizes existing tools used by the Cusco city government to consider how flood and landslide hazards may change by mid-century (2040s). To effectively inform future urban planning, it is important our approach be appropriately aligned with the available local data and tools. The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events include:

1. Reviewing available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collecting and investigating data on past landslide and flood events in Cusco to assess the degree of impact per event and the conditions that precipitate events.
3. Assessing available resources used by the municipality to describe zones vulnerable to landslides and floods, and inform emergency planning.
4. Assessing available future precipitation and temperature data for the 2040s.
5. Assessing and performing the application of three distinct approaches that consider how climate change may impact the resources investigated in Step 3.

Each step, available data, and tools are discussed in greater detail in Annex 1.

2.3 Physical description

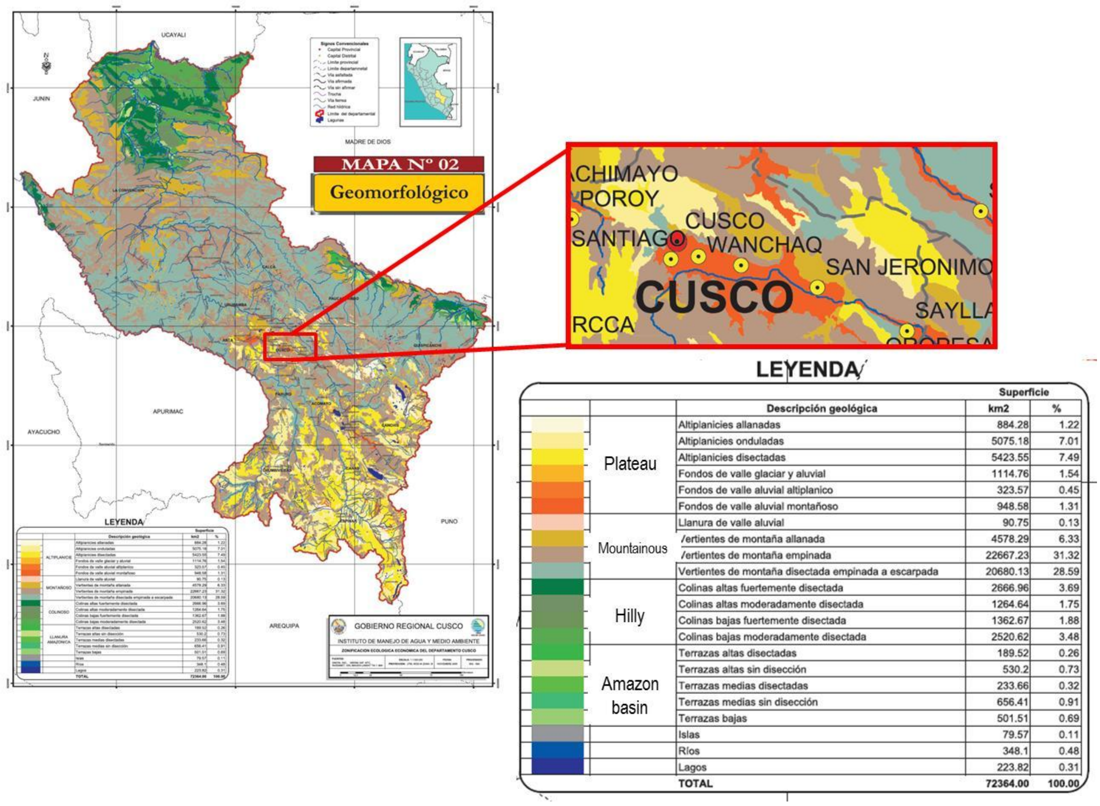
This section provides an overview of the physical attributes that affect floods and landslides in Cusco: geomorphology, soils, hydrology, and climate and weather.

2.3.1 Elevation, geomorphology, and seismic activity

The topographic features shown in Figure 2.2 drive a strong thermal gradient in Peru and affect the regional precipitation patterns. The lower elevations (below 2,000 meters (m)) are areas of warm temperatures, the intermediate elevations are considered temperate (between 2,000 m and 3,700 m), and the highest elevations (above 3,700 m) are dominated by cold temperatures (Mora Aquino, 2012). Cusco is located at an intermediate elevation at 3,400 m above sea level in the southeast section of Peru.

Figure 2.2 Elevation of the Amazon basin. Source: UNEP, 2004.

Figure 2.3 provides a description of the geomorphology of Peru demonstrating the country's varied terrain. Cusco is shown on the edge of a plateau surrounded by mountainous terrain.



	Descripción geológica	Superficie km2	%
Plateau	Altiplanicies allanadas	884.28	1.22
	Altiplanicies onduladas	5075.18	7.01
	Altiplanicies disectadas	5423.55	7.49
	Fondos de valle glaciar y aluvial	1114.76	1.54
	Fondos de valle aluvial altiplanico	323.57	0.45
	Fondos de valle aluvial montañoso	948.58	1.31
	Llanura de valle aluvial	90.75	0.13
Mountainous	Vertientes de montaña allanada	4578.29	6.33
	Vertientes de montaña empinada	22667.23	31.32
	Vertientes de montaña disectada empinada a escarpada	20680.13	28.59
Hilly	Colinas altas fuertemente disectada	2666.96	3.69
	Colinas altas moderadamente disectada	1264.64	1.75
	Colinas bajas fuertemente disectada	1362.67	1.88
	Colinas bajas moderadamente disectada	2520.62	3.48
Amazon basin	Terrazas altas disectadas	189.52	0.26
	Terrazas altas sin disección	530.2	0.73
	Terrazas medias disectadas	233.66	0.32
	Terrazas medias sin disección	656.41	0.91
	Terrazas bajas	501.51	0.69
	Islas	79.57	0.11
	Ríos	348.1	0.48
	Lagos	223.82	0.31
	TOTAL	72364.00	100.00

Figure 2.3 Description of the geomorphology of the Cusco region with an insert expanding on the city of. Source: adapted from IMA, 2009.

The city of Cusco is situated in a valley that is 30 km long with a NW-SE geographic orientation. There is a plateau to the northeast of the city, and valley flanks to the south and southeast (see Figure 2.4).

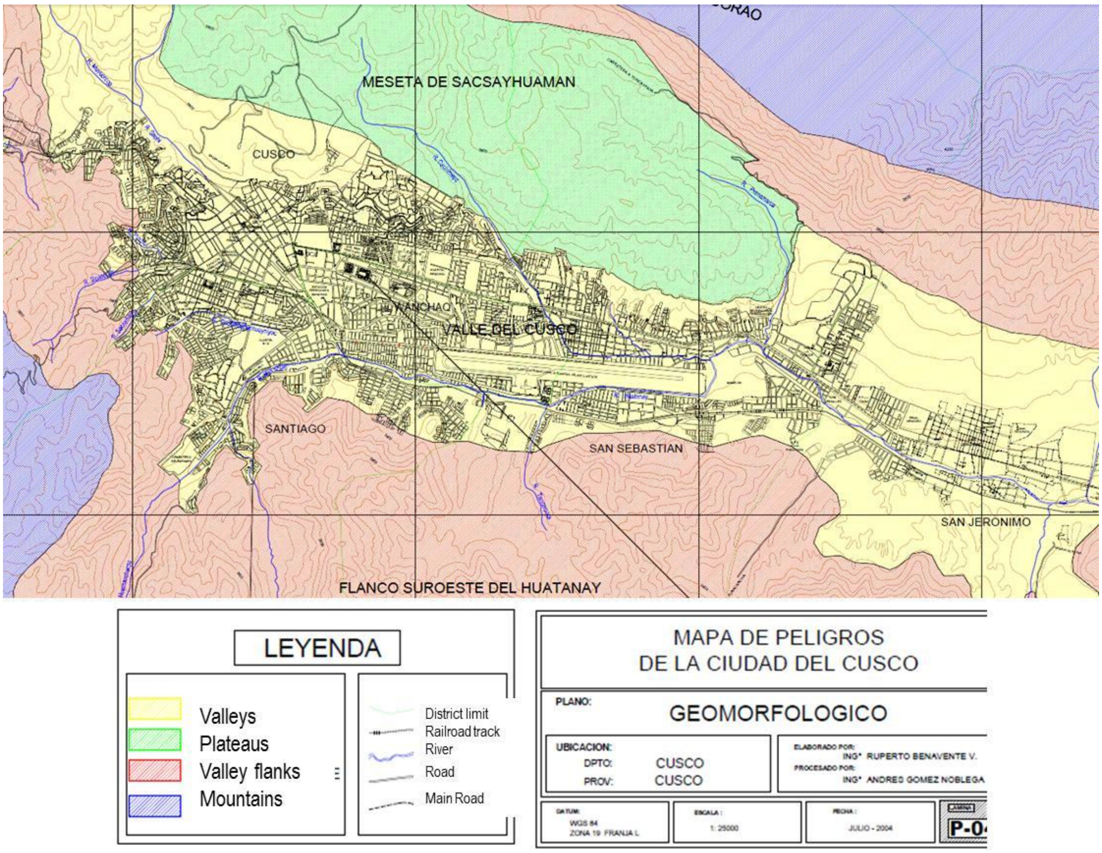


Figure 2.4 The local geomorphology of the city of Cusco and the surrounding areas. Source: adapted from Benavente Velasquez et al., 2004.

As with a precipitation event, earthquakes are also of concern to Cusco residents as they may trigger landslides, blocking natural water flow that can later be released as flash floods. Cusco is located in an area of deep seismic activity where the Nazca and American Continental plates meet. Seismic activity has triggered landslide events with minor earthquakes occurring every one to three years and strong earthquakes occurring every thirty years (Benavente Velasquez et al. 2004). A 7.4 Richter scale earthquake struck the city in 1950, destroying the majority of Cusco's housing and critical infrastructure. In 1986, a 6.8 Richter scale earthquake had less devastating effects and has been the last major seismic event.

Many low-intensity earthquakes have, however, been registered in recent years, causing limited damage to buildings. As illustrated in Figure 2.5, there are three regions considered susceptible to seismic activity in Cusco, with one near the central part of the city.[4] While earthquakes as trigger for landslides are not linked to changes in climate, such changes may affect the severity of landslide events driven by future seismic activity. For example, if changes in climate adversely affect soil moisture and vegetation growth change then landslides could become more prevalent.

[4] The analysis is based on a Poisson probabilistic model informed by historical seismic data (see Benavente Velasquez et al. (2004) for further description).

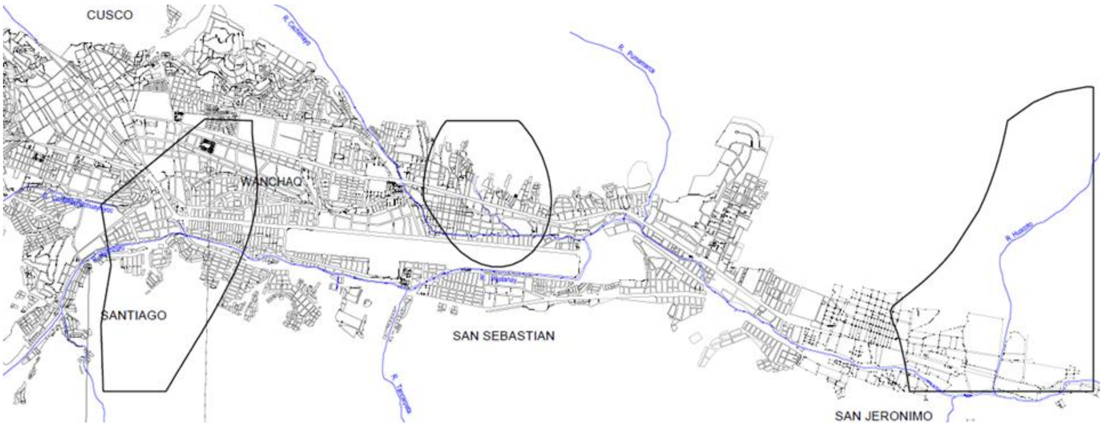


Figure 2.5 Outlines region considered susceptible to seismic activity for the city of Cusco and the surrounding districts, Source: adapted from Benavente Velasquez et al., 2004.

2.3.2 Soils

As illustrated in Figure 2.6, Benavente Velasquez et al. (2004) classify the soils of Cusco into four categories based on material size and origin: fine soils, gravel, rock, and organic soils.[5] This information is used when ranking the geotechnical hazard across the city based on the soil's stability for urban construction. Each soil is described below.

Fine Soils. Clay, silts, and sand constitute the fine soils of Cusco and are found across much of the city and nearby districts. These soils vary from moderately good to poor for urban settlements:

- Clay. Most of the clay soils in the area (red clay) are of high resistance and low compressibility, considered moderately good for urban settlements and construction. An exception is the lighter colored clay soils to the North of the Parque Industrial that are considered low quality for setting building foundations.
- Silts. The physical properties of silt make areas with this fine soil prone to landslides and these areas are considered at high risk for building development and slope stability. Most of the fine soils in the area are not comprised of silt.
- Sands. Sands are generally found in areas with clay or silt layers. These fine sands easily crumble when superficial and dry, and can suffer gully erosion, as in the Northern sector of San Sebastian. These sand soils are unstable when over slopes and during seismic activity.

Gravel. Gravel soils in the city are considered reliable for urban construction.

[5] There are no expandable or collapsible soils in the area of Cusco.

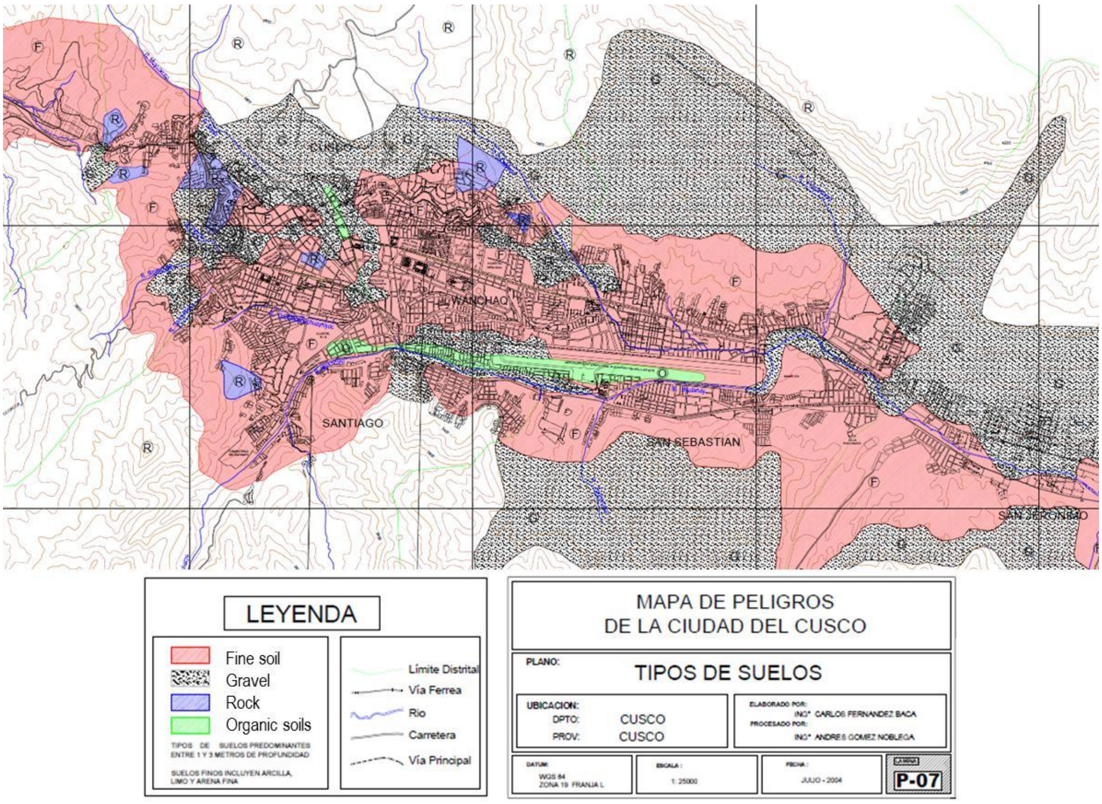


Figure 2.6 Soil types of the city of Cusco. Source: adapted from Benavente Velasquez et al., 2004.

Organic Soils. Organic soils are considered highly unstable for any construction project. There are two zones in the City that are comprised of organic soils: (1) Choquechaca y Tullumayo, and (2) Huancaro-Ttio-Aeropuerto. The Choquechaca y Tullumayo zone is along the channelled Saphy River and is comprised of red organic clay mixed with large stones of up to a depth of 6m. These stones are removed prior to any construction projects. The Huancaro-Ttio-Aeropuerto zone is comprised of black organic clay which forms a layer with a depth between 3 and 6 meters which is covered by gravel with high water content and a red clay surface. This zone is particularly dangerous, as construction site evaluators may falsely conclude they have reached a firm substrate at the gravel layer and not recognize the existence of the very unstable clay below.

Rocky Outcrops. The rocky outcrops consist of various geological constitutions, and are located at high areas surrounding the Cusco valley. A few rocky outcrops exist in the central part of the valley as detailed in Figure 2.6 and only one outcrop, composed of sandstone, has been identified in the rocky Urb sector Entel Peru (bottom of Huamantiana and Santa Monica).

When considering soil stability for construction, Benavente Velasquez et al. (2004) consider the bearing capacity of the soils which can also be a metric for landslide susceptibility. This metric describes the pressure that the soils can withstand and is ranked by allowable stress.[6] The soils with an allowable stress below 1kg/cm^2 or composed of organic soil are considered highly susceptible to failure. Figure 2.7 shows these areas of concern in yellow coloring. This susceptibility is compounded if the "yellow – colored" areas are also located in areas with slope. As shown by the light contour lines, these "yellow-colored" areas tend to be present in flat areas. . This information was also considered in the hazard maps described later in this chapter.

[6] Bearing capacity depends on the soil and foundation. A consistent foundation was used in the development of this map that is representative of the most common reinforced concrete buildings in Cusco.

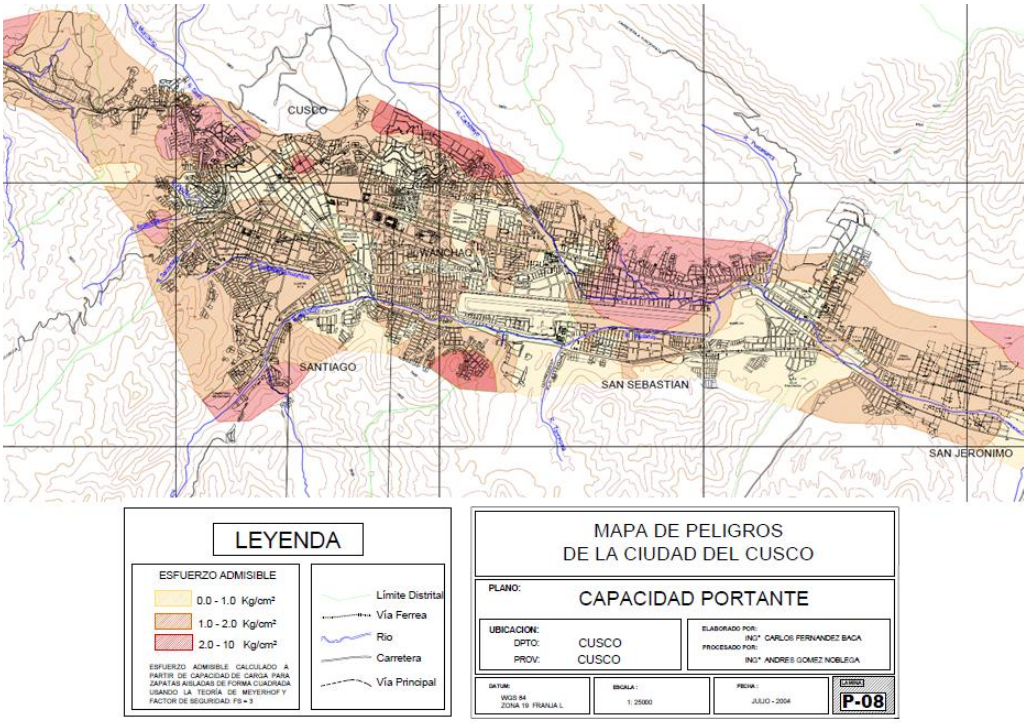


Figure 2.7 The bearing capacity (kg/cm^2) of the soils for the city of Cusco. Source: adapted from Benavente Velasquez et al., 2004.

2.3.3 Hydrology

Cusco is located within the Ucayali drainage basin. The Ucayali drainage basin is a complex network of sub-basins as shown in Figure 2.8. Cusco is located in the Alto Apurimac sub-basin in the Huatanay watershed, near the headwaters of the Huatanay River. The Huantanay River then travels downstream to the Urubamba River which is the largest river in the Cusco region (UNEP, 2004).

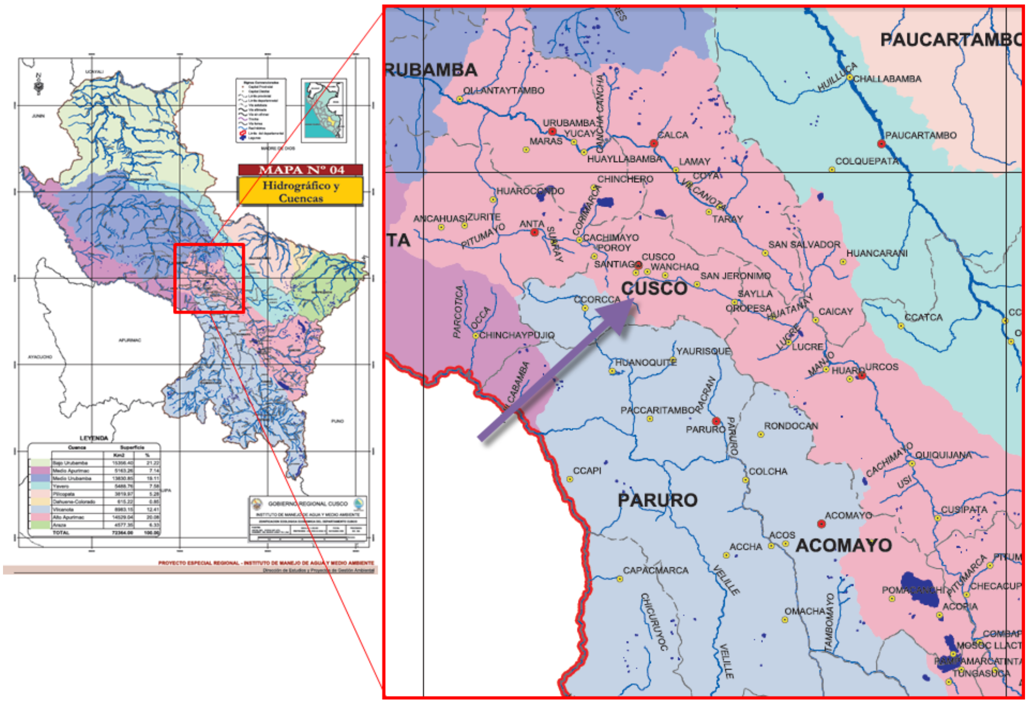


Figure 2.8 Water basins of the Cusco region. Cusco, Peru is located in the Alto Apurimac water basin, Source: adapted from IMA, 2009.

The Saphy and the Huancaro rivers are the main tributaries of the Huatanay river (see Figure 2.9). The Saphy River flows down into the city of Cusco and has been channelized as it enters the city, running underneath the city center before meeting the Huancaro River near the intersection of two roads, the Avenida de la Paz and the Avenida San Martin (as reported by the media and Benavente Velasquez et al., 2004). These rivers flood Cusco with some regularity during the rainy season.

Figure 2.9 Main rivers in the city of Cusco and nearby districts. Source: adapted from Benavente Velasquez et al., 2004.

2.3.4 Climate and weather

The city of Cusco sits in the upper basin of the Huatanay River in a valley at 3,400 m above sea level. Its topography affects the daily and monthly variation in temperature. Given its mountainous terrain (see Figures 2.2 and 2.3), Cusco experiences a large range in daily temperature: temperatures rise considerably during the day and drop significantly at night. The climate is characterized by dry, cold winters and wet, warm summers.

Peru and the Cusco region. The Cusco region experiences a large variability in monthly temperature (see Figure 2.10). For example, the Cusco region experiences a range of cold monthly mean winter (i.e., June, July, August) temperatures from 10^{o}C to below -0.5^{o}C and warm monthly mean summer (i.e., December, January, February) temperatures of roughly 0^{o}C to 15^{o}C.

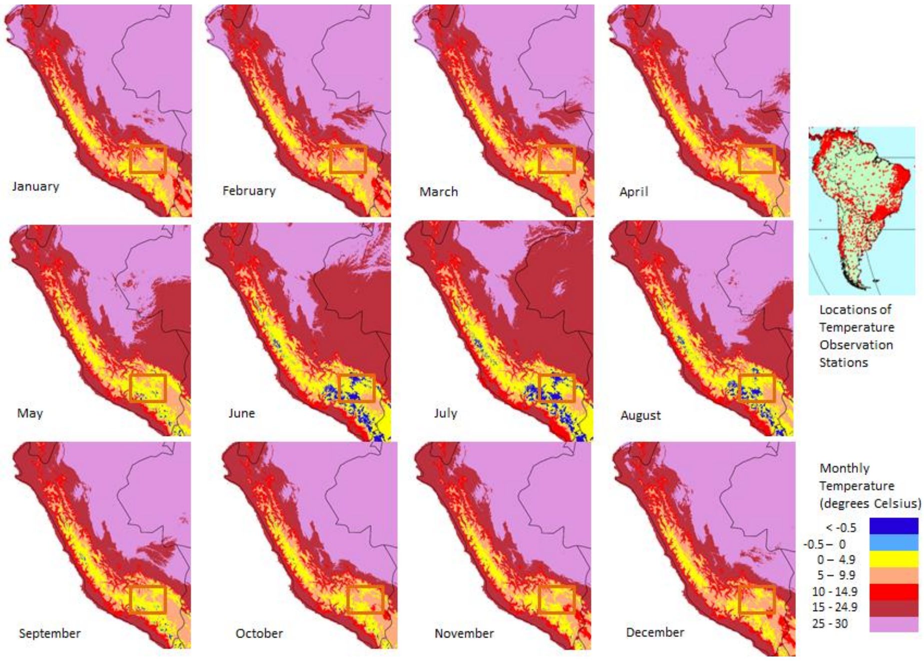


Figure 2.10 Monthly temperatures based on observational data averaged for 1950 to 2000, as available. The general location of the city of Cusco is indicated by the orange box. Source: data provided by Hijmans et al., 2005.

As illustrated by Figure 2.11Figure 2.11, the topographic variation across the region affects regional and local precipitation patterns. The Cusco region experiences a rainy season during November through April, with a monthly average rainfall of roughly 50 mm to over 200 mm. January, February, and March account for 50 percent or more of total annual precipitation (Mota 2003). During the dry season between May and September, the Cusco region receives less than 50 mm of precipitation per month.

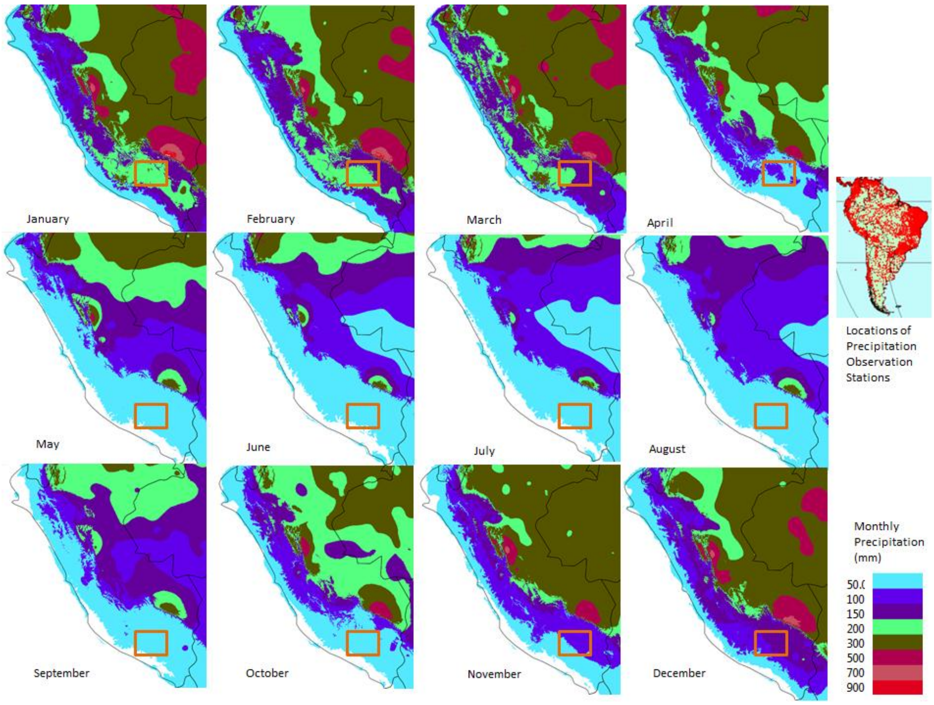


Figure 2.11 Monthly precipitation based on observational data averaged for 1950 to 2000, as available. The general location of the city of Cusco is indicated by the orange box. Source: data provided by Hijmans et al., 2005.

Cusco area. To inspect local changes in monthly temperature and precipitation data, five observation stations surrounding the Cusco area (see Figure 2.12) were used that were provided by SENAMH. Average monthly temperature and precipitation were derived by averaging monthly values from 1965 to 1990 (this period was chosen to ensure that the baseline climate in this analysis is consistent with the baseline climate used in the climate projections).

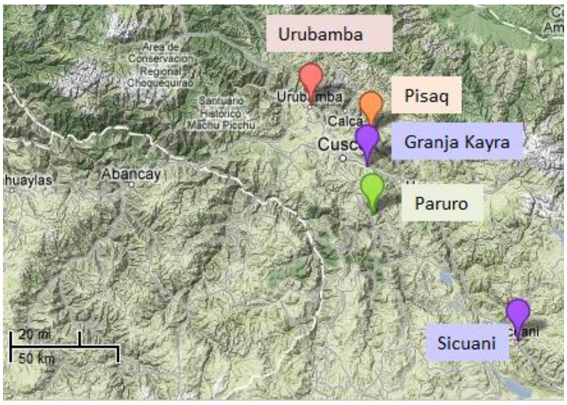


Figure 2.12 Locations of five observation stations in the Cusco area. Data for Quillabamba was not used due to differences in elevation and temperature.

As shown in Table 2.1, the monthly average temperature and total precipitation for the Cusco area demonstrates two distinct seasons: a warm, wet season from November through April and a cold, dry season from May through October. The warm, wet season (i.e., rainy season) has an average monthly mean temperature of 13.7°C with a peak in November of 14.1°C and constitutes about 88 percent of the annual precipitation. The cold, dry season (i.e., dry season) has an average monthly mean temperature of 11.7°C with July being the coldest month.

Table 2.1 Monthly average temperature and total precipitation for the Cusco area from 1965 to 1990. Source: Based on observation data provided by SENAMH.

Rainy Season	Average Temperature (°C)	Total Precipitation (mm)	Dry Season	Average Temperature (°C)	Total Precipitation (mm)
November	14.1	62.4	May	11.5	7.5
December	13.9	96	June	10.4	3.8
January	13.7	135.5	July	10.2	4.4
February	13.8	117.1	August	11.4	6.9
March	13.6	115.9	September	12.8	18.2
April	12.9	40.9	October	13.9	36.7
Season	13.7	568.2	Season	11.7	77.4
Annual	**12.7**	**645.6**			

Note: Where blue shading indicates the wet, warm season and red shading indicates the dry, cold season.

There is some variability in mean monthly temperatures across the four stations as shown in Figure 2.13; however, the general trend in cold and warm months remains constant.[7] Overall, the lower elevation stations (i.e., Urubamba and Paruro) are the warmest stations in the Cusco area and the higher elevation stations (i.e., Granja Kayra and Sicuani) are the coldest. Temperature data was not available for the fifth station, Pisaq.

[7] Given Pisaq temperature data was not provided, it is not included in Figure 2.12.

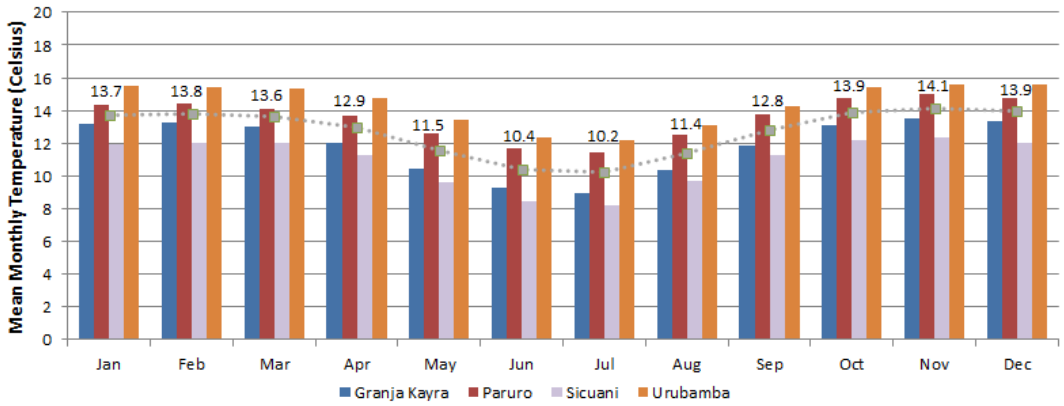


Figure 2.13 Average monthly temperature (°C) from 1965 to 1990 for the Cusco area with the dashed line representing the average monthly temperature of the four stations over the year.

Precipitation amounts also vary by station as shown by Figure 2.14. This captures the effect of the topographic variations across the stations that are located over a distance of approximately 80 miles. During the rainy season, Paruro exhibits the greatest amount of monthly rainfall followed by Granja Kayra and Pisaq. The general intra-annual trends of rainy and dry seasons, however, are largely consistent across the stations suggesting larger-scale atmospheric drivers influence key precipitation patterns across the area. In other words, although the magnitude of rainfall changes between locations, the annual trend in peak rainfall and dry periods is regional in nature. A Mann Kendall trend analysis of the monthly precipitation from the 1960s to 2011 conducted at each station did not demonstrate a statistically significant change.

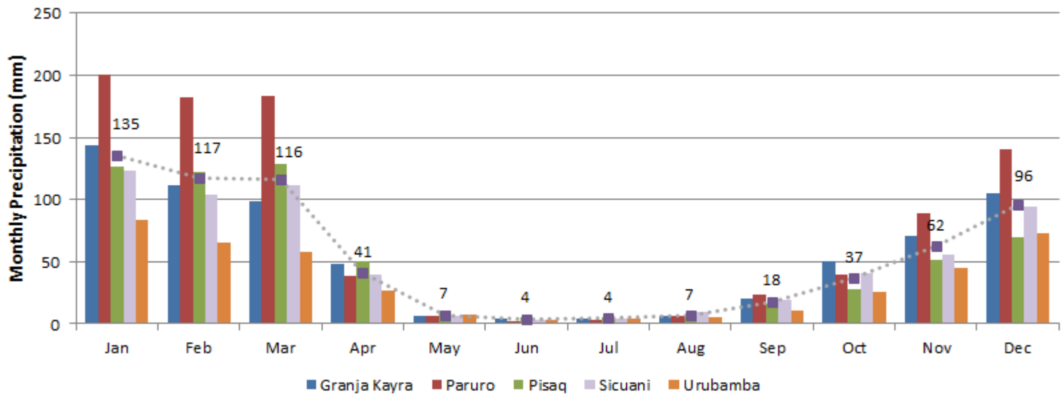


Figure 2.14 Average monthly precipitation (mm) for the Cusco area from 1965 to 1990 with the dashed line representing the average total monthly precipitation over the year.

The maximum daily precipitation event per year was also provided for four of the observation stations. Figure 2.15 illustrates the average maximum daily precipitation event per month from 1965 to 1990 along with the highest and lowest maximum daily event recorded. December through March represents the greatest chance of the occurrence of an extreme precipitation event while May through August represents the lowest. The heaviest storms on record have occurred in January, March, and December. Huggel et al. (2012) suggests the number of heavy precipitation events have increased since the mid-1960s.

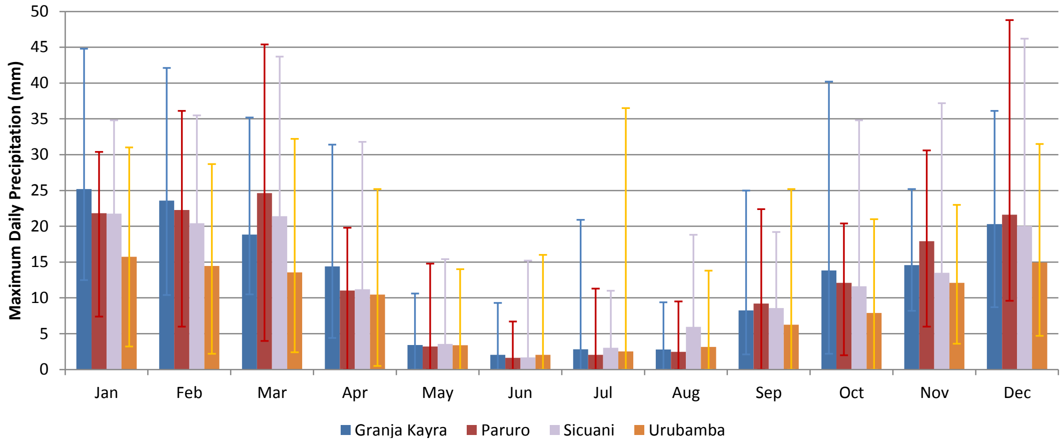


Figure 2.15 Average maximum daily precipitation events for the Cusco area from 1965 to 1990 with the bars indicating lowest and highest value recorded.

Drivers of precipitation-patterns. The Inter-Tropical Convergence Zone (ITCZ) and the El Nino/Southern Oscillation (ENSO) cycle impact the timing and magnitude of precipitation events (see Box 2). The ITCZ is one of the main factors responsible for the timing and magnitude of the wet season, producing intense rain events almost every year during the summer months. The ENSO cycle influences inter-annual precipitation in Cusco. During periods of high ENSO activity, precipitation is higher than usual and temperatures can be warmer (see Box 3 for a description of an event during an El Nino year). Though there is significant change in precipitation year-to-year, observations for the Cusco area suggest no noticeable long-term change in precipitation from 1965 to 2008; these findings suggest that much of the decadal variability is driven by ENSO (Mora Aquino 2012).

Box 2 Overview of meteorological processes that affect Peru's climate

Inter-Tropical Convergence Zone

The Inter-Tropical Convergence Zone (ITCZ) is a region along the equator that extends hundreds of miles north and south and is characterized by heavy rainfalls and a horizontal band of clouds, as shown in the image below. This low pressure band exists because of the temperature variations in the atmosphere which drive the Hadley cell and converge the trade winds equatorward: in the northern hemisphere, clouds move in a southwesterly direction while in the southern hemisphere they move in a northeasterly direction. The results are convective storms, which are short in duration but with intense rainfall: it is estimated that 40 % of all tropical rainfall rates exceed one inch per hour.

ENSO

The El Nino/Southern Oscillation (ENSO) cycle is the cyclical change in sea surface temperatures, rainfall patterns, surface air pressure, and atmospheric circulation that occurs around the Equatorial Pacific Ocean. The extremes of the ENSO cycle are termed El Nino and La Nina. El Nino is when the sea surface temperature in the Pacific becomes warmer than normal and the strength of winds reduce. Conversely, La Nina is when the sea surface temperatures become colder than normal and the strength of the wind increases. These events usually occur every 3 to 5 years and can last over 12 months.

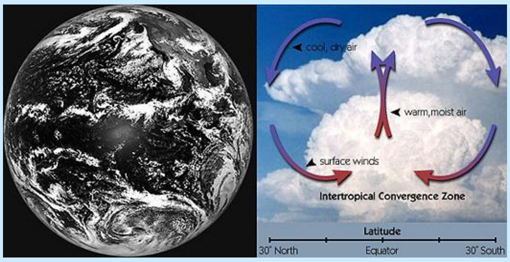


Figure 2.16 **Left: ITCZ image from the GOES 14 satellite; Right: Hadley Cell Circulation (Source: NASA GES DISC)**

Source: NWS 2012.

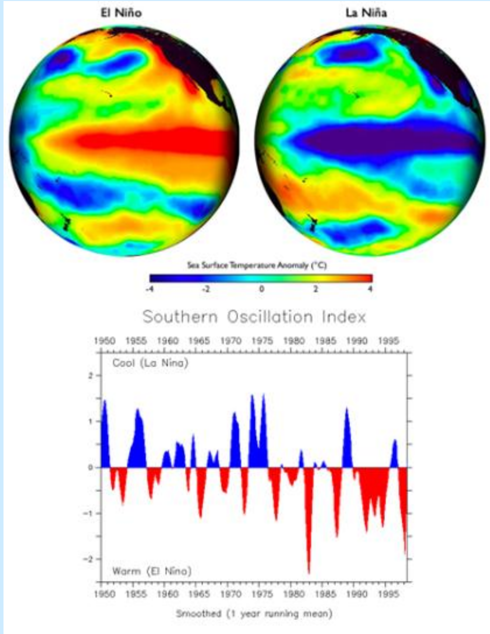


Figure 2.17 **Top: Sea surface temperatures for El Nino and La Nina events; Bottom: El Nino (blue) and La Nina (red) events from 1950 to 2000.**

Source: NOAA 2012a, NOAA 2012b

2.4 Current flood hazards

The city of Cusco lies, as discussed above, at the confluence of several major streams surrounded by steep terrain from the Andean Mountains. Cusco's irregular topography, small river micro-basins, urban expansion, and lack of an efficient drainage system all contribute to the city's vulnerability to flood events. Since records of media-observed disaster events began in 1970, floods have been the most frequently reported weather-related disasters in Cusco, with 111 flood-related events recorded from 1970 through 2011. Most notably, the city suffered from the greatest flood registered to date in 1974. Urbanization and urban development has increased the risk of flooding to the settlements in and around Cusco.

This section provides: (1) a description of the flooding in Cusco, discussing both the general conditions that cause or exacerbate flooding and the locations where flooding occurs; (2) a general summary of when prior flood events have occurred over time; and (3) a description of the flood tools used by the city planners and emergency management in the city of Cusco.

2.4.1 Description of flooding

The Cusco area is threatened by inland flooding from overland flow and riverine flooding. For example, within the city of Cusco the overflow of small river micro-basins is caused by either long periods of rains or short intense storm events flooding streets and houses that are exacerbated by the lack of an efficient drainage system.

Three hydro-meteorological conditions have been identified that cause flooding in the city of Cusco (Benavente Velasquez et al., 2004):

- Minor rain events followed by a heavy precipitation event. Such minor rains saturate the soils and decrease the infiltration volume. When followed by a heavy precipitation event, flooding ensues.
- Heavy precipitation in the surrounding mountains. Increased flooding results when heavy precipitation starts in the mountains and moves its way downstream toward the creeks

and into the city; such scenarios are exacerbated whenever the rainfall event moves at the same velocity as the runoff waters.

- A snow and/or hail event followed by a rain event. Cusco's mountainous topography results in the accumulation of hail and/or snow that subsequently melts during rains to produce a sudden, combined outflow which is much larger than the individual rain event.

Future work could further define these conditions to develop relevant precipitation thresholds and environmental conditions that are responsible for flooding. This would require access to daily precipitation observation data and an analysis between past flood events and the associated meteorological conditions that lead to the event.

In addition to these meteorological conditions that trigger flood events, anthropogenic changes in the natural landscape have also affected the frequency and intensity of floods. Urbanization is known to change various hydraulic parameters of the surface, such as reducing the ground's capacity to readily absorb water. By erecting sidewalks, roads and other impermeable surfaces, one of two scenarios occur: the first is the development of low , runoff coefficients due to reduced infiltration rates and a more expansive storm water distribution network which results in a more circuitous path before the water is released and absorbed (into the ground); while the second is the development of high runoff coefficient for opposite reasons, which are more conducive to flow channelization, lower friction between the water and surface, and greater flow velocities (Benavente Velasquez et al., 2004).

As a result, the city's existing drainage infrastructure has constantly had to accommodate increased volumes of water that historically was absorbed by the natural environment prior to changes in the landscape. As the landscape has changed from the natural ecosystem to an urban environment, the land that was enriched with permeable soils and could absorb the water has been replaced with pavement. This has increased runoff from the mountains.

The areas most prone to flooding include:

- The historical center within the city of Cusco can flood when the Saphy River overflows. The Saphy River has been channelized and floods once the channel has reached its maximum capacity. As reported by the media, Benavente Velasquez et al. (2004), and our interviews with different authorities in the city, there are two roads within the city of Cusco, Avenida del Sol and Avenida Tullumayo, that have become drainage channels and are very susceptible to flooding.
- Two nearby districts are also particularly prone to flooding, the lower areas of San Sebastian and San Jeronimo districts.

Annex 2 provides a detailed description of additional locations prone to flooding in and around the city of Cusco.

2.4.2 Past flood events

Floods represent a sizeable portion of the total hazards reported by the media. Table 2.2 provides a summary of the number of media reports that describe selected flood-related "disaster" events with serious impacts in the city of Cusco and nearby districts between 1970 and 2011.[8] Floods account for 30% of the all media-reported events and 40% of those considered weather-related. This suggests flood events are a concern for Cusco management.

[8] This database provides a record of all media reported events in Cusco. Seventy-eight percent of all the 364 "disaster" events recorded in the media for Cusco were weather-related. Other disaster events include: fire, structural collapse, flash flood (huayco means flash flood as mentioned somewhere in the text), forest fire, epidemics, pollution, frost, accidents, earthquakes, explosions, fog, cold waves, plague, drought, food poisoning, heat waves, and other. Some of the events reported were not reported as natural disasters (e.g., accident, other, structural collapse) but have been included because the causes of the events are weather-related and relevant to this effort (e.g., rains, floods, landslides, El Nino), according to the original source of the information.

Table 2.2 The number of flood-related events in Cusco reported by the media between 1970 and 2011.

Floods reported	Number of events reported (1970-2011)
Floods	49
Flash floods (*huaycos*) and other events related to floods (accidents, structural collapse, etc.)	111
Hailstorms reporting floods	9
Snow storms reporting floods	7
Total	176

Note: The data presented in this table has been extracted from DesInventar Database (Version 2012.05.1065) (1970-2011).

The number of flood events per year reported by the media since 1970 is illustrated in Figure 2.18. This figure shows that there has been frequent reporting of floods for Cusco, particularly in the early 1970s, the 1990s, and the early 2000s. Nine years of the 41 were marked with more than five flood events. In particular, 1994 was marked by 11 floods during the rainy season affecting several rural and urban areas in the region. Many of the years with reported flood events are associated with years with ENSO activity (e.g., 1970-1975, 1984, 1985, 1987-1989, 1991-1992, 1999-2002).[9] Though ENSO activity can provide some indication of potential flooding, it is not fool-proof. Recent ENSO activity (e.g., 2004, 2007-2011) does not exhibit similar flood events and there are years without ENSO activity with a substantial number of flood events. This figure does not describe the intensity of the events. For example, although a severe flood occurred in 2010 this year does not stand out since there was only a single event (see Box 3 for a description of the 2010 event). Future work defining the magnitude of impact and the associated costs would be beneficial in identifying important precipitation events and thresholds. Overall, this suggests Cusco is consistently prone to flood events large enough to be reported by the media.

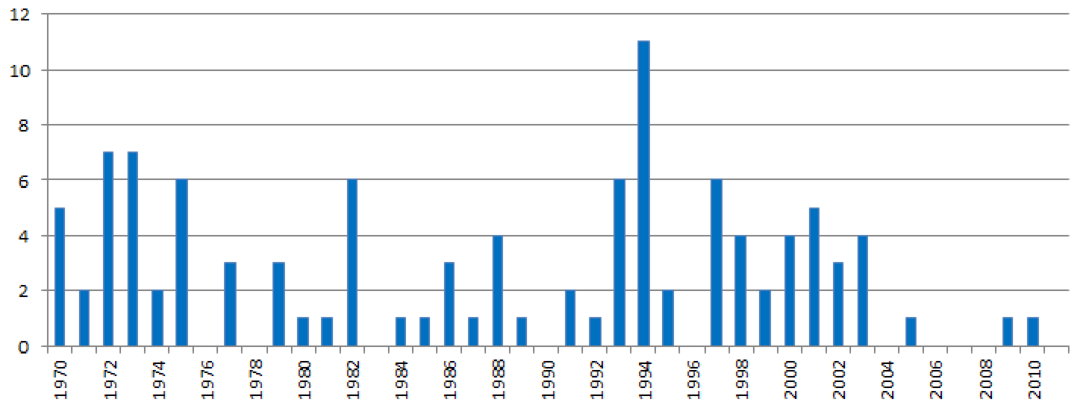


Figure 2.18 Number of flood disasters reported for Cusco between 1970 and 2011, Source: informed by data in the DesInventar database (version 2012.05.1065).

It is important to also consider when these floods occur during the year. To that end, Figure 2.19 provides the distribution of flood and landslide events by month. The greatest number of flood and rain events as reported by the media occurs during the wet season from December through April, with the highest number of events occurring in January. During this period, stream levels are high from not only the increased precipitation but also as a result of the warm temperatures melting the Andes snow and glacial ice. Future work could incorporate stream gage data that was not available for this study to further investigate the relationship

[9] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears_1971-2000_climo.shtml; accessed June 2, 2013.

between precipitation and runoff. In addition, stream gage data is useful for calibrating monthly water balance models that can then be used to project how the stream gage parameters may change in response to future changes in monthly temperature and precipitation.

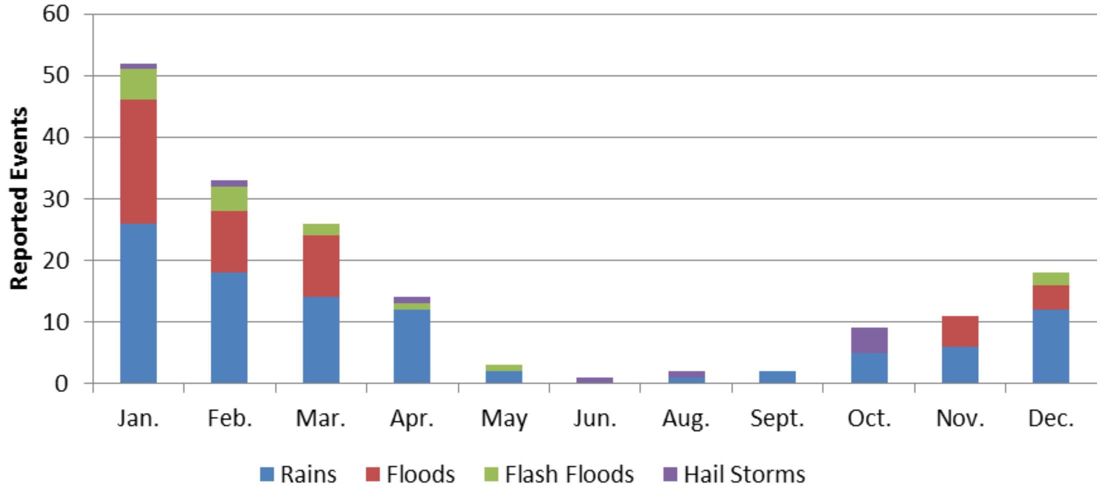


Figure 2.19 Cumulative weather-related events reported by the media between 1970 and 2011 in a monthly basis that have originated as floods or landslides across the city. Droughts have not been considered. For rains, storms and hail storms, only those events that have been linked to floods or landslides have been considered. Source: based on data in the DesInventar database (Version 2012.05.1065).

Box 3 The 2010 Floods in the Cusco Region

The 2010 floods changed how local authorities and the population view their vulnerability to hydro-meteorological events. From January 22 to 24, 2010, a south-easterly flow from the South Atlantic convergence zone carried large amounts of moisture to the southern half of Peru. The result was most extreme in the Region (Department) of Cusco, where nearly 22,000 people were affected and more than 6,000 houses collapsed as a result of the severe flooding (La Republic Newspaper, 2010).

Within the Cusco region, the Huayllabamba and Ollantaytambo districts were hardest hit. Damages included the loss or disruption of 56 km of railroad tracks, 18 km of asphalt road, 27,231 hectares of farmland, 477 streetlights, eight schools, 143 public places, and more. Altogether, the estimated losses amounted to US$250 million (El Comercio Newspaper (February 8, 2010) as cited by Rosa, 2010).

Nearly a week after the incident, the district of Yucay was still inaccessible, a consequence from the overtopping of the Urubamba riverbanks over the only major highway in the area. There were also several instances of landslips along the Inca trail and in the districts of Zurite and Provincia de Anta (Civil Defence Institute cited by Rosa, 2010). Tourists, who comprise a major economic resource for the area, were forced to spend the night in the main plaza of Aguas Calientes (en route to Machu Picchu) and were provided food and water by the local authorities (La Republic Newspaper, 2010). Machu Picchu, a main touristic attraction, was closed for three weeks.

Further, the impacts of the 2010 floods to the railroad in the Urubamba watershed cut access from Aguas Calientes to Cusco. This severely affected the regional economy, as the site had to shut down for several weeks. It was estimated that the disruption of the service caused the indirect temporal suspension of 17,000 jobs (del Carpio Polar & Michel, 2011). The government had to take emergency measures and encouraged the promotion of other touristic sites (The Economist, 2010). The closure of Machu Picchu was of extreme significance to the national economy, the site, generates an annual turnover of US$800 million which is almost 1 percent of Peru's GDP (del Carpio Polar & Michel, 2011).

During the rainfall event, precipitation reached 26 mm per day in Pisac-Cusco, resulting in record local monthly rainfall levels for January at 137.8 mm (Figure 2.20). Pisac-Cusco is located about 10 miles north of Cusco and, on average, experiences less total precipitation than the city of Cusco but the increases described here are illustrative of the percent change experienced across the region. Stream flow rates were also extreme (Figure 2.21), as demonstrated by the Vilcanota River (the Huatanay river is a tributary to the Vilcanota River), where maximum flow rate eventually reached 327m^3/s, or a threefold increase compared to the previous year (Rosa, 2010).

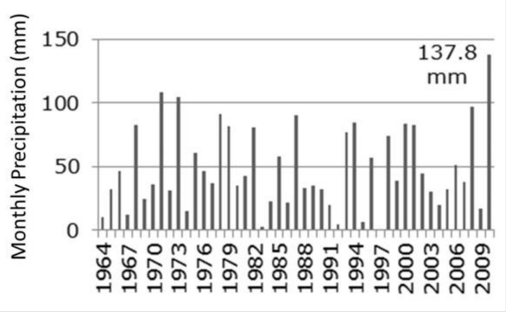


Figure 2.20 Observed January precipitation (mm) for Pisac-Cusco. Source: Rosa, 2010.

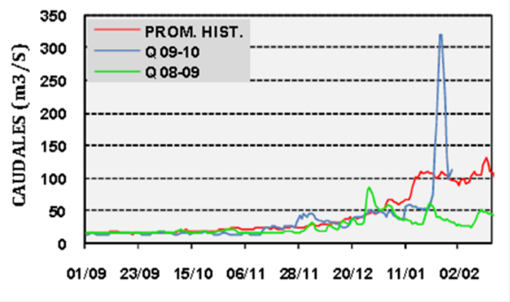


Figure 2.21 Strong flow of Vilcanota river in Pisac, Cusco with 327 m^3/s top exceed its historical values. Source: Rosa, 2010.

2.4.3 Flood resources

The Cusco municipality has developed a flood map that describes areas in and around the city which are prone to flooding. There are no flood risk maps, however, nor formal emergency flooding management tools and flood warning systems. Consequently, this analysis is limited to the information presented in the flood map.

Flood Susceptibility Map. Benavente Velasquez et al. (2004) developed the flood susceptibility map, shown in Figure 2.22, based upon a detailed catalogue of past flood events around the city. Information was qualitatively added by local experts adjusted the flood map by including the stream elevations surrounding the city, the rates of erosion near the rivers, and the level of groundwater. The latter two factors increase the possibility of flooding since they affect soil saturation. Saturated soil is less able to absorb rainfall or snow during a precipitation event, resulting in increased runoff.

This map informs local planning in Cusco. This map, however, limits our analysis in considering how changes in future climate may affect flood prone areas since the flood susceptibility map does not connect flood events to precipitation or meteorological thresholds/events.

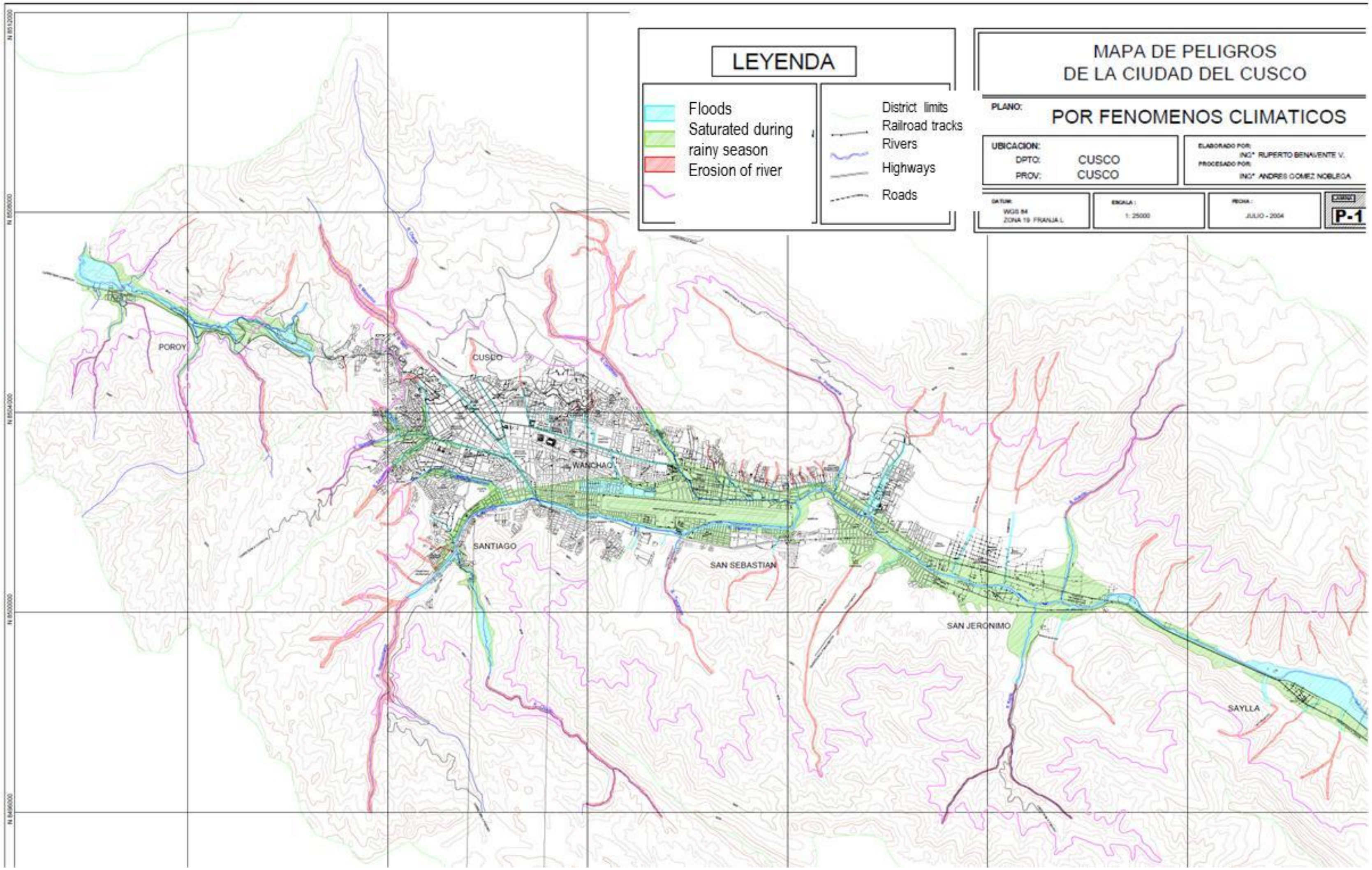


Figure 2.22 Flood susceptibility map for Cusco, Peru. Source: adapted from Benavente Velasquez et al. 2004.

Figure 2.23, an excerpt of the flood map shown in Figure 2.22, suggests flood hazard is high along many of the rivers including the Sipaspuio, Sacramayo, Picchu, Saphi, Ccorimachachuayniyoc, Huamancharpe, Chocco, Huancaro, Cachimayo, and Pumamara that drain to the Huatnaney basin. Though the district of Cusco is not considered at risk to overland flooding during the rainy season, the city's other districts are at risk, i.e. Wanchaq, Santiago, San Sebastian, and San Jeronimo. River erosion does, however, affect the district of Cusco along the banks of the Muyuorcco, Chacan, and Saphi rivers, along with other smaller-sized streams. These regions are flood-prone areas in Cusco.

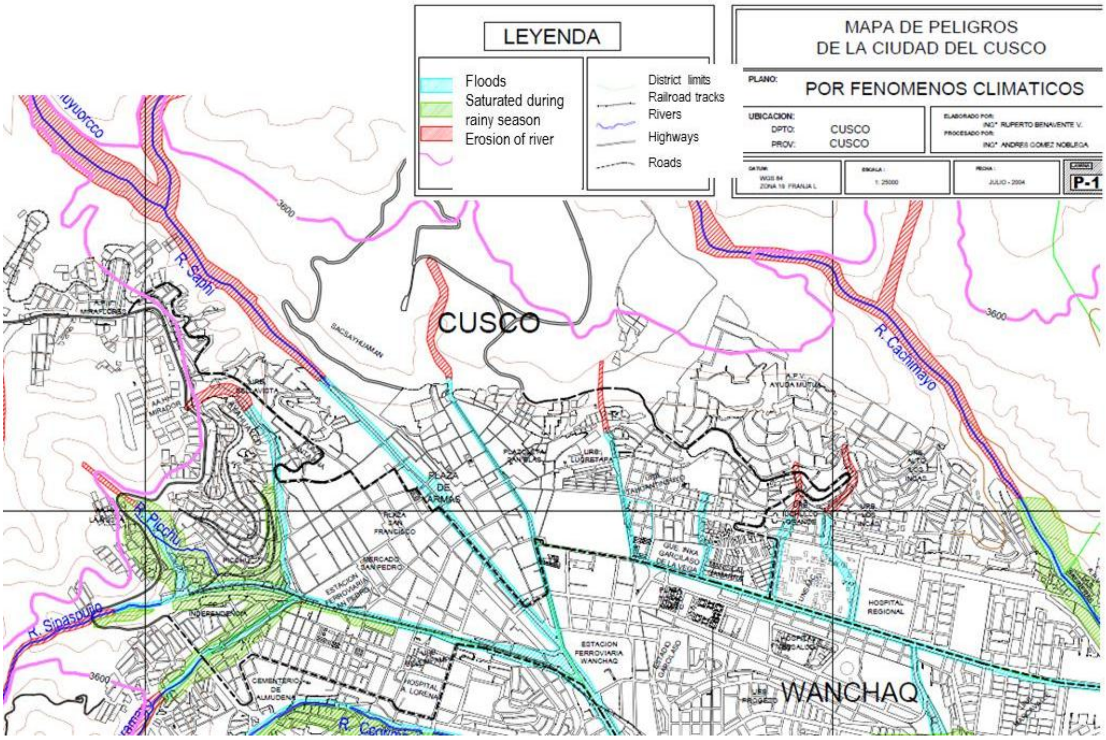


Figure 2.23 Flood map of the Cusco district area. Source: adapted from Benavente Velasquez et al., 2004.

2.5 Current landslide hazards

Landslides are generally caused by precipitation events and/or seismic activity and are particularly dangerous for those settling along the steep slopes of the Andes. Since records of media-observed disaster events began in 1970, 39 landslide events have been recorded in Cusco with the majority of landslides occurring during the peak of the wet season. Urbanization has increased the risk of landslides to the settlements around Cusco.

This section provides: (1) a description of the landslides in Cusco, discussing both the general conditions that cause or exacerbate landslides and the locations where landslides occur; (2) a general summary of when prior landslide events have taken place over time; and (3) a description of the landslide tools used by the city planners and emergency management in the city of Cusco.

2.5.1 Description of Landslides

Landslides (see Box 4 for an overview of landslide classifications and terminology.) represent a great risk for much of the population of Cusco, particularly those inhabiting the steeper slopes of the Andes located towards the north, east and west of the central part of the city. Per discussions with stakeholders, though landslides in Cusco have been frequently related to seismic activity at the location of geologic faults, the most recent landslides have been triggered by heavy precipitation events or sustained periods of rain. A number of physical characteristics or changes in the landscape discussed below can help identify areas that may be susceptible to landslides.

The location of landslides and mudslides are often associated with changes in the slope's topography and other factors such as scouring caused by nearby streams, removal of earthen material from the bottom of the slope and/or relocation of excess material to the upper part of the slope (Lopez-Zapana et al. 2005). The latter two can affect the geo-mechanical equilibrium between the forces from materials at higher slopes and the soils that support this weight. Erosion along riverbeds may be mitigated by the placement of riprap and other confining structures, but may also adversely change the flow of water upstream (Benavente Velasquez et al., 2004).

Other important aspects include whether there is equilibrium between any acting forces (such as hydraulic or seismic) and the underlying soil tensile strength. More often, dry soils tend to be more resistant than wet soils to landslides; however, such characteristics change when urbanization becomes a factor and vegetation – which facilitates soil moisture evaporation and ensures a strong soil tensile strength – is removed. In these instances, the resulting increased erosion may alter its stability and affect the pore pressure.

The vegetation in Cusco tends towards mountain tall grass and scrub (UNEP, 2004). Steep slopes that do not have vegetation develop natural protection against such hazards by having a thick, dry lateral crust which acts as a stabilization agent. However, when these slopes are covered by pavement or other impermeable surfaces, the moisture in the soil is unable to evaporate. This results in the breakdown of the lateral crusts and an increased likelihood for a landslide event. Leaks from sewers and other pipelines may have similar effects.

Increased water levels of a river or stream, e.g. during a flood event, can also undermine the soil integrity along adjacent slopes. These effects occur with greater frequency when the waters are blocked by landslides causing the water to infiltrate into the soil; as in a self-perpetuating cycle, the landslides which trigger greater ponding lead to further slope undercutting and soil saturation which then increases the likelihood of additional landslide events.

Box 4 Landslide terminology

Landslides may involve falling, toppling, sliding, spreading, or flowing motion of ground material that may be triggered by such events as heavy precipitation or earthquakes (see Table 2.3 for a classification of landslide types).

Table 2.3 Classification of landslide types

Type of movement		Type of material		
		Bedrock	Engineering soils	
			Coarse	Fine
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris flow	Earth flow
Complex		Combination of two or more types of movement		

Source: USGS 2004, based on Varnes 1978.

Debris flows involve rapid movement of slope material (e.g., soil, rock, organic matter) that is saturated by rainfall to form a slurry that flows downslope. Debris slides are triggered by separation of a weak zone of material from a stable, underlying material. Slides can be either rotational or translational, as shown in Figure 2.24; rotational slides generate a concave rupture, whereas translational slides move along a planar surface (USGS 2004).

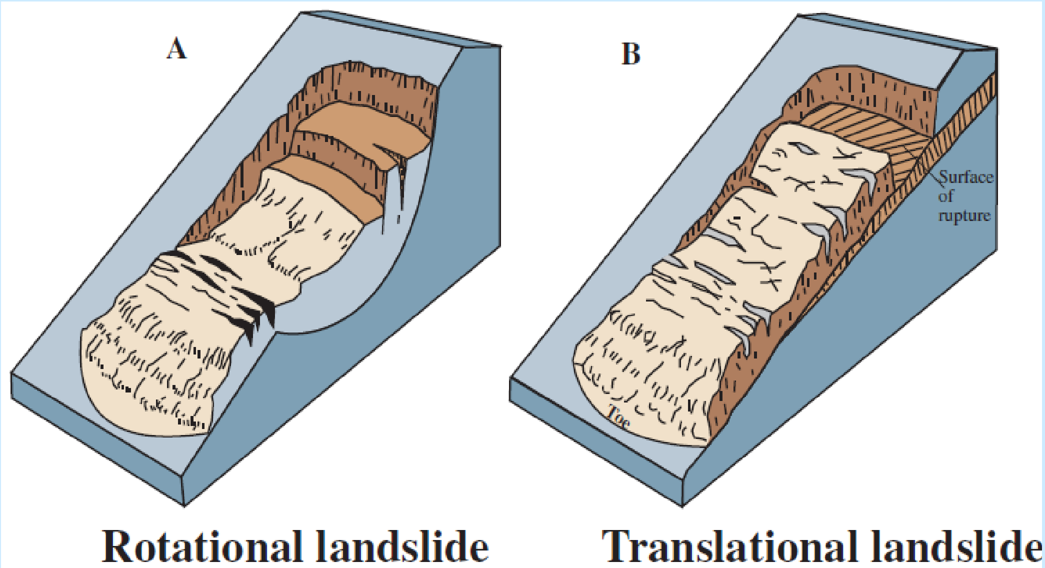


Figure 2.24 Diagrams of rotational (A) and translational (B) landslides, Source: USGS, 2004.

2.5.2 Past landslide events

In Cusco, heavy precipitation events have caused landslides and debris flows with volumes of a few tens of thousands of cubic meters, and occasionally up to several millions of cubic meters (Huggel et al., 2012). Though heavy precipitation events have been occurring with an increased frequency since the mid-1960s, a causal relationship between heavier rainfall and an increased frequency of landslides has not been shown (Huggel et al. 2012).

Figure 2.25 shows the number of landslide disasters for the city of Cusco from 1970 to 2011 demonstrating the frequency with which landslides occur in Cusco. Over the 41 year period, there have been a total of 39 landslides reported with 10 years experiencing two or more landslides per year. This suggests landslides significant enough to be reported by the media do occur at least every few years.

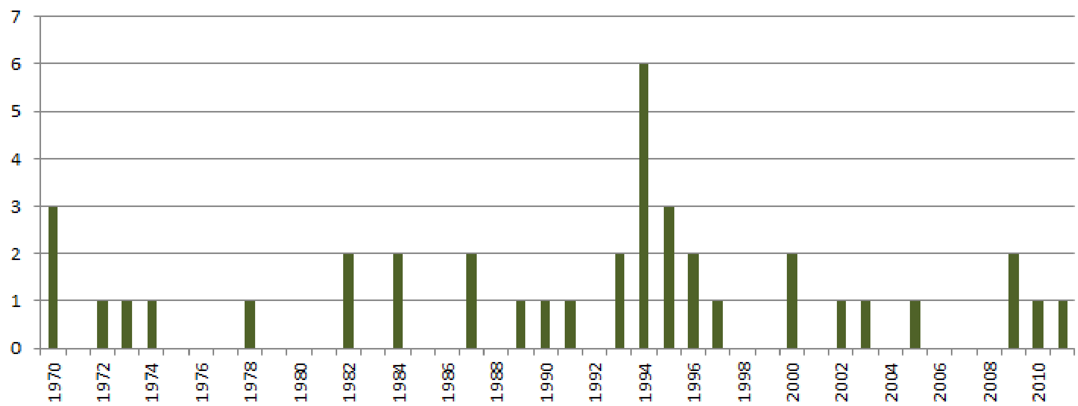


Figure 2.25 Number of landslide disasters reported for the city of Cusco between 1970 and 2011, Source: based on data in the DesInventar database (version 2012.05.1065).

As shown in Table 2.4, over 50 percent of landslides reported in Cusco since the 1970s have occurred in January and February, which is consistent with the region's wet season. However, it has to be kept in mind, that these numbers only indicate the frequency of reported events and not the magnitude or the associated damage. For example, though only "one" event is shown for 2010, this is associated with significant landslide events (see Box 5).

Table 2.4 The number of landslide events in Cusco by month as reported by the media since 1970.

Event	Months											
	Jan	Feb	Mar.	Apr.	May	Jun.	Aug	Sept	Oct	Nov.	Dec	**Total**
Landslide	9	10	4	5	2	1	1	1	1	0	3	**37**

Box 5 Landslides during the 2012 floods in Peru

Whereas the 2010 floods affected only the southern portion of Peru, the rains from February 1 through March 12, 2012 affected the entire national territory and northern Chile (see Figure 2.26). Major flooding occurred in 22 regions across Peru, and thousands of hectares of croplands were destroyed. Nearly 80 percent of the country was directly affected. There were reports of 15 fatalities; 5,500 homeless; and 48,000 people affected in total.

Figure 2.26 Locations of major floods in Peru shown in orange during February to March 2010. Source: Shelter Cluster, 2012.

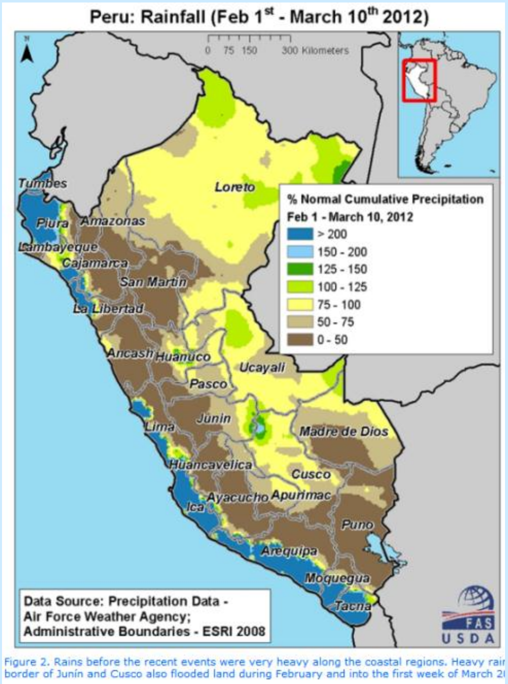


Figure 2.27 Percentage increase in precipitation from February 1 to March 10, 2012 compared to normal conditions. Source: Shelter Cluster, 2012.

Rainfall from this event originated south of the mountain range near Puno and Cusco and fell upon the western slopes. The rain dramatically increased the flow of coastal rivers, inducing landslips, and created multiple flash flood episodes. At its peak, precipitation amounts exceeded 100 mm (or 4 inches) an hour near the town of Iñapari, and as shown in Figure 2.27, most coastal regions received an excess of 200% of normal 6-week cumulative precipitation.

Impact on the Cusco region. Floods, mudslides, and highway/rail blockages affected thousands of people in the regions of Ancash, Cusco, Huanuco, and Pasco (USDA 2012). Approximately 3,400 people were directly affected by the floods in the Cusco region, along with two fatalities and one person missing. In addition, 246 houses collapsed while another 482 were classified uninhabitable. 72 km of highways were destroyed while another 737 km were affected either physically or operationally; alongside, 17 bridges were destroyed with another 38 affected. Agriculture was also disrupted, with approximately 3,896 hectares of cropland affected and 998 hectares destroyed (Shelter Cluster 2012). The total financial loss in the Cusco region has not yet been estimated.

2.5.3 Landslide resources

The Cusco municipality has developed a landslide map that describes areas in and around the city which are prone to landslides. Similar to flood risk maps and emergency planning, there are no vulnerability maps, formal emergency landslide management tools, or warning systems in place. This analysis is therefore limited to the information presented in this map.

Landslide Planning Tools. Cusco's landslide susceptibility is not only related to the physical characteristics of the terrain but also to the population density on potentially instable slopes and the infrastructure within the settlements (i.e., informal/formal, construction material, access to services, drainage).

Technical reports and consultation with city authorities, geologists, and engineers working on hazard assessment and reduction in the city of Cusco have determined that landslides in the Cusco area are influenced by the following key mechanisms:

- Slope
- Soil type
- Geomorphology
- Climatology
- Hydrology
- Urban development.

During our meeting with stakeholders it was suggested that these factors were not formally quantified and connected to produce a landslide vulnerability map, but were qualitatively considered by local experts in the production of the landslide map shown in Figure 2.28 (additional information regarding criteria and/or weighting was not available). The areas deemed susceptible to landslides were verified in situ.

Our analysis is particularly interested in the areas that are influenced by landslides and mudflows. . Many of the active landslides are located near waterways or in regions of steep slopes as demonstrated by the tightness of the grey contour lines. The areas exposed to landslides include: the Saphy river basin, quebradas Huancaro- Chocco (SW), Cachimayo micro-basin, Pumamarca-Teneria micro-basin, Huaccoto micro-basin, Kayra micro-basin, Quebrada Ayahuayco, Quebrada Picchu, Quebrada Sipaspuquio, Quebrada Sacramayo, Quebrada Hermanos Ayar, Quebrada Ccorimachahuayniyoc, San Sebastian (North and South), San Jerónimo (North and South), and parts of Saylla and Poroy. The use of this map is limited by not explicitly describing which areas are influenced by precipitation versus seismic activity.

This map is used by the local municipality to inhibit siting of critical infrastructure in landslide susceptible locations. For example, our discussions with local stakeholders suggested schools and hospitals were not allowed to be built in these locations; however, housing was allowed.

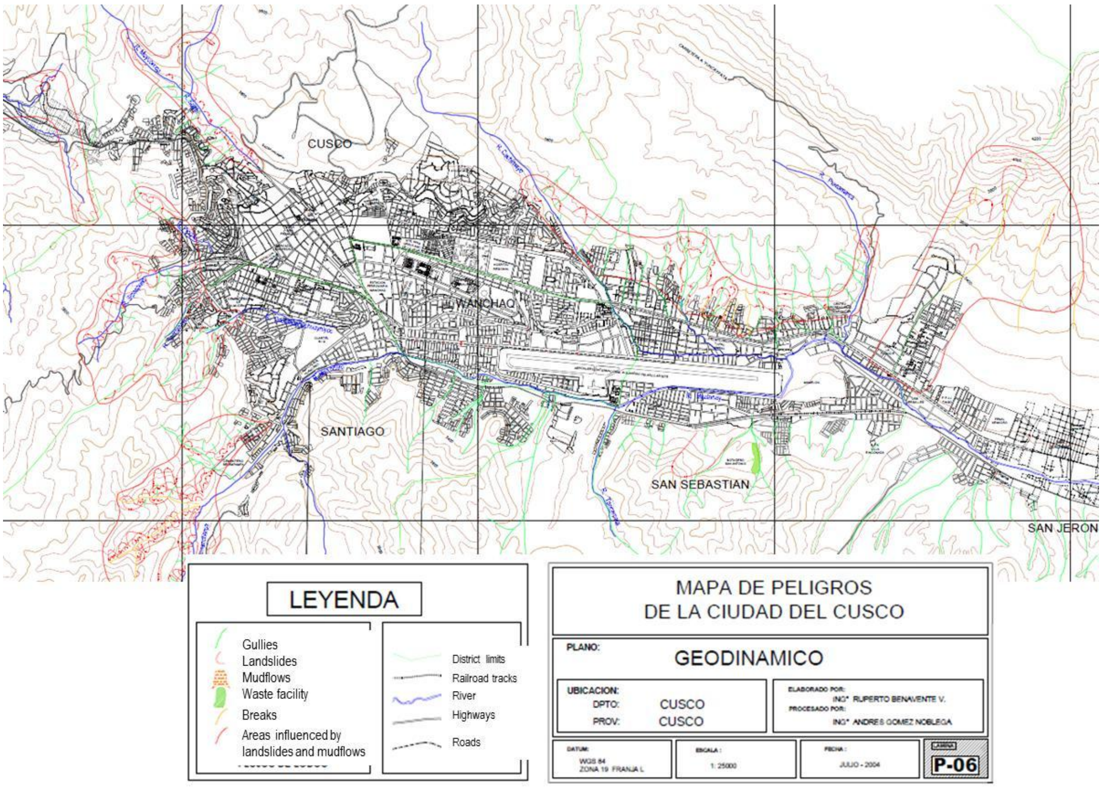


Figure 2.28 Landslide susceptibility map for section of the city of Cusco and surrounding locations. Source: adapted from Benavente Velasquez et al., 2004.

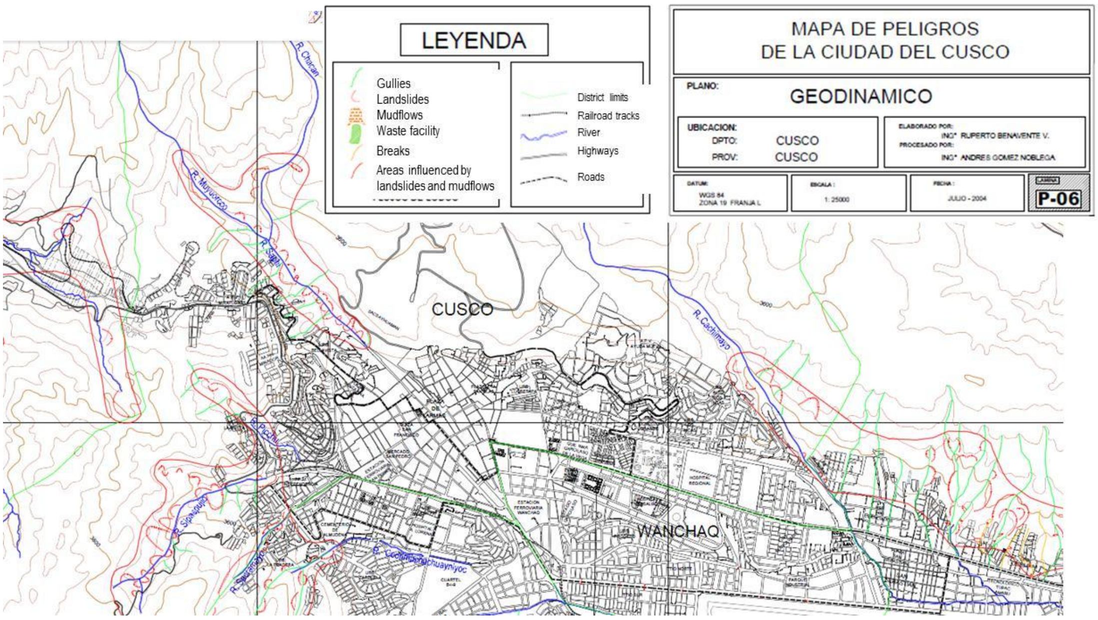


Figure 2.29 Landslide map of the Cusco district area. Source: adapted from Benavente Velasquez et al. 2004.

2.6 Future hazard

This study uses available information and data to identify zones within the study area region that are susceptible to flooding and landslides. This study reviewed available climate change projections and considered their impact on these existing hazards. This analysis does not account for future changes in the landscape (e.g., deforestation or urbanization) that may shift and/or expand current areas threatened by landslides and floods.

As flooding and landslide events for Cusco are both triggered by intense or prolonged precipitation events and excessive runoff, projections of how precipitation and runoff may change under a changing climate can help assess future susceptibility to flooding and landslide events. Runoff is not treated in this analysis given the lack of stream gage sites in Cusco (i.e., the existing sites cannot support an adequate record of observed runoff).

There are a few challenges for producing climate projections for Cusco. Precipitation projections are inherently uncertain given climate model uncertainty in simulating cloud processes. This uncertainty is further complicated by Cusco's variable terrain, which can lead to large differences in precipitation received in one location versus another. Because of these challenges, the findings presented here should be carefully applied to the municipality planning within the context of the associated uncertainty.

2.6.1 A changing climate

Since the 1960s, temperature has increased for the Cusco region from 0.02˚C to 0.06˚C/year (Mora Aquino 2012), with greatest temperature increases at higher elevations (Vuille et al. 2008). This temperature increase has impacted glacial melt and runoff. A recent study, Vuille et al. (2008), considered the effects of future climate change in the tropical Andes surrounding Cusco and found that a continued warming of the tropical troposphere (i.e., the lower atmosphere near the Earth's surface) was projected throughout the 21^{st} Century. Under the moderately-high (A2) emission scenario, the tropical Andes may experience a significant warming between 4.5˚C and 5˚C by the end of the 21^{st} century. Such changes would likely exacerbate the heavy rains in the wet season (October through April) and droughts in the dry season (May through September).

To consider how climate change may impact the likelihood of landslides and floods, two questions were posed: (1) Will the monthly precipitation pattern during the traditional rainy and dry seasons remain consistent with today's conditions? (2) Will the frequency and/or intensity of precipitation events change in the future? Specific details, such as the frequency with which precipitation may exceed thresholds that are likely to trigger landslides, or regions where these thresholds are most-likely to be exceeded could not be evaluated given the constraints of the climate projections available.

Monthly Precipitation and Temperature. Figure 2.30 illustrates the projected change in monthly precipitation in the 2040s under Scenario 1 and Scenario 2 compared to baseline conditions (1961 to 1990).[10] The bars on the figure indicate the average monthly precipitation across fifteen climate model projections (i.e., climate model ensemble mean). The error bars show the minimum and maximum projections made by an individual climate model; hence, all of the available climate model projections fall within the range shown by the error bars.

By the 2040s, the ensemble average suggests the following for months within the rainy season and dry season:

- **Rainy season:** Under both scenarios, precipitation for each month will increase by 3 to 6.5 percent. Cusco may experience an extension of the rainy season with heightened rainfall occuring a month earlier (i.e., November) and lasting a month longer (i.e., April).
- **Dry Season:** Under both scenarios, the dry season will become more intense in May, June, and July, with precipitation reducing by 7 to 13 percent.

Consequently, Cusco could potentially be subject to an amplified rainy season leading to heightened concern of flooding and landslides.

Though the top figure shows there is a large range across all climate models in the monthly projections, the bottom figure suggests that the majority of the models agree with the direction provided by the climate model ensemble mean. This suggests that the climate

[10] As described in the methodology section, the projections are presented for two scenarios: Scenario1 represents the climate model ensemble average under the low (B1) emission scenario and Scenario 2 represents the climate model ensemble average under the moderately-high (A2) emission scenario. The climate model ensemble average is an average of the climate models under a given emission scenario.

model ensemble average is well representative of the potential future for Scenario 2 and somewhat well representative for Scenario 1.

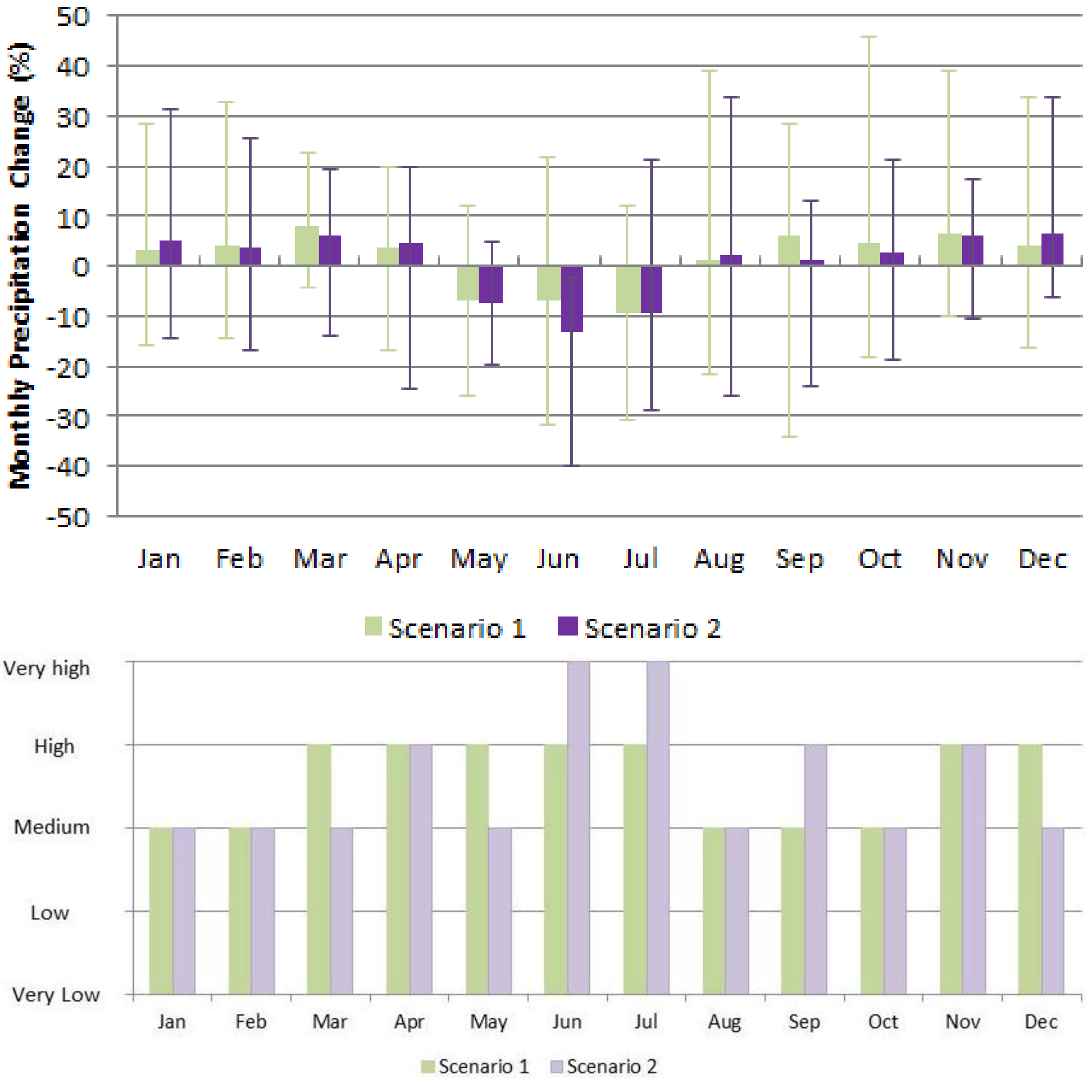


Figure 2.30 Top graph: Projected change in monthly precipitation in the 2040s compared to baseline conditions (1961 – 1990). Bottom graph: Illustrates the confidence in the reduction of precipitation suggested by the climate model ensemble average. A "very high" suggests 13 to 15 climate models agree, "high" suggests 11 to 12, "medium" suggests 6 to 10, "low" suggests 3 to 5, and "very low" suggests less than 3. Source: based on our analysis of data from Girvetz, 2009.

By the 2040s, the projected increase in monthly temperature ranges from 1.3°C to 1.7°C under the Scenario 1 and from 1.7°C to 2.3°C under Scenario 2 compared to recent monthly averages. Both scenarios suggest the greatest warming will occur during the dry season from May to October. This could also reduce the number of snow events that contribute to snow accumulation in the mountaineous areas and the associated accelerated snow melt that occurs during a rain event.

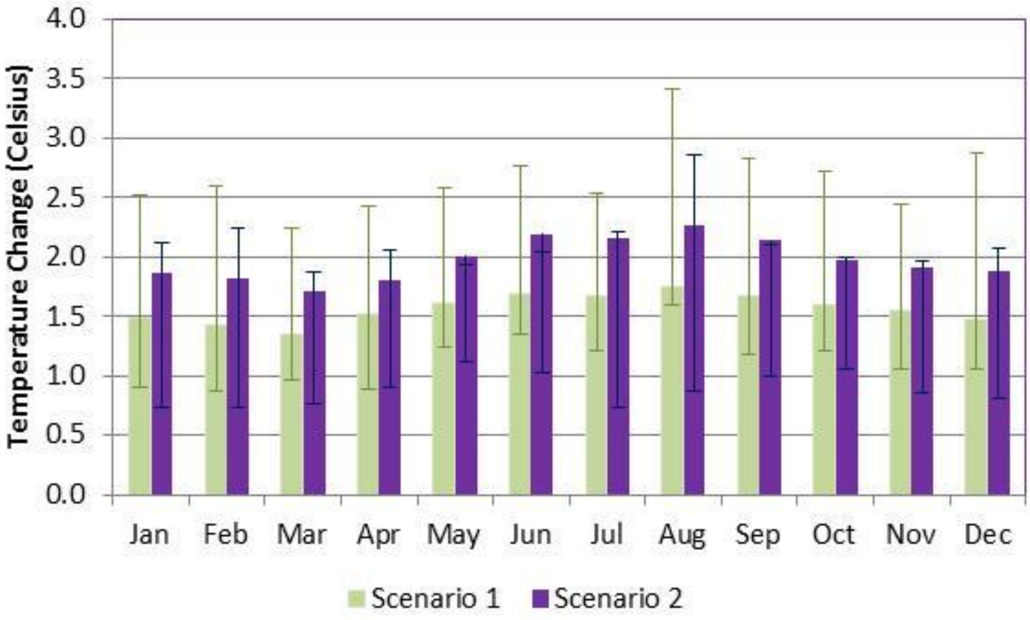


Figure 2.31 Projected change in monthly temperature in the 2040s compared to baseline conditions (1961 – 1990). Source: based on our analysis of data from Girvetz, 2009.

The dry season is projected to become shorter, and more intense with less precipitation during the months of May, June, and July. The projected decrease in precipitation during these winter months (Figure 2.30), combined with a projected 2°C increase in temperature (Figure 2.31), increases the risk of drought during these months. Drier soil during these months may reduce the risk of landslides if a heavy rain event were to occur. Areas where vegetation has been removed and/or the land has been covered by impermeable surfaces, though, may be at increased risk to landslides due to drought (for more detail, see Section 2.5.1). These are also the areas most likely to concentrate urban development. In addition, it is believed by some informants that higher temperatures and drought may increase landslide risk by limiting the growth of vegetation, leading to an increase in land surface exposure and less protection against erosive agents. It is also unclear how existing forest and vegetation may change in response to climate change (e.g., disapperance or reduction of forest cover) which could further exacerbate the landslide risk.

Seasonal Precipitation. Overall, the dry season is projected to become drier and the wet season is projected to become wetter. Table 2.5 shows how precipitation patterns may shift in the 2040s by providing projected precipitation amounts for the dry and wet season under both scenarios. As with the monthly scale, the climate model ensemble average (labelled "median" in Table 2.5) suggest an overall reduction in precipitation during the dry season of about 40 percent and an increase in precipitation during the rainy season of about 5 percent.

Table 2.5 Projected precipitation for the Cusco area in the 2040s relative to current precipitation (i.e., the 1965 to 1990 average). Projected data is shown for the minimum and maximum result from climate models, the results corresponding to the 25th and 75th percentile, and the ensemble median. Source: based on data from Girvetz, 2009.

Precipitation (mm)		Current	Projected				
			Min	25%	Median	75%	Max
Scenario 1	Dry Season	77.4	26	37.1	**46.2**	51.2	71.9
	Rainy Season	568.2	495.2	545.8	**588.5**	629.6	740.8
Scenario 2	Dry Season	77.4	28.6	36.6	**45.0**	50.1	60.4
	Rainy Season	568.2	485.9	559.0	**595.6**	627.5	711.7

To consider the variability in the precipitation projections across climate models, Table 2.7 also shows the minimum projection by an individual model, the maximum projection for an individual model, and the 25- and 75-percentiles across climate model projections. Though the model ensemble trend is clear and consistent across emission scenarios, there is some disagreement amongst the climate models in the magnitude and direction of the changes in seasonal precipitation. The projected values under the 'median' column in Table 2.7 are bolded to illustrate that the majority of the climate models are in agreement regarding the direction of the projected precipitation (i.e., projected increase or decrease in precipitation).

Changes in intensity and frequency of storm events.[11] Precipitation rates provide some indication of how storm intensity and frequency may change in the future. If the number of storms impacting the Cusco area remains constant, then an increase in the monthly precipitation rate (i.e., amount of precipitation per day averaged over the month) would indicate an increase in storm intensity. If the amount of precipitation per storm were to remain constant, then an increase in monthly precipitation rate would suggest an increase in the number of storms.

The projected precipitation rates in the 2040s do not specifically describe how the number of storms or the amount of precipitation per storm may change in the future, but they do indicate an overall decrease in the rate of precipitation in nearly all months (see Table 2.6). This suggests the intensity and/or frequency of precipitation events may decrease in the 2040s relative to 1961 to 1990. May is the only month that is projected to experience an overall increase in precipitation events. During the rainy season, there is substantial reduction in the rainfall rates which, when combined with the projections of increased monthly rainfall, suggests more frequent but less severe rain events. This could lead to a reduction in the potential flooding such as flash floods associated with heavy precipitation events. It should be noted that as these projections are based on a few models - and since precipitation projections tend to change substantially amongst climate models – other climate models may project different changes in precipitation rates.

Table 2.6 Change in precipitation rate (mm/day) projected for the 2040s relative to 1961 to 1990 for Cusco using data from PRECIS-Caribe.

Rainy Season	Precipitation Rate (mm/day)		Dry Season	Precipitation Rate (mm/day)	
	Scenario 1	Scenario 2		Scenario 1	Scenario 2
November	-1.5	-1.3	May	0.5	0.4
December	-1.2	-1.0	June	-0.8	-0.6
January	-0.5	-0.4	July	-0.4	-0.3
February	-0.1	-0.1	August	-0.7	-0.5
March	-0.2	-0.1	September	-1.7	-1.3
April	-0.4	-0.3	October	-1.9	-1.5
Season	-0.8	-0.7	Season	-0.8	-0.6
Annual	**-0.7**	**-0.6**			

Summary. While there is considerable uncertainty associated with the available climate projections, this first order approach indicates that, by the 2040s, the rainy season may be intensified and extended by a few months, slightly increasing precipitation and the possibility of floods and landslides (see Table 2.9). This may be moderated by a reduction in the intensity of rainfall during precipitation events, suggesting that there will be more frequent, but less severe rainfall events in the future.

Cusco's dry season is projected to become even drier, which—combined with projected warming in the future—may reduce soil moisture. Drier soils may reduce the threat of

[11] This analysis used a different set of climate projections to investigate potential changes in the intensity and frequency of precipitation events; this dataset is based on the projections of climate models developed by the Hadley Centre of the Meteorological Office of the United Kingdom.

landslides if a heavy rain event were to occur, except in regions where vegetation has been removed and/or the land has been covered by impermeable surfaces which increases the threat of landslides.

Table 2.7 Summary of the projected change in temperature, precipitation, and precipitation rate for the 2040s.

Scenarios	Season	Seasonal Temperature Change	Seasonal Precipitation %Change	Change in Precipitation Rate
Scenario 1	Dry season	1.7°C	-40%	-0.8 mm/day
	Rainy season	1.5°C	4%	-0.8 mm/day
Scenario 2	Dry season	2.1°C	-42%	-0.6 mm/day
	Rainy season	1.8°C	5%	-0.7 mm/day

Figure 2.32 qualitatively illustrates today's dry, cold season (i.e., dry season) and wet, warm season (i.e., rainy season) and the associated changes projected in the 2040s for each of the scenarios. The dry, cold season is projected to become drier and warmer. The projected warming of 2°C approximately represents the difference between today's cold and warm seasons. Based on current climate, this suggests a renaming of this season from 'dry and cold' to 'dry and warm.' The wet, warm season is projected to experience a slight increase in precipitation but a larger increase in temperatures. Hence, the wet, warm season is projected to become a wet, hot season.

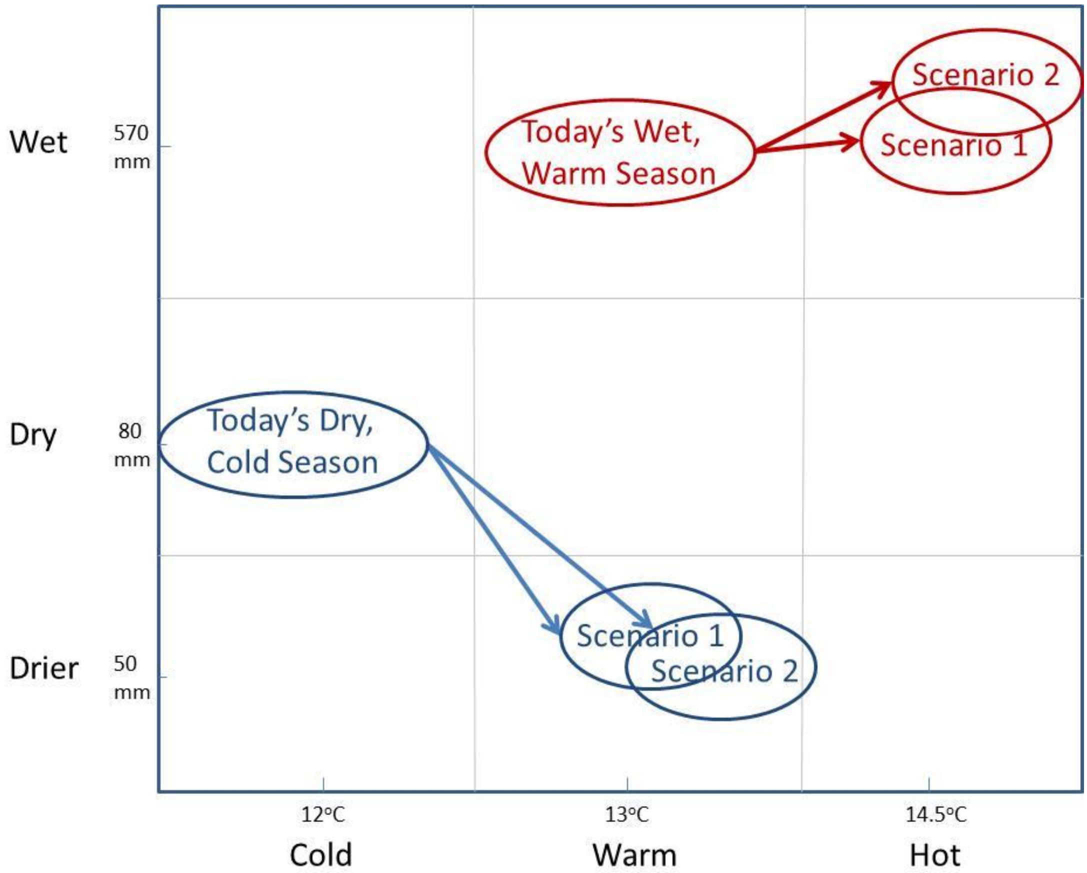


Figure 2.32 Illustrative diagram of the projected change of today's dry, cold and wet, warm seasons (not to scale).

In addition two other factors that may influence landslide vulnerability in the Cusco area, the ITCZ and runoff from glacial melt (refer to Box 6). These factors are discussed qualitatively and are separate from the above analysis because it is difficult to link them directly to temperature and precipitation projections given the uncertainty in the projections and limited runoff projections for the Cusco area.

Box 6 Additional Considerations

ITCZ. Though the effects of climate change on the ITCZ in Southern Peru are not conclusive, most studies agree that a constant increasing trend of temperature over the Andes is expected, as observed by the faster rate of increase in the last two decades. Similarly, as is the case in Southern Peru and Western Bolivia, the overall region is likely to continue the trend of slightly drier conditions, which could have a mitigating effect on landslide and flood risk (Francou et al 2003).

Glacier melt. Although glacier melt may not be important to the hydrologic cycle in the city of Cusco, it is discussed here as it does affect the Cusco region. Based on different Intergovernmental Panel on Climate Change (IPCC) scenarios for 2050 and 2080, all models indicate that glaciers will continue retreating and permafrost will continue degrading, resulting in the formation of new glacial lakes and an increased susceptibility to landslides, respectively (Vuille, 2008). For smaller glaciers, this discrepancy in the mass-energy balance equilibrium may lead to their disappearance possibly within the next few decades. As glacial volume decreases and run-off from glaciers increases, communities will be at greater risk of enhanced flood events from increasing glacial streamflows. As glaciers begin to disappear over the longer-term, streamflows will subside and the decrease in the “glacial buffer” or run-off during the dry season may lead to concerns over the availability of year-long drinking water rather than flooding and landslide hazards. The extent to which these dynamics affect the livelihood of communities downstream depends on their ability to adapt to alternative scenarios.

2.6.2 Change in future floods and landslide events

As the climate projections were available at the regional scale (e.g., not downscaled to a scale that reflects localized change for the city of Cusco), our findings are applicable at the regional scale. They suggest that the current locations prone to landslides and floods described in Figures 2.22 and 2.28 above will continue to be at risk. Table 2.8 provides a summary of the highest-risk locations and how flood and landslide hazards will qualitatively change in the future due to climate changes.

Table 2.8 Qualitative summary of change in flood and landslide hazard in Cusco by 2040 compared to current levels.

Hazard	Location	Future change in climate (mid-century)	Impact on hazard	Projected change in hazard
Flooding	Flooding has been observed along the Sipaspuio, Sacramayo, Picchu, Huamancharpe, Saphi, Ccorimachachuayniyoc, Chocco, Huancaro, Cachimayo, and Pumamara rivers that drain to the Huatnaney basin. Though the city of Cusco is not considered at risk to overland flooding during the rainy season, many of the nearby districts are at risk including Wanchaq, Santiago, San Sebastian, and San Jeronimo. River erosion does affect the City of Cusco along the banks of the Muyuorcco, Chacan, and Saphi rivers, along with other smaller-sized streams.	Slightly prolonged and intensified rainy season though this may be mitigated by less – intense rainfall episodes that occur more frequently, but, on balance, the projected increases in precipitation will likely increase flood risk	Increased flood hazard	

Hazard	Location	Future change in climate (mid-century)	Impact on hazard	Projected change in hazard
Landslides	Landslides have been observed along the Saphy river basin, quebradas Huancaro-Chocco (SW), Cachimayo micro-basin, Pumamarca-Teneria micro-basin, Huaccoto micro-basin, Kayra micro-basin, Quebrada Ayahuayco, Quebrada Picchu, Quebrada Sipaspuquio, Quebrada Sacramayo, Quebrada Hermanos Ayar, Quebrada Ccorimachahuayniyoc, San Sebastian (North and South), San Jerónimo (North and South), and parts of Saylla and Poroy.	See above	Increased landslide hazard	⬆
		Increased chance of drought during the dry season	Reduced soil moisture may reduce the threat of landslides for unaltered vegetation	⬇
			Drying soils may increase the threat of landslides where vegetation has been removed and/or covered by impermeable surfaces	⬆

Figures 2.33 and 2.34 present a qualitative analysis of how the intensity and/or frequency of floods and landslides may change in the 2040s consistent with both scenarios. We used the rankings described in Table 2.9 to distinguish areas on the map where the projections suggest a reduction, increase, or no change in flood and landslide events. The ranking system also reflects differences in the projected hazard by season. This approach could be broadened and enhanced by engaging stakeholders to consider how the climate projections presented in this analysis may impact the findings of these maps.

Table 2.9 A ranking system to distinguish areas on the map projected to experience change or no change in landslide and flood hazards.

Ranking	Description of Projected Change in Hazard
⇩	The temperature and precipitation projections suggest that an overall reduction in the intensity and/or frequency of the hazard.
▭	The temperature and precipitation projections suggest that areas prone to the hazard will not change in the future.
⬆	The temperature and precipitation projections suggest that an overall increase in intensity and/or frequency of the hazard.
⇧⇩	The temperature and precipitation projections suggest the hazard may reduce in intensity and/or frequency during the dry season and increase during the rainy season.

Figure 2.33 denotes the areas that are currently prone to flood events and how the hazard will change in the future. The hazard is projected to increase within the red lines. This reveals that the areas identified as prone to flood events are projected to continue to cause concern to Cusco in the 2040s. This determination was reached based on both scenarios projecting slightly greater precipitation and a longer rainy season. However, given the change in precipitation rate, there may be a reduction in heavy rainfall events which could reduce certain flood patterns currently experienced.

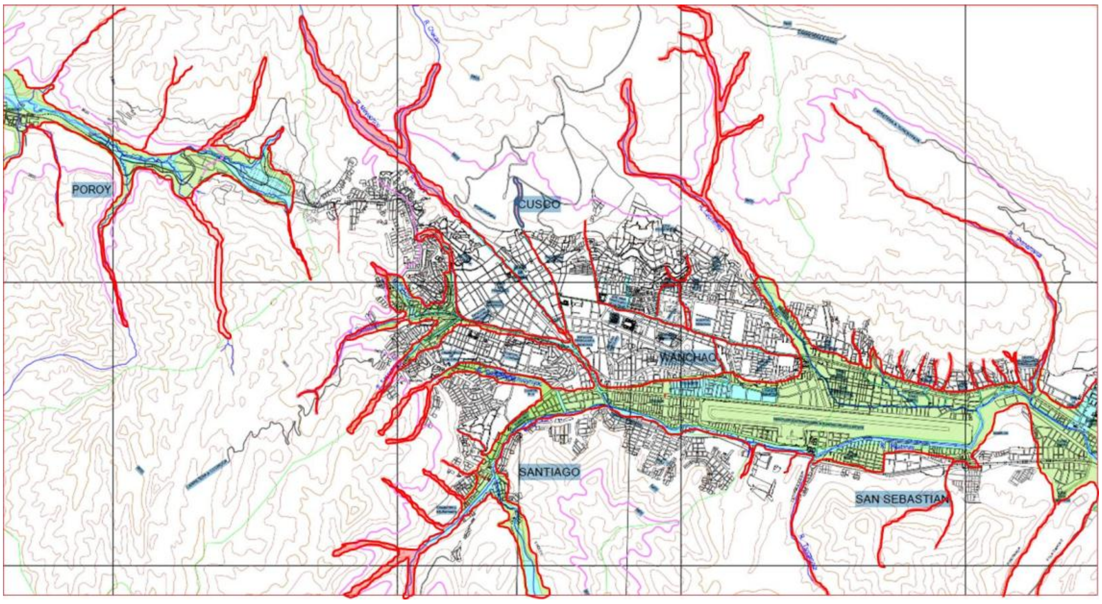


Figure 2.33 Projected change in floods in 2040 for both Scenario 1 and Scenario 2 where the red line denotes areas that are currently prone to flood events and are projected to increase. Source: adapted from Benavente Velasquez et al. 2004.

The change in landslide hazard is less clear; some regions may experience an increase in activity while others experience a decrease. Figure 2.34 shows areas in red where an increase in landslide events in the 2040s is possible during the rainy season. This is because the precipitation during the rainy season is projected to increase. The red lines also suggest an increase in the drier season where impermeable surfaces are located. The yellow areas suggest regions that may experience an increase in landslides during the rainy season but a decrease in landslides during the drier season (given these areas are largely of unaltered vegetation). This assumes the current vegetation adapts to future climate variability and other factors such as land use does not change.

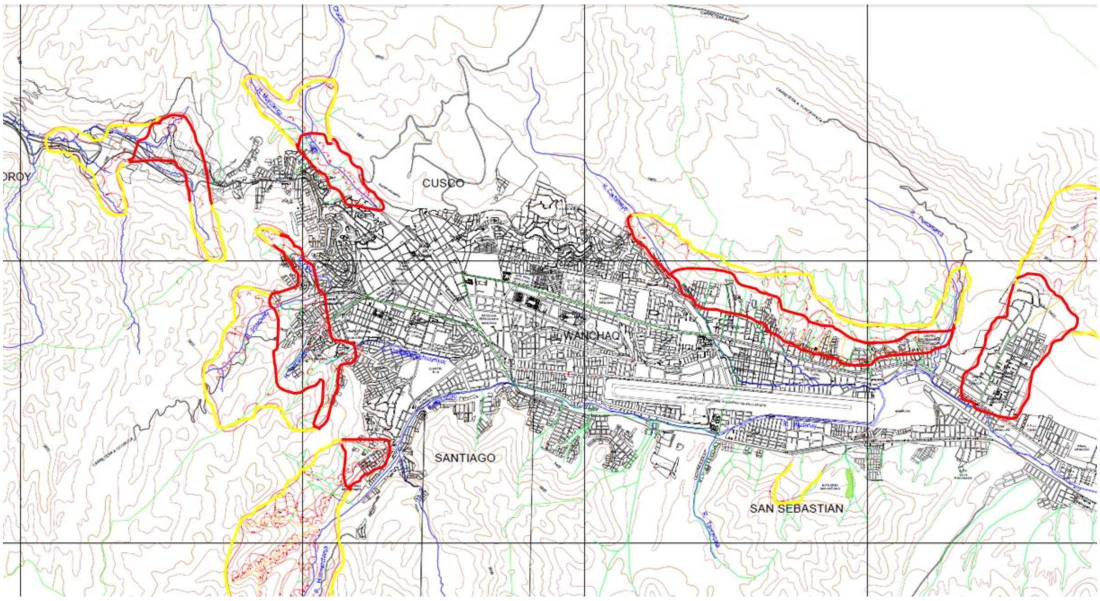


Figure 2.34 Projected change in landslides in 2040 for both Scenarios where the red line denotes areas that are currently prone to landslide events and are projected to increase while the yellow line denotes areas that are currently prone to landslide events and are projected to increase in frequency in the rainy season and decrease in the frequency in the dry season. Source: adapted from Benavente Velasquez et al. 2004

2.6.3 Gaps and limitations

The following bullets consider the gap and limitations:

- Data to support the development of robust local meteorological and hydrological conditions are limited. This analysis would benefit from an intensified network of hydro-meteorological stations providing multi-decadal information. In addition, this assessment would have benefited from the availability of daily observed precipitation data.
- A limitation to our analysis is that the current identification of areas prone to floods does not explicitly describe the magnitude of precipitation events associated with each flood event. The landslide hazard map does not indicate the potential areas susceptible to debris flows (i.e., debris can be carried long distances causing damage in downstream areas). It is unclear, however, the importance and prevalence of debris flows in Cusco.
- This analysis would have benefited from the development of precipitation thresholds and indicators associated with historic floods and landslide events.
- There is no early warning systems which could have been used to provide additional precipitation threshold(s).
- The use of monthly regional climate projections does not provide enough resolution to consider how extreme precipitation events may change.
- Stream gage data was not available though would be useful to explore the relationship between precipitation and runoff. In addition, stream gage data is useful for calibrating monthly water balance models that can then be used to project how the stream gage parameters may change in response to future changes in monthly temperature and precipitation.

3 Urban, social and economic adaptive capacity assessment

3.1 Urban, social and economic context

The urban area of Cusco is marked by a long-run expansion and settlement pattern. The urban core emerged through an Inca occupation process. It was followed by the Spanish occupation period, in which urban expansion truly took off. It gradually included areas located at the bottom of the valley as well as the slopes. This process had a significant impact in shaping Cusco's current urban structure and layout.

Cusco is characterized by an irregular topography. The city is located in the Huatanay River basin and has a complex watershed system. The river is crucial for the city's urban structure. Expansion has occurred in the valley where there is a confluence of the Saphy and Huancaro Rivers.

Cusco's urban area had a population of 407,488 in 2011 (INEI, 2011). As mentioned above, the urban area is spread across five of the province's districts: Cusco (including the historic centre), Santiago, San Sebastián, San Jerónimo and Wanchaq. Cusco, Santiago and Wanchaq are the urban districts with the most intensive land use development. The incorporation of the two remaining districts into the urban area occurred more recently. San Sebastián was incorporated in the 1970s and 1980s, while San Jerónimo in the 1980s and 1990s. They are both still going through a process of consolidation and densification, and mainly hold supportive housing functions to the existing core.

Cusco is still going through an important phase of urban expansion. Projections estimate that Cusco's population will reach 434,714 by 2015. As an important economic centre, Cusco is a hub for in-migration, attracting people from the surrounding region and the rest of Peru, and mostly from the rural areas, although informants did mention that migration had occurred in recent years from other cities, notably Lima.

Due to its geographical location in a valley, Cusco has grown following a linear, horizontal and low-density pattern, covering in this fashion all available space. The urban area is marked by the following characteristics (MPC, 2006):

- A mononuclear city structure, coinciding with Cusco's historic centre. Services and commerce, highlighting tourism, constitute the city's main economic activity. As will be seen below, there may now be a shift to a more multi-centered structure.
- Peripheral urban areas located in slopes and hazard-prone zones, as a result of a process of informal and unplanned urbanization.
- Inappropriate provision of basic public services amongst a considerable part of the population.
- A pattern of territorial integration between the districts composing the province of Cusco.
- A pattern of urban growth following the main road infrastructure network.
- An urban-rural continuum: projections estimate that as urban expansion continues, adjacent new population pockets and older standalone settlements will be absorbed into the existing urban structure.
- A growing pattern of individual land use focusing on the economic utilization of land, disregarding the urban and environmental degradation this can cause.

Since the 1990s, large infrastructure investments and the crackdown on narcotics trafficking and production within Peru paved the way for future economic development. This has led to a considerable increase in the country's standard of living and Human Development Index (HDI) rating. GDP growth for 2012 is forecasted at 5.6 per cent, and on the assumption that global conditions improve, GDP growth will pick up to an annual average of 5.8% in 2013-16.

This is slower than in the past decade, but still robust by regional and international standards (Economist Intelligence Unit, 2012). Mining, agriculture, fisheries, and industry were traditionally the sectors with the highest growth potentials, but in the period since, tourism has become increasingly important both for Peru, and particularly for the region of Cusco.

3.2 Methodology

For the assessment, qualitative information supported by the quantifiable data which was collected during consultations and from publicly available reports and other material are both used to discuss a number of issues. These include economic and residential land uses, their interplay, and the connectivity provided by infrastructures as well as the distribution and quality of critical infrastructure networks, including those that extend beyond the urban administrative boundaries, and with special focus on transportation, water and energy. This is set within the trajectory of urban expansion and growth as it is currently taking place in Cusco.

Limitations

There are no obvious limitations associated with the extent of the data. Specific limitations include:

- **Patterns of urban expansion and demographic change.** Some fast growing urban areas, for example towards the north and south of the city, fall outside the study area.
- **Distribution and quality of critical infrastructure.** Water-related issues associated with changes in the water resources due to climate change and variability in the wider region of Cusco are not discussed.

3.3 Economic characteristics

The 2010 floods described above revealed the city's economic dependency on tourism and the devastating effects that climate-related natural disasters can have. The floods caused damages of an estimated value of USD 250 million. This raised awareness amongst government officials to pay closer attention to disaster risk reduction strategies and preparedness.

Although until the early 1990s tourism was not considered an important sector for the country's future economic development, in the period since tourism has expanded faster than all other sectors (Anderson, 2008; Plan Estratégico, 2010). Cusco is considered the main tourist destination in Peru and has experienced sustained growth for the past years. For the period 2002 to 2007, the growth of tourists was 19 percent a year, with foreign arrivals increasing at 22 percent (whereas nationals increased at 15 percent) (Plan Estrategico, 2010). In 2008, 1,498,376 tourists visited the region of Cusco, with 66 percent of this total foreign in origin. Although the highest concentration of tourism resources is found in the province of Urubamba (Machu Picchu), the province of Cusco has the most intense tourist use (Plan Estrategico, 2010).

Table 3.1 shows how tourism activities are spread across the five districts that comprise urban Cusco.

Table 3.1 Tourism activity in Cusco

District	Tourism agencies	Hotels	Restaurants/ bars	Concentration of total activity (%)
Cusco	350	287	661	58
Wanchaq	74	78	376	24
Santiago	32	17	127	8
San Sebastián	23	23	104	7
San Jerónimo	6	3	38	2

Source: SUNAT – CUSCO, 2004 – Equipo Técnico de Gestión del Plan Director de la Gerencia de Desarrollo Urbano y Rural de la Municipalidad Provincial del Cusco.

Although tourism is linked with an increase in jobs, particularly those filled by the unskilled labour that is needed by tourist businesses such as restaurants, hostels, hotels, and tour guide businesses, a number of diverse problems have emerged. These include seasonal unemployment, poor urban planning, and destruction of the environment. In addition, tourism as an industry naturally fluctuates more than other sectors and depends upon the wider global economic environment. For example, when the US or Europe fall into recession, the number of tourists visiting Cusco falls.

Capital flight is another problem that is evidenced in Cusco (Anderson, 2008). As Wong (1996) points out, international firms may cause tourism profits to flow out of the country while placing the burden of the taxes on the local population. Tourism requires significant investment into infrastructure and services but unfortunately the growth of tourism in Cusco has not always generated positive tax receipts and the resulting higher tax base has not resulted in significantly higher local government spending (Anderson, 2008; Plan Regional).

Cusco has thus seen a shift in its main economic activity from agriculture to tourism. The dependence upon tourism however can potentially inhibit economic diversification, and hence the potential resilience of the economy

3.4 Urban development, spatial expansion and demographic change

Until the start of the 1950s, Cusco was marked by its inherited colonial layout. Colonial Cusco was structured around the gridiron system[12] (Steel and Klaufus, 2010). However, after the 1950 earthquake that destroyed more than 3,000 homes and left 30,000 to 40,000 people homeless, the city started to expand (Rey, 2007). The earthquake raised national and international attention to the historic city core. UNESCO sent a team of technical advisors tasked with developing an urban plan for reconstruction. The plan aimed to preserve the architectural heritage of the city while modernizing it (Steel and Klaufus, 2010). The 1952 Pilot Project divided the city into districts and clearly defined the city centre as the core development area (Rey, 2007).

In parallel, the city went through a phase of eastwards expansion. At first, and as an urgent measure following the earthquake, a high proportion of the population occupied land that belonged to the state. Further along, rural areas surrounding the historic urban core were sold by landowners to pro-housing associations (*asociaciones pro-vivienda*). These associations were groups composed by middle-class members that wanted to build new housing (Carazas, 2001). This new land was located in close proximity to the urban core, in low parts of the valley, and was characterized by a regular topography.

Cusco started to experience strong demographic pressure in the early 1970s (Table 3.2). Lacking resources to buy land in proximity to the urban core or in areas characterized by regular topography, the newcomers started to settle in high altitude areas in the valley (Carazas, 2001). This led to the appearance of human settlements along slopes surrounding the existing urbanized area (Rey, 2007).

Table 3.2 Demographic growth in urban Cusco

District	1972	1981	1993	2011	2015
Cusco	63,942	86,307	90,774	117,776	118,316
Wanchaq	22,831	36,826	51,584	63,742	63,778
San Jerónimo	4,562	7,426	13,668	39,869	47,101
San Sebastián	3,698	10,941	29,341	95,898	115,305
Santiago	34,691	50,476	70,201	90,203	90,154
Total	129,724	191,976	255,568	407,488	434,714

[12] The gridiron urban form in urban planning is the type of city in which streets run at right angles to each other, forming a grid.

Source: INEI - Censo Nacional VII de Población y II de Vivienda 1972- INEI - Censo Nacional VIII de Población y III de vivienda 1981.- INEI - Censo Nacional IX de Población y IV de vivienda 1993 - INEI - Perú Proyecciones de Población, por años calendario, según departamentos, provincias y distritos; INEI, PERÚ: Estimaciones y Proyecciones de Población por Sexo, según Departamento, Provincia y Distrito, 2000-2015 Boletín Especial N 18. 2009.

This urbanization process was mostly unplanned. Public intervention, if any, occurred after the new populations were already settled, and was mainly directed towards providing basic public services, such as sewage and electricity. This transformed Cusco's urban structure, as it outstripped the gridiron layout. As a result, informal settlements next to the existing urban core followed an incoherent urban pattern, and became an integral and accepted part of the urban landscape (Rey, 2007).

It is thus the lack of policies addressing the fast demographic growth (consisting mostly of low income groups) that resulted in uncontrolled urbanization and contributed to the emergence of urban hazard risks in Cusco. In this sense, the city's population has now to deal with disordered patterns of urbanization that have persisted for over 50 years.

The widening development gap between the urban and rural areas still generates a continuous flow of in-migration. Within the department of Cusco, there is a marked division between the largely urban province of Cusco and other provinces. Despite high levels of economic growth in recent years, rural areas have struggled to reduce poverty levels (Plan Peru et al., 2011). In fact, the department of Cusco is among the poorest in Peru, ranking 20th out of 24 departments in the United Nations Development Program's 2007 Human Development Index (HDI) (PNUD, 2009).[13] Although the HDI for the department of Cusco in 2007 was 0.5796, in the province of Cusco, which is, to reiterate, distinctly urban, it was much higher at 0.6510 (see Table 3.3).

Table 3.3 HDI departmental and provincial by departments grouped by quintiles

	Departamental	Provincial	
		Max	Min
Cusco	0,5796	0.6510 (Cusco)	0.4844 (Chumbivilcas)

Source: Anexo estadístico del Informe, PNUD Perú 2007. Elaboración: PNUD / Unidad del Informe sobre Desarrollo Humano, Perú.

The city is currently horizontally expanding towards the northwest and southeast peripheral suburban areas. At the same time, due to the fact that land in central areas is increasingly becoming expensive and scarce, a vertical urban growth model has also emerged, notably in the denser districts of Wanchaq, Santiago and Cusco. These districts occupy 58 percent of the total urban area but concentrate 77 percent of the urban population of the city and 89 percent of the commercial establishments and services. This high concentration of people and assets also potentially increases exposure to climate change impacts and the risks of disasters that accompany it.

Table 3.4, shows that San Sebastián and San Jerónimo have the lowest densities, but as mentioned above, these districts are expected to experience the fastest demographic growth in the years to come.

Table 3.4 Urban density

District	Population	Urban Area (hectares)	Density (population/hectare)
Cusco	100,712	905.83	111
Santiago	84,097	638.54	132
Wanchaq	63,894	481.71	133

[13] The 2007 HDI classification for the upper quintile ranges from 0.6124 to 0.7745, the medium-high quintile from 0.4186 to 0.5914, the medium quintile from 0.3164 to 0.3949, the medium-low quintile from 0.2245 to 0.3066, and the low quintile: 0.1482 to 0.2206.

District	Population	Urban Area (hectares)	Density (population/hectare)
San Sebastián	45,287	860.20	53
San Jerónimo	18,966	635.28	30
Total	312,956	3521.56	89

Source: INEI - Censo Nacional IX de Población y IV de vivienda 1993 - INEI - Perú Proyecciones de Población, por años calendario, según departamentos, provincias y distritos.- Area Ocupada1993, Plan Qosqo1993 - Area Ocupada 1999, Plan Urbano- s/i Sin información.

Table 3.5 is an inventory of basic infrastructure in the five districts that form Cusco.

Interestingly, Cusco concentrates most municipal level institutions, education establishments and recreational areas, while Wanchaq concentrates most regional level institutions and health-related infrastructure, illustrating the appearance, in the last decades, of a new administrative and business central district to the south in the Wanchaq district, in adjacency to the city's airport. This marks the emergence of a poly-nucleated structure for the city.

Table 3.5 Inventory of basic infrastructure in the Cusco districts

Type of infrastructure	Cusco	Wanchaq	Santiago	San Sebastián	San Jerónimo	Totals
Education	**51**	23	28	27	12	141
	36%	16%	20%	19%	9%	100%
Hospitals & health centres	2	**3**	2	**3**	1	11
	18%	**27%**	18%	**27%**	9%	99%
Recreational areas	**16**	7	5	9	6	43
	37%	16%	12%	21%	14%	100%
Municipal government institutions	**22**	9	4	5	4	44
	50%	20%	9%	11%	9%	99%
National & regional government institutions	6	**22**	2	0	0	30
	20%	**73%**	7%	0%	0%	100%
Bus terminals	0	0	**1**	0	0	1
	0%	0%	**100%**	0%	0%	100%
Airport	0	0	0	**1**	0	1
	0%	0%	0%	**100%**	0%	100%
Police stations	**12**	5	6	2	3	28
	43%	18%	21%	7%	11%	100%
Fire brigade	0	**1**	0	0	0	1
	0%	**100%**	0%	0%	0%	100%
Army barracks	1	0	1	1	1	4
	25%	0%	25%	25%	25%	100

Source: complied with data obtained from Equipo Tecnico de Gestion del Plan Director de la Gerencia de Desarrollo Urbano y Rural de la Municipalidad Provincial del Cusco, Febrero, 2005. Area de Planificacion del Hospital Regional del Distrito de Cusco, enero del 2006. Equipo Tecnico Sub Gerencia de Gestion del Plan Director – GDUR – MPC.

Figure 3.1 in the next page shows the actual location of basic infrastructure within the city, and when combined with a climate related hazard map, can highlight potential hotspots of vulnerability.

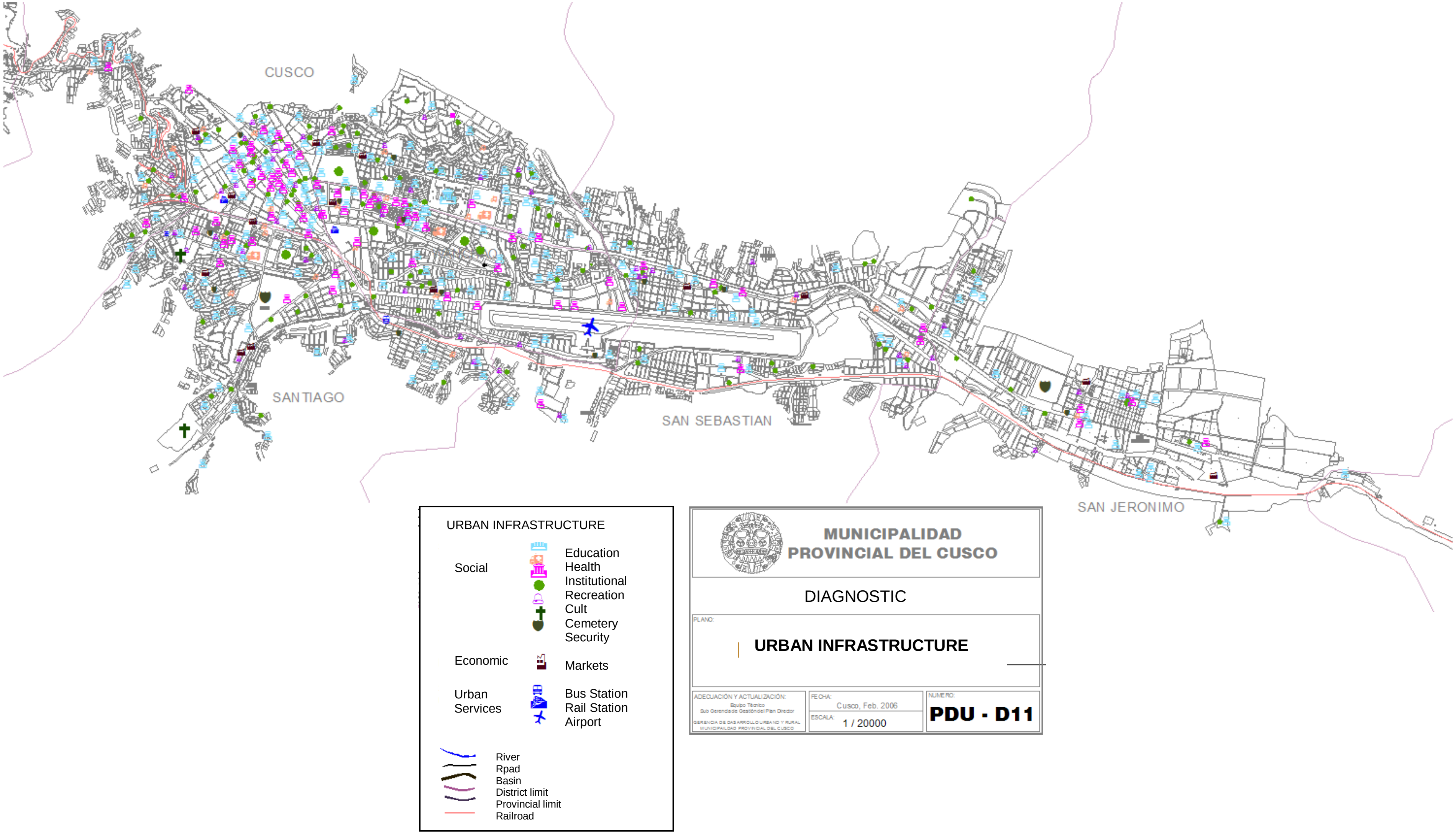


Figure 3.1 Map of basic urban infrastructure. Source: MPC.

In the next five years the districts of Poroy in the northwest and Saylla in the southeast will certainly become an integral part of the Cusco urban system. The new international airport that will be located in the province of Urubamba in the town of Chinchero will further increase migrant influx to the northwest in the districts of Cusco and Poroy.

The MPC has acknowledged the problems caused by unplanned urban expansion. It has identified the demand of land by low income groups and the lack of access to housing as the main cause leading to the appearance of informal settlements in high-risk areas. Informal growth has accounted for approximately 80 percent of the total urban expansion in recent years (MPC, 2006). Areas at greater risks have been identified in the northwest slopes, in Pichu, Ayahuico, and the Saphy River basin. San Sebastian district is at high risk from landslides, while the Wanchaq district, where middle class residents predominate, is an area where limited risk has been identified. Overall, the Urban Planning Unit of MPC estimates that up to 40 percent of Cusco's population is located in risk areas, this rising to up to 60 percent of the population in the city's northwest neighborhoods.

Recognizing the urban planning challenges that the city of Cusco faces, the MPC has developed planning instruments in order to attempt to orient growth in a more sustainable pattern. The "2006-2016 Cusco Territorial Planning Map" and the "2006-2011 Cusco Province Urban Development Plan" present a general overview of the social, economic and environmental issues in the Cusco region. In addition to just identifying risk areas in each district, perhaps more significantly they present tendency, and probable and desirable scenarios in urban expansion. They try to introduce initiatives on how to reach the desirable growth scenario and the actions that should be taken for this.

Despite the existence of these proposals however, unplanned growth remains a problem, and is thus a key factor in determining risk.

In recent decades, the MPC has also tended to concentrate development efforts in the historic urban core, in order to assert the city's position as a tourism centre (Steel and Klaufus, 2010). With the aim of attracting foreign investments and visitors, urban planning designated land use zoning in the historic core as commercial, introduced strict rules for the preservation of old historic buildings and removed street vendors. Although these policies managed to reinforce the historic core as a tourist destination, low income groups that were unable to keep up with the rising real estate prices and construction regulations were effectively removed. Further, increasing prices in commerce in the area meant that low income groups are also excluded from the leisure options the city centre offers. As Crawford and Bell (2012) argue, in Cusco there are "enclaves where investment happens and others where it does not", which results in urban fragmentation.

The next section discusses the locational dynamics of the urban population in more detail, and how unplanned growth relates with poverty and this, in turn, with vulnerability.

3.5 Urban poverty

Many authors have highlighted the linkages between poverty and climate change, particularly in the urban context. This is also reflected in Cusco. Poverty and location of the population interrelate and this social geography of the city influences vulnerability. Vulnerability is thus not limited to the direct impacts of climate change but considers the underlying causes, including social, economic and political factors in addition to the physical susceptibility of the built environment.

3.5.1 Social development characteristics

A close look at social and economic variables in Cusco allows the determining of poverty disparities amongst the five districts that compose the city. Although statistics show a strong overall decrease in poverty from 1993 to 2009, the incidence of poverty remains high in some districts (see Table 3.6). Figures clearly show that poverty is only negligible in

Wanchaq, as all other districts experience poverty rates of above 25 percent.[14] Santiago, San Sebastián and San Jerónimo concentrate more poverty (Table 3.5), as well as a higher number of households with unsatisfied basic needs (UBN), as shown in Table 3.7.

Table 3.6 Poverty and extreme poverty levels

District	Poverty		Extreme Poverty	
	1993	2009	1993	2009
Cusco	35.5	25.5	N/A	4.7
Santiago	49.3	30.1	N/A	3.3
Wanchaq	17.4	4.8	N/A	0.3
San Sebastián	43.6	25.7	N/A	4.2
San Jerónimo	58.8	25.1	N/A	5.8

Source: INEI, UNFPA 1994 in Municipalidad Provincial del Cusco, Gerencia de Desarrollo Urbano y Rural, Sub Gerencia de Gestión del Plan Director. 2006 & INEI, PERÚ: Estimaciones y Proyecciones de Población por Sexo, según Departamento, Provincia y Distrito, 2000-2015 Boletín Especial N 18. 2009.

Table 3.7 Households with Unsatisfied Basic Needs (UBN)

District	Households with at least one UBN	Households with 2 or more UBN
Cusco	15.2	1.6
Santiago	23	3.7
Wanchaq	11	0.4
San Sebastián	21.5	2.9
San Jerónimo	22	4.1

Source: INEI, PERÚ: Estimaciones y Proyecciones de Población por Sexo, según Departamento, Provincia y Distrito, 2000-2015 Boletín Especial N 18. 2009.

A similar pattern is observed when examining overcrowding and access to sewage data. Although figures show good progress over time in Cusco, Santiago and San Jerónimo (Wanchaq has always had better indicators), progress in Santiago and San Sebastián is much slower (Table 3.8).

Table 3.8 Overcrowding and lack of access to sewage connection

District	Overcrowded households		Households without sewage connection	
	1993	2009	1993	2009
Cusco	19.7	8.4	18.6	5.9
Santiago	24.5	13.6	29.3	8.9
Wanchaq	9.6	7.5	5.1	0.4

[14] "The national poverty lines are based on the National Household Survey (ENAHO) conducted annually by the National Statistics and Information Institute (INEI). The national poverty line represents the expenditure necessary to purchase a basic basket of food and non-food items and is equivalent to a monthly value of 257 Soles (or $95 US at the nominal exchange rate) per capita. The national extreme poverty line represents the expenditure necessary to purchase a basic basket of food items only and is equivalent to a monthly value of 144 Soles ($53 US) per capita (INEI 2010)".

In 2011, according to INEI, poverty at the national level was 27.8 percent and extreme poverty 6.3 percent (INEI, 2012). Although poverty levels remain high in Peru, it is estimated that only 18 percent of the households are extremely poor when international comparisons are taken into account (for urban areas such as Cusco this will be considerably lower). Nevertheless, in relative terms, many households are characterized as poor or extreme poor, if the Peruvian context is taken into consideration (Plan Peru et al., 2011).

District	Overcrowded households		Households without sewage connection	
	1993	2009	1993	2009
San Sebastián	17.2	12.2	28	8.7
San Jerónimo	22	9.8	46.5	12.1

Source: INEI, UNFPA 1994 in Municipalidad Provincial del Cusco, Gerencia de Desarrollo Urbano y Rural, Sub Gerencia de Gestión del Plan Director. 2006 & INEI, PERÚ: Estimaciones y Proyecciones de Población por Sexo, según Departamento, Provincia y Distrito, 2000-2015 Boletín Especial N 18. 2009.

The lack of sewage infrastructure is of particular concern in Cusco. The lack of treatment in major cities of the Vilcanota River Basin causes pollution. In 2007, the Public Sanitation Services Company (SEDA) in Cusco produced 22,834,656 meters cubic of water and the volume of treated wastewater was only 9,918,181 meters cubic (or 44 percent). In addition, in 2004, from 112,032 tons of solid waste only 41,040 tons (or 37 percent) were disposed in landfills (GRCUSCO, 2008). As a result, the Huatanay and Saphy rivers and their banks are contaminated by sewage that is discharged untreated or by solid waste (PAT, 2006).

As mentioned in the climate-related hazard assessment, when floods cause the Huatanay River and its tributaries to overflow in the urban area of the city of Cusco, the city faces water pollution caused by wastewater discharge, littering and the need to clear the river beds. The reduction in water quality is also likely to impact upon health.

Crawford and Bell (2011) analysed how differentiated access to water in Cusco influences upon vulnerability. Their findings are discussed in Box 7.

Box 7 Water provision and vulnerability: the cases of San Blas, Angostura and Manco Capac communities

Crawford and Bell (2011) found that by comparing water provision systems in San Blas, Angostura, and Manco Capac different forms of infrastructure organization co-exist in the city of Cusco. Further, they explored how the different modes of infrastructure organization result in inequalities and how this impacts upon vulnerability to flooding.

- ***San Blas*** is a well-established neighborhood adjacent to Cusco's historic core. Household vulnerability to flooding is present due to poor physical assets, such as *adobe* constructions, inappropriate patio drainage, and limited financial resources. Nonetheless, the neighborhood is connected to the municipal water provision system, as the provincial water company.
- ***Angostura*** is located at the edge of the city, on the district of Saylla (although outside the study area, but as seen above Cusco is currently expanding towards there, and the community will become part of the Cusco urban system in the future). It is a previously rural settlement, which is now experiencing fast expansion, with settlements located on both sides of the Huatanay River. Livelihoods are dependent on urban employment and agriculture. The neighborhood has established its own water provision system, which is operated by a committee that is composed by users, and is supported by the local NGO, Centro Guamán Poma de Ayala. The settlement is exposed to annual floods due to deposits of solid waste and untreated wastewater moved by the river.
- ***Manco Capac*** is an impoverished community located on the right side of the Huatanay River in the district of Santiago. Although the neighborhood is relatively close to the city centre, it is not connected to the municipal water system. There is an independent but failing water system operated by a water committee known as ASAPASC. The area is exposed to flooding due to heavy rains, inappropriate solid waste collection, unsealed roads and the absence of a storm water drainage system.

Drawing from the findings of this study, it can be suggested that development-oriented interventions such as improving water and sanitation services can enhance the resilience of people to climate change and variability.

Source: Crawford and Bell, 2011.

3.5.2 Urban design and characteristics of low-income housing

In understanding socio-economic vulnerability to climate-related hazards, assessing the quality of construction is also important. Carrazas Aedo (2001) analyzed the urban structure of Cusco and proposed the following three categories of urban morphology:

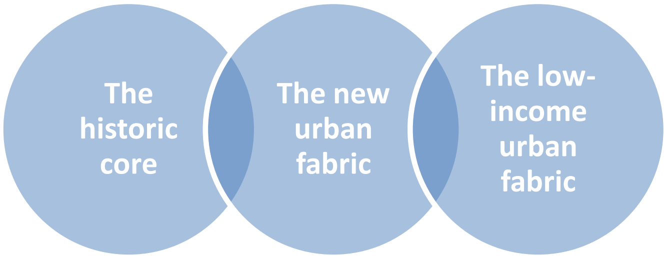


Figure 3.2 Types of urban morphology in Cusco

The low-income urban fabric is characterized by the presence of *adobe* or *quincha* dwellings. *Adobe* and *quincha* are local construction materials derived from mud. The morphological characteristics of low-income housing in Cusco are the result of socio-historic processes – *adobe* and *quincha* are materials that were used by low-income groups since the Inca period. *Adobe* remains nowadays as the predominant material used by low-income households that informally settle in the periphery of Cusco (Tarque et al, 2009). According to the 2005 INEI census, around 80 percent of the building stock in Cusco is made of *adobe* (Tarque et al, 2009).

This is an extremely important factor that may influence vulnerability, as *adobe* dwellings are the most vulnerable buildings in Cusco (Benavente et al, 2004). Adobe dwellings are usually built of unreinforced brickwork and are characterized by strong structural deficiencies: foundations are of little depth, and a high percentage of openings for windows and doors are present in walls (Rojas-Bravo et al, 2004).

The MPC clearly acknowledges in the 2006 Cusco Province Urban Planning Plan that the city is marked by an inappropriate urban design in relation to the unstable characteristics of slopes. Embedded within the urban morphology of Cusco, the lack of physical security of settlements is a poverty factor. Further, due to the unplanned pattern of urban expansion, *adobe* dwellings are often located in the most exposed areas to floods and landslides, such as in proximity to rivers or along risk-prone slopes (Benavente et al, 2004).

The vulnerability of human settlements to floods and landslides in Cusco is thus largely the result of three factors: location, poverty levels, and quality of urban settlements. This, coupled with limited financial resources and limited access to basic services, increases the vulnerability, notably for the low-income groups, to climate-related hazards.

3.5.3 Educational characteristics and perceptions of climate extremes

Educational achievement figures show small differences amongst districts, with Cusco and Wanchaq having, nonetheless, better educational results (Table 3.9).

Table 3.9 Educational achievements

District	Households with kids that don't go to school (%)	Educational achievement of the population aged 15 and more
Cusco	1.1	0.71
Santiago	1.8	0.65
Wanchaq	0.8	0.8
San Sebastián	1.7	0.68

District	Households with kids that don't go to school (%)	Educational achievement of the population aged 15 and more
San Jerónimo	1.5	0.66

Source: INEI, PERÚ: Estimaciones y Proyecciones de Población por Sexo, según Departamento, Provincia y Distrito, 2000-2015 Boletín Especial N 18. 2009.

Note: Educational achievement is an indicator of the learning and knowledge achievements by the population of age of 15 and above, in the different stages of the national education system and corresponds to the different phases of personal development. The educational levels are: elementary, secondary and tertiary (university and non-university education).

Another consideration relates to how people think and feel about climate-related hazard risks and how this relates to whether action is taken to reduce risks. In Cusco, as in most places worldwide, people are more comfortable about understanding landslides and floods as hazard events, and the need for disaster risk management to mitigate these events, rather than seeing that these events can be exacerbated by climate change.

The 2010 floods are the most recent disaster event in people's memory. During our interviews, this event was often cited as an example to highlight that disaster risk mitigation must be a fundamental component of future plans. Considering the historic knowledge of people to better understand climate-related risks is sensible. Continuous communication is thus critical as we suffer from 'half-life memory' when it comes to disasters.[15] In addition, people most often think of mitigation when they hear about climate change, and they are not familiar with the concept of climate change adaptation. Further, according to respondents very technical (and often academic) analyses are not helping to raise awareness about climate change. People need to be well informed about climate change but it has to be done in a way that can be understood by everyone.

Major disasters draw media attention, remain vivid in people's memory and may initiate political action. Yet it is not just major disaster events that need to be considered. Often, smaller events are also devastating, particularly for the low income households. Certainly, as many commentators have pointed out, large concentrations of low-income households face high levels of risk for the whole continuum of risk (every day, small disasters, through to major disasters).

3.6 Spatial, social and economic impact upon disaster risks

Overall, the urban social and economic adaptive capacity assessment of Cusco can be summarized in the following table (Table 3.10). It describes key characteristics that impact upon climate related disaster risks, such as floods and landslides. A qualitative codification is applied to each characteristic: minimal (it is unlikely that this characteristic will impact upon hazard risk), moderate (it is likely that this characteristic will impact upon hazard risk), and significant (it is highly likely that this characteristic will impact upon hazard risk). Classification follows a subjective, multi-criteria approach. The level of influence assessment is thus based on a combination of stakeholder meetings, secondary literature and the institutional mapping and rapid diagnostic developed in the first phase of the initiative.

Table 3.10 Socio-economic characteristics that impact upon climate related disaster risks

Characteristic	Description	Level of influence
Location of human settlements	Cusco is characterized by an irregular topography. It is located in the Huatanay River basin and has a complex watershed system. Human settlements also exist along slopes surrounding the existing urbanized area.	Significant
Demographic change	Cusco is still going through an important phase of urban growth. Projections estimate that Cusco's population will reach 434,714 by 2015. The city is hub for in-migration,	Minimal

[15] See "Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century," by Abhas K. Jha, Robin Bloch and Jessica Lamond. Available at: www.gfdrr.org/gfdrr/urbanfloods

Characteristic	Description	Level of influence
	attracting people from the surrounding region and the rest of Peru, and mostly from the rural areas. Annual population growth, however, has decreased over time in Cusco.	
Economic characteristics	Cusco has seen a shift in its main economic activity from agriculture to tourism. The dependence upon tourism can potentially inhibit economic diversification, and hence the potential resilience of the economy. Further, although the highest concentration of tourism resources is found in the province of Urubamba (Machu Picchu), the province of Cusco has the most intense tourist use.	Significant
Spatial expansion	Expansion has occurred in the valley where the Saphy and Huancaro Rivers come together. The city has grown following a linear, horizontal and low-density pattern, covering in this fashion all available space. The city is currently horizontally expanding towards the northwest and southeast peripheral suburban areas. San Sebastián and San Jerónimo have the lowest densities, but these districts are expected to experience the fastest demographic growth in the years to come.	Moderate
Urban structure and layout	Cusco, Santiago and Wanchaq are the urban districts with the most intensive land use development. The incorporation of the San Sebastián and San Jerónimo districts into the urban area occurred more recently. San Sebastián was incorporated in the 1970s and 1980s, while San Jerónimo in the 1980s and 1990s. They are both still going through a process of consolidation and densification, and mainly hold supportive housing functions to the existing core. This urbanization process was mostly unplanned. Public intervention, if any, occurred after the new populations were already settled, and was mainly directed towards providing basic public services, such as sewage and electricity. This transformed Cusco’s urban structure, as it outstripped the pre-existing gridiron layout.	Significant
Urban design and characteristics of low-income housing	Around 80% of the building stock in Cusco is made of *adobe.* This factor may influence vulnerability, as *adobe* dwellings are the most vulnerable buildings in Cusco. Adobe dwellings are usually built of unreinforced brickwork and are characterized by strong structural deficiencies.	Significant
Urban infrastructure	Although figures show good progress over time in Cusco, Santiago and San Jerónimo (Wanchaq has always had better indicators), progress in Santiago and San Sebastián is much slower. Cusco concentrates most municipal level institutions, education establishments and recreational areas, while Wanchaq concentrates most regional level institutions and health-related infrastructure, illustrating the appearance, in the last decades, of a new administrative and business central district to the south in the Wanchaq district, in adjacency to the city’s airport. Figures also show access to services is considerably better in Wanchaq.	Significant
Urban poverty	Although statistics show a strong overall decrease in poverty over the past decades, the incidence of poverty remains high in some districts. Figures clearly show that poverty is only negligible in Wanchaq, as all other districts experience poverty rates of above 25%. Santiago, San Sebastián and San Jerónimo concentrate more poverty, as well as a higher number of households with unsatisfied	Significant

Characteristic	Description	Level of influence
	basic needs (UBN).	
Educational characteristics and perceptions of climate extremes	Educational achievement figures show small differences amongst districts, with Cusco and Wanchaq having slightly better educational results. The 2010 floods are the most recent disaster event in people's memory. People are more comfortable about understanding landslides and floods as hazard events rather than seeing that these events can be exacerbated by climate change.	Minimal

4 Institutional adaptive capacity assessment

4.1 Institutional context

Cusco as a city is an important historical and economic site in Peru. As seen above, it serves as a tourism hub in its own right, but also functions as a transit point on the tourist trail to Machu Pichu and the Sacred Valley. Transport routes in and out of the Cusco are vital for the sustained flow of tourism to Peru's most important historical tourist destination. Tourism and potential employment opportunities draw a growing number of immigrants to Cusco. The migration into the city is closely related to the increasing impact of climate change on agriculture and the livelihoods of rural communities in surrounding regions.

As well as an increasing number of regional migrants, Cusco contains a large transient population from its tourism industry. The latent vulnerability present in the city due to its shifting demographic make-up cannot be viewed in isolation from socio-economic activities in its surrounding areas. The rapidly evolving population of the city, and subsequent pressures on infrastructure and services, pose a unique challenge for city-level institutions engaged in risk management. Any long term strategic approach to adaptation planning for urban Cusco cannot be divorced from regional plans for both risk reduction and disaster management.

4.2 Methodology

Data collection for the institutional assessment was based on three phases. The first phase utilised background data provided in the local consultant report from the initial rapid diagnostic assessment, along with other relevant secondary data and reports. The second phase was undertaken during the preparatory scoping visit, where interviews with key informants were used to characterize the background institutional architecture and culture of decision-making for risk management in Cusco, verify the appropriateness of the overall framework, and identify any remaining written data sources. Additionally, the visit was used to contact a wider range of stakeholders from government agencies, civil society and the private sector that were willing to complete the questionnaire survey. In the third phase, the questionnaire survey was circulated to these respondents, and the results collated with all other collected data.

4.2.1 Background data

For Cusco, a fair amount of data required was available through documentary evidence – dates and extent of legislation, urban planning guidelines, etc. The primary source for this type of information was the report prepared by local consultant Carlos Alfaro. Using desk based research and interviews with key stakeholders, the local consultant report provided an overview of the relevant institutions and policy frameworks for climate change adaptation and risk management in Cusco. A list of some available documents, reports and policy resources was also provided. Although the report outlined the main institutions involved in risk management functions in Cusco, further data was required to effectively map relevant risk management agencies and organizations. More information was also required to assess the efficacy and robustness of risk management structures, and their potential to adapt in the context of increasing climate change risk. Interviews using the Adaptive Capacity Index were conducted during the preparatory scoping visit to provide this information.

4.2.2 Adaptive Capacity Tool

The institutional assessment focussed on the risk management and planning structures and capacities of city governments in each urban location, since adaptation is a planning challenge that must be incorporated into most areas of government activity in order to shape local changes; as well as positively influence the relationships between municipal authorities and local level organizations working to adapt to climate change.

For the analysis of the institutional context and capacity for adaptation building, the consultants deployed the Adaptive Capacity Index (ACI) developed for the EC FP7 project

MOVE, which assesses institutional adaptive capacity for climate change and multi-hazard disaster risk at the local and national levels. The ACI seeks to measure disaster risk management in terms of the perceived performance of public policy and adaptive capacity for four fields: risk identification, risk reduction, disaster management, and adaptive governance. Each policy field is evaluated using the benchmarking of a set of sub-indicators that reflect performance targets associated with the effectiveness of disaster management activities. The participation of external experts as well as disaster managers in validating the quality of specific activities and capacities is incorporated to minimise bias. Each of the four elements of the framework identified above is populated by four sub-indicators. A detailed list of the variables can be found at http://www.move-fp7.eu/. The figure below illustrates the framework structure of the ACI (Figure 4.1).

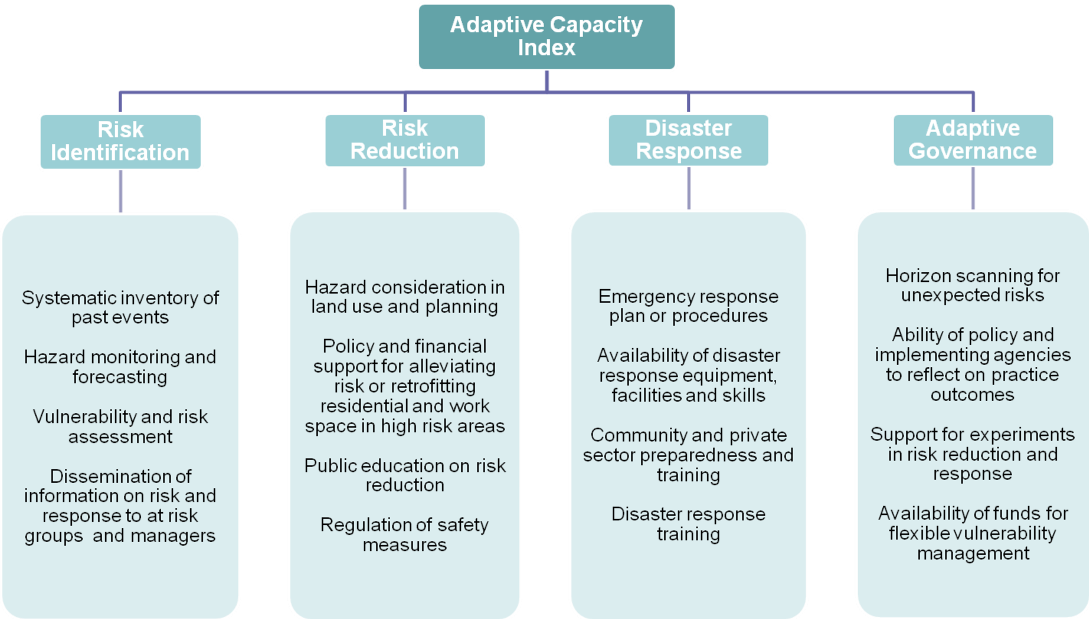


Figure 4.1 Framework structure of the ACI

The ACI was presented in questionnaire form to match the data collection needs of this project. The questionnaire survey is a single tool with different methods of data collection. In Cusco, it was used as a framework for discussion on the institutional risk management system with key respondents during the scoping visit. Some sections were filled out by our team during the field visit and others by the respondent as part of a detailed conversation about risk management and adaptation practices and policies. In addition to one-on-one interviews, a shortened version of the survey was emailed to a larger group of respondents identified during the initial visit. The combination of the two types of survey responses allowed for a wider sample of stakeholder groups, as well as providing a detailed discussion of risk management mechanisms in Cusco.

A quantitative (though relativistic) assessment of each of the four topic areas in the ACI questionnaire was developed using the following performance levels:

- Limited (No formalized capacity; Activity is ad hoc, very infrequent and not planned or captured by strategy)
- Basic (A low level of formal capacity. Activity is planned. Action is infrequent and superficial, below the levels or intensity required to make a concrete difference to outcomes)
- Appreciable (A modest level of formal capacity. Activity is planned and strategic. Action is regular and outcomes can be identified but are limited in the depth of impact)
- Outstanding (Strong formal capacity. Activity is planned, strategic and integrated into all major sectors. Action is frequent, outcomes have made a clear difference to risk and its management), and

- Optimal (Very strong formal capacity. Activity is planned, strategic, integrated and a part of everyday practice. Action is constant, and outcomes have reshaped risk and its management and continue to do so in continuous cycles of activity).

Assessment of each topic area was also differentiated across prescribed time periods to generate a trajectory of capacity over time and assess how these trajectories are changing for different sample groups.

There were an insufficient number of completed questionnaire surveys to attribute a numerical value to each performance level in order to derive a quantitative representation of management performance. However, the qualitative data generated using performance indicators was adequate in allowing for a direct comparison of performance across organizations and time. In addition, interviewed respondents were also asked for statements describing examples of capacity or of capacity changing tools or events. This discussion-review process served as a verification tool for the qualitative performance assessments, and was an important way of revealing cross-cutting and influential practices that could be transferred to other participating cities in a process of horizontal learning.

A final stage of the methodology will be local verification of findings. The findings of this assessments report will be presented to respondents to provide scope for additional input and as a verification exercise.

4.3 Policy instruments

4.3.1 National

Peru is one of the most advanced countries in Latin America in terms of policy action on climate change adaptation. As a function of its obligations to the UNFCCC, it submitted its Initial National Communication in 2001. Its Second National Communication was produced in 2010 with the support of the Global Environmental Facility (GEF) and United Nations Development Programme (UNDP). The Second National Communication outlines climate scenarios to the year 2030 and evaluates vulnerability and adaptation planning in virtually all major sectors of the economy. It contains a strong focus on capacity building, data collection and information, and on improving the enabling environment for climate change adaptation.

Overall, the General Environmental Law (Law 28611), is the legal instrument for regulating the management of the environment and its components in Peru, based on the balanced integration of social, environmental and economic aspects of national development, as well the needs of present and future Peruvian generations. The National Environmental Management System Law (Law 28245) ensures the effective implementation of the national environmental objectives by strengthening mechanisms for cross-sectoral environmental management. Through this Act, the Ministry of Environment (MINAM) is authorised to act as the lead institution responsible for participatory design and management strategies for the progressive implementation of the Peru´s obligations arising out of the provisions of the UN Framework Convention on Climate Change.

The National Environmental Policy (DS-MINAM 012-2009) sets out the national policy guidelines and prioritises the adoption of preventive measures to adapt to climate change. The policy encourages the development of forestry, waste management activities, and the use of renewable energies as instruments to help climate change adaptation. It also promotes the dissemination of knowledge about the consequences of climate change and improves training skills for the use of appropriate technologies for both adaptation and mitigation.

The National Environmental Action Plan 2011-2021 (DS-MINAM 014-2011) sets mitigation targets for wastewater, solid waste, and forest fields, with implementation horizons for 2012, 2017, and 2021. This plan aims to ensure that by 2021, a 100% of urban wastewater is treated and 50% of is reused. Similarly, it sets out a target of 100% for non-reusable solid waste coming from local administrations (municipalities) to be properly treated and disposed, and that 100% reusable solid waste is recycled. Environmental management and climate change are often linked together in Peruvian governmental assessments and plans as demonstrated by the Peruvian Climate Change and Air Quality Program (PROCLIM) and the environmental management and adaptation/compliance program (PAMAs).

The Action Plan for Climate Change Adaptation and Mitigation (*Plan de Acción de Adaptación y Mitigación frente al Cambio Climático*) is the central policy instrument for dealing with climate change in Peru. Developed in December 2010 by the Climate Change Directorate in the Ministry of Environment, it shows the manner in which Peru has identified and defined adaptation actions. The plan outlines five pillars of national and global adaptation priorities for meeting Peru's commitment towards global mitigation and adaptation to climate change, two of which are building institutional capacity, and creating policy instruments and legal frameworks that take into account the impacts of climate change.

This emphasis on role of institutions and local governments in adaptation planning is a recurring theme, and the plan, as well as Law 27867 (discussed below) requires each regional government to develop a Regional Strategy on Climate Change within the framework of the national strategy. It promotes the inclusion of actions addressing climate change in short and medium term investment and development activities of the national government and regional administrations and sets out public spending and investment priorities for mainstreaming climate change programs and development projects in government actions.

In the *Plan de Acción de Adaptacion y Mitigación Frente al Cambio Climático*, there is also a detailed listing of adaptation and mitigation projects that have been approved and funded, are in development, or still in concept phase. These projects are funded by both the Government of Peru and its development partners, and are being implemented in cooperation with the Government of Peru – primarily through the Ministry of Environment. Under the plan, detailed regional assessments have been completed in four priority watersheds, although this does not as yet include Cusco region.

The 2010 Plan complements two earlier national strategies created in 2003 - the National Climate Change Strategy and the National Strategy Study for the Clean Development Mechanism. The National Climate Change Strategy (DS-PCM 086-2003) was later revised in 2009 with the aim of providing guidance and information on climate change for national, sectoral and regional development plans and projects. The objective of this strategy is to reduce adverse impacts of climate change through integrated studies of vulnerability and adaptation. It sets out the following 11 strategic objectives: (1) conduct research; (2) develop policies and projects related to adaptive capacity development; (3) participate in international negotiations; (4) introduce mitigation policies and actions; (5) foment knowledge dissemination; (6) promote poverty reduction projects with adaptation and mitigation co-benefits; (7) appropriate technology use; (8) include civil society participation; (9) encourage forest ecosystems management; (10) promote just compensation from polluters; and (11) management of fragile ecosystems, particularly in high mountains. Each objective is divided into several sub-objectives. The National Strategy Study for the Clean Development Mechanism identifies investment and potential and financing options for projects on greenhouse gas reduction. In addition, the National Mitigation for Climate Change Guidelines emphasize a mitigation policy that does not compromise the national goals of sustainable development, and poverty reduction.

The Organic Law of Regional Government (Law 27867) and its following amendments (Law 279 029) requires each region to develop its own regional climate change strategy. Peru has also developed the Bicentennial Plan: Peru as a strategic vision for the country in 2021 (DS-PCM 054-2011). In one of its strategic axes, it promotes the adoption of mitigation and adaptation strategies based on scientific studies and research for managing climate change impacts at all three levels of government.

More recently the issue of climate change adaptation has also been addressed by the Ministry of Economy and Finance (MEF). The Multi-annual Macroeconomic Framework (MMF) developed by the Ministry, one of the most important financial planning instruments for public investment used at the national level, highlights the impact of climate change as an issue that threatens competitiveness of the country’s economic base. It requires the consideration and impact of climate change in all planning activities made by national, regional and local administrations.

In an effort to give more responsibility and resources to municipalities, the MEF has instituted the Program of Municipal Modernization (*Programa de Modernización Municipal)*. Under this program, the national government determines objectives based on national policy, and as an incentive scheme provides funds to municipalities that take steps to achieve those objectives. Another financial tool, the National Environmental Fund (*Fondo Nacional del Ambiente* – FONAM), was originally set up as a fund for promoting national environmental projects but now focuses mainly on climate change adaptation.

Peru's Disaster Risk Management (DRM) legal framework has recently been through significant changes. In 2011, Law 29 664 was published, creating a National System of Disaster Risk Management (*Sistema Nacional de Gestión del Riesgo de Desastres* – SINAGRED). The law divides Peru's DRM scheme into two main components: the National Civil Defence System (*Instituto Nacional de Defensa Civil* – INDECI) is the government organ responsible for coordination and response when a disaster occurs, while the National Centre for Disaster Risk Estimation, Prevention and Reduction (*Centro Nacional de Estimación Prevención y Reducción de Riesgo de Desastres* – CENEPRED) is in charge of preparedness and reconstruction efforts.

At the technical level, the primary responsibility for climate and water information falls upon the National Meteorological and Hydrological Service (SENAMHI). However, SENAMHI faces a problem common to many meteorological agencies in developing countries - the growing attention to climate change has placed increasing demands upon its services without a corresponding increase in budget resources. According to staff at SENAMHI, much of the data on Peru's water basins is 20 to 25 years old, if it exists at all. Information is fragmented. SENAMHI staff noted that, in addition to private companies, universities and NGOs also have important data on Peru's water resources but, currently, there is no centralized repository or process to capture these non-government sources of data and information

Under a new law passed in May 2011, the National Institute of Civil Defence (INDECI) will no longer be the lead agency dealing with natural disasters and risk management. The National Center for Strategic Planning (CEPLAN) is in charge of planning, and the National Center for the Prevention of Disasters (CENAPRED) will be in charge of risk prevention. However, INDECI remains responsible for disaster preparedness, response, and rehabilitation, and regional and local governments are responsible for the execution of the necessary actions.

4.3.2 City level

The 2003 National Municipalities Law establishes that local governments are in charge of urban and territorial planning. As part of SINAGRED, regional and local governments are responsible for establishing work groups, integrated by senior government officials, to develop and execute DRM strategies. Under the law, presidents of regional governments and local mayors are the apex authority in charge of supervising, leading and executing disaster risk management processes.

The National Institute for Civil Defense (INDECI) has recently shifted focus from disaster management to planning for reducing vulnerability to disasters (including those from climate change). INDECI manages the Sustainable Cities Program, which attempts to keep population centres from being severely affected by intense natural or manmade phenomena. The program aims to help municipalities to better understand their vulnerabilities, so that growth and development will be better able to withstand climate and non-climate disasters such as flooding, earthquakes, and tsunamis. The first stage (1998 – 2007) of the program collected data and created hazard maps and land use plans. At the national level, 103 urban centres have participated in the Program. Of those 103, 54 urban centres have Land Use Plans and measures to mitigate disaster, and 42 municipalities have approved studies for municipal ordaining and begun their implementation. The city of Cusco has participated in these initiatives. However, implementation by municipalities is a weakness in the program since very few of them have the capacity to take the information provided by INDECI and implement a plan of action.

A major undertaking addressing climate change issues in Peru is the Program on Climate Change Adaptation (Programa de Adaptación al Cambio Climático en el Perú – PACC). PACC focuses on two Andean Regions of Peru, Cusco and Apurimac, and is a joint effort of the Peruvian and Swiss Governments (Swiss Agency for Development and Cooperation, SDC). A large number of different institutions and actors in Peru and Switzerland participate, including national, regional and local governments, NGOs, universities and research institutions.

The main goal of PACC is to improve the adaptive capacities of the local population, through provision of a number of adaptation measures and stimulation of the awareness at different social and political levels. The program includes a scientific component that aims at identifying scientific gaps and providing approaches to overcome the main weaknesses. Furthermore, the improvement of the dialogue between the scientific community, implementing agencies and political authorities is another vital aspect of PACC that is expected to increase awareness and promote adaptation. PACC initiatives have had a significant impact on on-going developments in climate change adaptation and disaster management in Cusco.

4.4 Institutional mapping

4.4.1 National

Peru's Ministry of Environment (MINAM) was created in 2008 to manage the national environment sector in line with goals of economic growth and social equality. The Ministry has five dependent agencies that collect and analyze data, help to manage risk, and enforce existing laws and regulations related to natural resource use and protection. While MINAM has a number of direct responsibilities in relation to climate change issues, it was established only recently, and is just beginning to assert its institutional presence within the Peruvian government. MINAM has an inter-sectoral role and its legal framework is still evolving. The Climate Change Unit in MINAM approaches adaptation as a form of risk management. The identification of risk is carried out through a process of natural and social vulnerability mapping. The results of this mapping are intended to contribute to the formulation of climate adaptation pilot projects and address the broader challenge of land use planning.

Other national institutions engaged in climate change research in the country are the National Service of Meteorology and Hydrology Service of Peru (SENAMHI), the Geophysical Institute of Peru (IGP), the Peruvian Institute for Research on Amazon (IIAP), and the National Institute of Natural Resources (INRENA), which all fall under MINAM. MINAM also has a Directorate General for Climate Change, Desertification and Water Resources (DGCCDRH) which is the National Focal Point to the UNFCCC.

The government agencies responsible for undertaking climate adaptation are coordinated through the National Program for the Management of Climate Change (PRONAGCC), which is run as an interagency process (including MEF, MINAM, Ministry of Foreign Affairs, and regional and local government representatives) under the prime minister's office (PCM). The MEF initiative to mainstream climate change into government policies is coordinated by these organizations and although MEF funds are provided to designated regional and local governments, it is the agencies under PRONAGCC that are accountable for identified benchmarks and measurable results. Wherever possible, government agencies identify public-private partnerships that can be incorporated into investment plans and initiatives for adaptation. National, regional and local government authorities that achieve goals for environmental management are rewarded with continued or additional funding. The country's districts have been prioritized based on estimates of their present capacity.

4.4.2 City level

As mentioned earlier, Cusco's urban area is distributed across the districts of Cusco, Santiago, San Sebastián, San Jerónimo and Wanchaq. The Cusco Provincial Municipality

(Municipalidad Provincial del Cusco – MPC) is responsible for urban planning and local development. At the same time, each district has the specific role of approving District Urban Plans. The MPC leads the urban development process, taking into consideration the initiatives stemming from district municipalities.

MPC also leads actions of the DRM system. Within the Provincial Municipality, the Committee of Civil Defence, part of the Office of Civil Defence, is the leading government organ in terms of disaster preparedness and relief. It is chaired by Cusco's Provincial mayor. The Committee is a permanent government organ responsible for preserving the physical and material integrity of the population in the event of a disaster. The Committee leads institutional coordination when emergencies and disasters occur. For the past 30 years, it acted as the local operative cell of INDECI. However, with the recent division of responsibilities between INDECI and the newly created CENEPRED, there is fragmentation of responsibilities.

Cusco also benefits from two non-profit organizations – Centre for Disaster Study and Prevention (Centro de Estudios y Prevención de Desastres – PREDES) and Guamán Poma de Ayala Centre (Centro Guamán Poma de Ayala – CGPA) – that are strongly involved in climate change adaptation initiatives. They play an active role in information collection, in producing risk and to a lesser degree vulnerability studies, and in providing relief by working directly with affected populations.

The MPC Urban Development Unit is responsible for Cusco's urban planning strategies. However, due to the city's complex administrative and governance structure, and although each district is supposed to identify its urban risk and incorporate it into its agenda, Cusco still lacks an integrated proposal covering the whole metropolitan area and articulating all the main urban stakeholders. The MPC Urban Planning Unit has a project to produce a Metropolitan Plan including urban Cusco and its area of influence by 2013.

The MPC has been proactive in setting up DRM and climate change adaptation plans. A Regional Plan of Disaster Attention and Prevention was published in 2007. In terms of climate change, a Regional Climate Change Adaptation Strategy was adopted in 2011. An Earthquake, Floods and Landslides Provincial Operations and Emergency Plan was also developed in 2011 by the Civil Defence Committee. However, despite the existence of these policy instruments, the local population is often unaware of their presence and potential effects.

4.5 Gaps in existing capacity and opportunities for adaptation

At the national level, the key institutions in Peru appear to be proactively addressing the threats and impacts of climate change on the environment, economy, and society. There exists a complicated and evolving policy framework for climate change adaptation, which is backed by an institutional structure that is increasingly being mobilized to reduce vulnerability and respond to risk. However, there appears to be a gap between policy initiatives for planning and adaptation, and the capacity of government agencies to implement, regulate, and enforce these measures. Respondents identified weakness of government institutions as a core issue in building climate change resilience, with poor coordination and cooperation among government agencies and lack of capacity for enforcement featuring as the primary deficiencies affecting government departments. Lack of a coordinating mechanism for data collection and analysis also restricts the ability of national, regional and local agencies to identify and manage exposure to risk.

The recent reconfiguration of the institutional architecture of Peru's national, regional, and local governments (e.g., MINAM, Water Basin Councils, Environmental Councils, and the semiautonomous *Defensorías*) promises improved functionality and efficiency in the future, but the newly created organizations require time, review and realignment, and clear channels for institutional coordination prior to an effective engagement with climate change risk. During this period of transition, a certain degree of uncertainty can be witnessed in the system for risk planning, as institutions try and establish their exact roles and responsibilities, and develop the capacity and skills to meet these goals.

The centralised nature of Peru's government facilitates national planning but the strength of climate change institutions at the national level has also resulted in weak local adaptation capacity as municipal governments await direction and budgetary resources from above. The secondary role played by local level government institutions in decision-making for climate change planning and management strategies has created an imbalance between national priorities and local needs. Reconciling this difference and improving communication and information exchange between the three scales of government is a crucial gap in addressing vulnerability to climate change hazards in Peru.

Cusco has a devolved system of governance at the regional, provincial, city and district level. Each district has its own mayor, civil defence, and planning unit, and experiences varying degrees of social and geo-physical vulnerability. This has resulted in an uneven application of risk management strategies across the entire urban conurbation of Cusco, with certain districts prioritizing risk management exercises to a greater degree than others.

According to respondents, the individual personality and priorities of each mayor played an important role here in determining the amount of human and capital resources invested in risk reduction. The district of Santiago has the most developed strategies and plans for risk management and adaptation. It regularly invests in risk prevention planning and public awareness campaigns. Similarly, only six districts in Cusco have emergency plans in place for disaster management. According to PREDES, the Mayors of two districts have actively resisted efforts to develop emergency plans or risk management procedures since they do not consider it as a priority for their area. A devolved structure of municipal governance offers both opportunities and constraints for urban management. In order to take full advantage of the localised and democratic nature of municipal governance in Cusco, greater collaboration and coordination is required across all districts. There is a need for a platform or forum for regular exchange on risk management strategies across the various districts of the city.

One central challenge faced by municipal institutions in Cusco is the need to reconcile economic growth with a reduction in risk and vulnerability. Population growth, in-migration and tourism is a leading cause of uncontrolled building and construction activity in the city, placing increasing pressure on already stressed public services and infrastructure. It will be a daunting challenge for city officials to balance socio-environmental risk with economic priorities and the promotion of an expanding city that serves as a commercial and regional hub. Unless this balance is achieved, the potential for disaster and loss remains high, with no clear strategy for long term growth and planning at the city level. Along with compliance to national directives for climate change adaptation planning, a strategic policy is needed for the city as an independent urban unit – with a necessary consideration of future trends in development and risk of the surrounding rural regions.

Risk management for natural hazards in Cusco is to a very large extent guided by the national policy framework for environmental management and disaster risk reduction in Peru. Although implemented through a devolved system of local government, efforts towards the integration of climate change risk and vulnerability in city level public policies are usually initiated and funded by national ministries and government departments. The system for disaster risk reduction in Peru has changed considerably over the past decade, with the creation of new laws and the on-going restructuring of coordinating bodies for risk management at the national level. For example, previously INDECI was responsible for all disaster preparedness and management activities through its regional and local branches since 1972. This included the operation and management of all civil defence organizations at the municipal and district level. The recent re-distribution of responsibilities between INDECI and the newly created National Centre for Disaster Risk Estimation, Prevention and Reduction (*Centro Nacional de Estimación, Prevención y Reducción de Riesgo de Desastres* – CENEPRED) promises greater engagement across government departments, but has also created gaps and overlaps in organizational functions at the local level in the short term.

In an interview with the research team, the INDECI staff in Cusco demonstrated a sound awareness of the potential linkages between climate change, natural disasters, and watershed management. However, the division of responsibilities between INDECI and

CENEPRED at the national level have led to fragmentation of responsibilities and institutional vacuum in the short term. More staff and investment is needed at the regional and municipal level to carry out the functions of the newly created agency at the local level, including issues such as risk identification and planning. Currently, regional and municipal wings of Civil Defence in Cusco have to carry out the responsibilities of disaster planning and preparedness, even though their budgetary resources only allow for disaster management and response.

National initiatives to institutionalize the incorporation of risk analysis and climate change adaptation strategies in Peru have achieved a significant degree of success in transforming policy of local level public institutions in Cusco. The National System of Public Investment (*Sistema Nacional de Inversión Pública* – SNIP) through the Ministry of Economics and Finance (*Ministerio de Economía y Finanzas* – MEF) offers monetary incentives for city level government departments to mainstream risk analysis in their strategic frameworks. Although there is evidence that such efforts are so far limited to policy and not practice, and that funds gained through this scheme are rarely invested back into risk management, it appears to be an important means through which risk awareness has infiltrated city level policies. Most government departments in Cusco now have plans that incorporate climate change adaptation and risk management.

Shortage of resources and qualified staff is prevalent in city level institutions involved in risk management activities. Lack of financial resources and legislative capacity has resulted in weak implementation and regulation of risk management policies. For example, implementation of building controls and land use planning is extremely limited due to a shortage of resources. This capacity deficit is exacerbated by a rapid rate of urbanization and population growth in Cusco, stressing a system for urban risk management that is already operating beyond capacity. Basic systems of sewage, drainage and river basin management are also missing in the city. In addition to policy strengthening for climate change adaptation, there is likely the need for greater investment into capacity building for risk management and infrastructural strengthening at the city level.

There is clear consensus amongst respondents on the urgent need for more and better climate data as well as the mapping of socio-environmental vulnerabilities under conditions of climate change. There also is an interest and readiness to move forward on developing early warning mechanisms and adaptation measures to avert or mitigate climate-related conflicts. However, there is a very large need for capacity building and improved coordination among the key players in Cusco for data collection and information sharing. The gap between planning initiatives and implementation of risk strategies can be observed below in the Figure 4.2 below aggregating respondent evaluations of risk identification indicators in Cusco. In the categories indicating an availability of systems for inventory of disasters and losses, risk monitoring and forecasting, and vulnerability and risk assessment, participants observed an improvement from very limited to basic capacity since 2010. This reflects awareness of actions such as the creation of hazard and risk maps by INDECI after the 2010 flood event.

Nonetheless, the real term impact of all three indicators remains very limited, with respondents pointing to the poor quality, inadequate scale and availability of risk data and disjointed governance structures as impediments to the application and use of this information in framing policy and action. In reality, INDECI produced hazard risk maps for Cusco in 2005 but there was little public knowledge of the maps or how they could be utilised. Also, hazard maps created by INDECI in 2010 revealed that a large portion of the population was already resident in high risk areas and could not be relocated. Since high risk areas are already constructed, the aim is to use mitigation measures to reduce vulnerability in high risk areas red zones and convert them to orange zones. However, since the implementation of risk zoning is beyond the mandate of INDECI, it is up to the discretion of municipal agencies and district mayors to determine the extent to which these maps are used as guidance in regulation and planning in each district.

On the other hand, efforts towards improving the availability of information on risk and response measures to risk managers and at risk populations appear to have resulted in a much greater impact in increasing overall risk identification and planning capacity in the city.

Respondents ascribed this to good communication and liaison channels between government institutions and local organizations involved in risk management, especially after the occurrence of disaster events in the city. According to one respondent, 'A little information goes a long way in improving awareness since it is assimilated quickly by the population. People, especially those involved in risk management, are a lot more interested in data on hazard and vulnerability after the 2010 floods and are eager to absorb information on how to prepare and respond to future threats'. Increased availability of accurate and relevant data, disseminated through established systems of communication can provide for more informed and appropriate policy decisions on urban risk management by city institutions. This needs to be supported by organizational capacity for implementation and regulation.

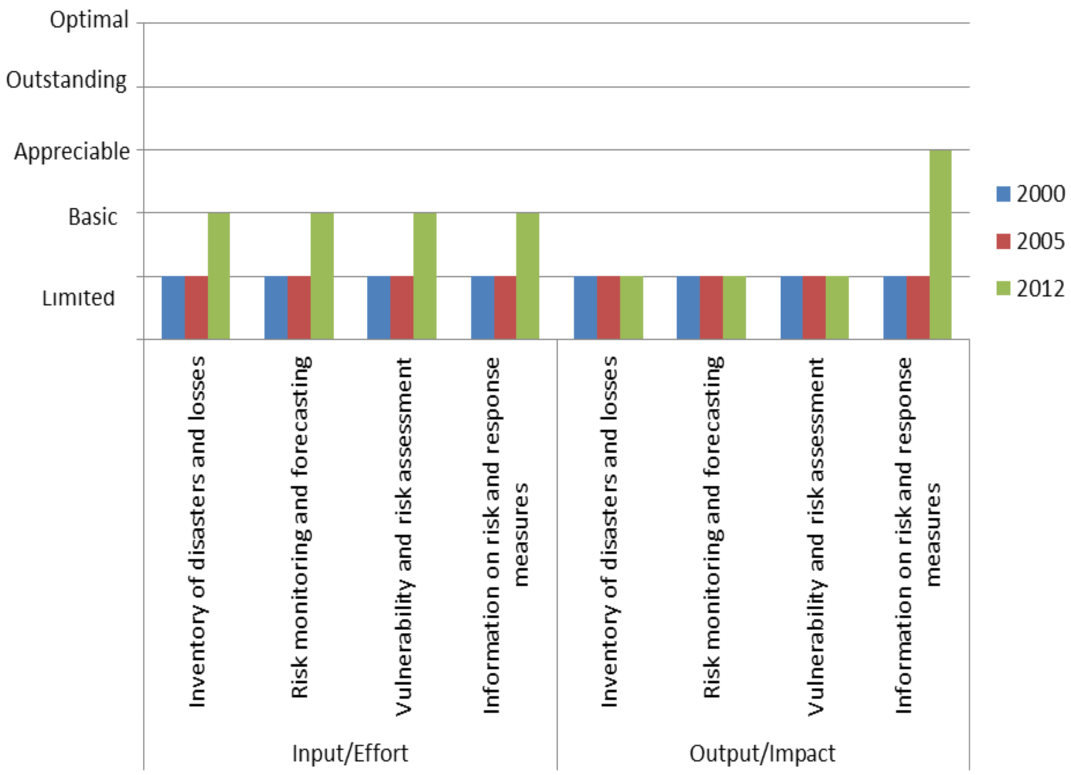


Figure 4.2 Risk identification in Cusco, Source: The Authors.

Tourism is the biggest employer in the city and has played a very important role in the development of Cusco. As seen above, the flooding in 2010 suspended travel to Machu Pichu and the Sacred Valley, and incurred heavy losses for the tourism industry. However, there is little evidence of cooperation or coordination between city level government agencies and tourism organizations in mediating future disaster risk through development and investment initiatives. No formal platforms for collaborative planning or public-private initiatives to address climate change risk have been initiated in the city. An alignment of tourism industry interests with urban risk management strategies can potentially result in greater local level action on adaptation and risk reduction.

Civil society organizations such as PREDES have played a significant role in affecting risk reduction and management practices in Cusco. PREDES is one of the few organizations active in influencing changes in practice and capacities of district governments and civil defence organizations. Their work targets district and regional institutions by providing assistance to local government units in developing early warning systems, preparing emergency plans, risk management strategies, and undertaking vulnerability assessments.

Over the years, PREDES has increased institutional resilience in Cusco through the promotion of risk management and planning techniques. Other local level institutions such as the Red Cross are also engaged in working with communities to reduce vulnerability. These two forms of civil society engagement -- expert institutional input and community level participation -- are important contributions if progress is to be made on the issue of climate change adaptation. Ideally, national level policy change initiatives need to be combined with practical work at the local level by such non-governmental organizations to develop more resilient systems for climate change adaptation and planning.

Overall, the institutional capacity of Cusco can be summarized in the following table (Table 4.1). The assessment is based on a combination of completed questionnaires, stakeholder meetings, secondary literature and the local consultant report.

Table 4.1 Institutional capacity of Cusco

Risk Identification	
Inventory of disasters and losses	Basic
Risk monitoring and forecasting	Basic
Vulnerability and risk assessment	Basic
Information on risk and response measures	Basic
Risk Reduction	
Hazard and vulnerability in land use and urban planning	Limited
Financial support for risk reduction	Limited
Policy support for risk reduction	Appreciable
Public education on risk	Limited
Regulation of safety measures	Limited
Disaster Management	
Emergency response plan or procedures	Appreciable
Availability of disaster response equipment	Basic
Liaison between organizations in risk management	Appreciable
Disaster response training	Basic
Adaptive Governance	
Foresight and planning for risk management	Appreciable
Critical self-reflection	Basic
Learning and transformation of practices	Basic
Experiments in risk reduction and response	Limited
Resources to enable adjustment	Limited
Capacity to influence change	Basic

Although risk identification and disaster management capacities in Cusco have seen a relative improvement, risk reduction and adaptive governance remain weak. This indicates a low level of institutional capacity, resources, and flexible management systems in the city. National policy frameworks have started to improve knowledge creation and communication on risk, and have helped establish efficient procedures for coordination during disaster situations. But implementation of procedures and regulations that require technical and human resources is poor due to a lack of funding and capacity, and will need to be improved to deal with increased risks associated with climate change.

Despite the institutional weaknesses discussed here, there are emerging opportunities and a variety of positive steps to build on, including the on-going work on climate adaptation at the local level. There is considerable capacity in Cusco to take further action to not only increase resilience but also to operationalize planning in order to reduce vulnerability, climate-related and otherwise. Adaptive governance practices and flexible systems for change remain weak in the city, not least because of a lack of resources and low levels of continuous and critical engagement across municipal, district, and community scales. Most city-wide institutions such as the MPC and municipal Civil Defence have an operational mandate that functions beyond electoral cycles and can be used to ensure continuity of policy goals and long-term strategies in district organizations such as the Mayor’s office and district civil defence forces.

As a start, joining the agendas of tourism and city level climate change adaptation would strengthen both sectors of activity. Engaging district mayors to undertake coherent action in collaborative adaptation and planning for risk under district level organizations will also enhance overall adaptive capacity in Cusco. Field interviews identified a number of governmental and nongovernmental institutions and organizations staffed with well informed and committed personnel keen to collaborate on issues of climate change and disaster management. Given the right resources and operational capacity, there clearly are new initiatives and partnerships that can be forged to promote strategic climate change adaptation in Cusco.

5 Climate-related vulnerability and risk assessment

5.1 City profile

The city of Cusco sits high in the Andes Mountains. It is situated in a valley within the upper basin of the Huatanay River at 3,400 m above sea level. Irregular topography and streams that overflow as a result of long periods of rains or short intense storm events expose Cusco to a wide variety of climate-related hazards, including landslides and floods.

The purpose of the climate-related vulnerability assessment is to synthesize information on landslide and flood vulnerabilities, focusing on physical risk, urban, social and economic conditions and institutional arrangements to create maps that identify the most vulnerable areas and populations within the city exposed to flood and landslide hazards.

Due to the city's complex administrative configuration, urban boundaries are not clearly defined in jurisdictional terms. Cusco simultaneously denotes a region (or department), province and city. Cusco Department is one of Peru's 25 regional administrations. Cusco also forms a province within the department. Defined as a city, Cusco's urban area had a population of 407,488 in 2011 (INEI, 2011). The urban area is spread across five of the province's districts: Cusco (including the historic centre), Santiago, San Sebastián, San Jerónimo and Wanchaq.

Cusco, Santiago and Wanchaq are the urban districts with the most intensive land use development. The incorporation of the two remaining districts into the urban area occurred more recently. San Sebastián was incorporated in the 1970s and 1980s, and San Jerónimo in the 1980s and 1990s. Both districts are still going through a process of consolidation and densification, and mainly hold supportive housing functions to the core city.

The Cusco Provincial Municipality (MPC) is responsible for urban planning and local development. At the same time, each district has the specific role of approving District Urban Plans. The MPC leads the urban development process, taking into consideration the initiatives stemming from district municipalities.

While there is much discussion about Cusco's regional sphere of influence as a city, there is broad agreement amongst our informants that the city of (or urban) Cusco – as the study area for this project – can be specified as the urban neighborhoods (or zones) in the five districts mentioned above, and presented in the graphic below (Figure 5.1). These zones are identifiable through the national census statistics.

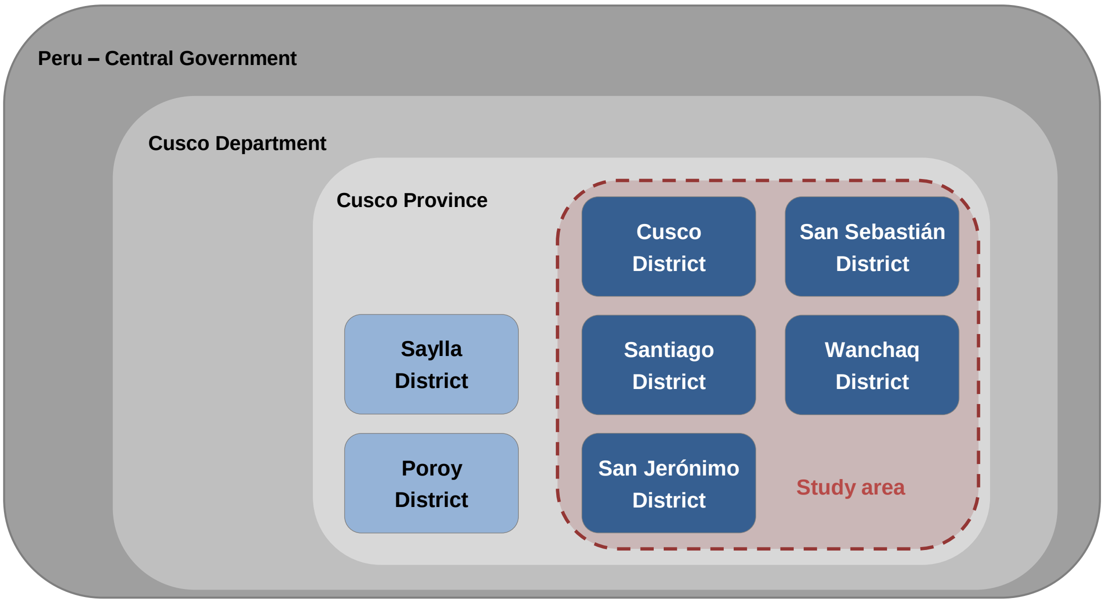


Figure 5.1 Cusco administrative organization

Cusco's location in a valley surrounded by mountains has shaped its urban structure. The historical and current patterns of spatial expansion and demographic change affect the vulnerability of people and infrastructures to climate-related hazard risks.

Cusco is still going through an important phase of urban expansion. As an important economic centre, it is a hub for in-migration, attracting people from the surrounding region and the rest of Peru, and mostly from rural areas, although informants did mention that migration had occurred in recent years from other cities, notably Lima.

Due to its geographical location in a valley, Cusco has grown following a linear, horizontal and low-density pattern, covering all available space in this fashion. The locational dynamics of the urban population is a key issue in this context. A considerable group of newly-arrived migrants locate in areas not designated for habitation, for example, archaeological, ecological protection, forestry, agricultural and hazard risk areas. Understanding urban expansion in and even adjacent to the city basin – as economic and spatial linkages ramify between the Cusco and the Sacred Valley – is crucial if appropriate measures for reducing climate-related risk are to be identified and detailed.

It is again not just the concentration of people and assets that increases vulnerability, but rather, the way urban development takes place. The formation of new urban areas in Cusco is in the main not following urban plans and development control regulations, and a large percentage of households lack basic services. According to our interviews, laws, plans and regulations are often not respected because of a combination of political and socio-economic factors. Urban growth is thus largely unplanned and much of the new population settles in or near hazard prone areas susceptible to floods and landslides. Areas at greater risk have been identified in the north-west slopes, in Pichu, Ayahuico, and the Saphy River basin. San Sebastian district is at high risk from landslides, while the Wanchaq district, where middle-class residents predominate, is the only area where no risk has been identified.

Unplanned urbanization has contributed over time, then, to the emergence of urban flood and landslide hazard risks in Cusco. In this sense, the city's population has now to deal with disordered patterns of urbanization that have persisted for over 50 years.

Predominant features of the built environment and urban population that impact upon flood and landslide hazard risks are summarized in Figure 5.2.

In the sections that follow, available information is compiled into a profile of vulnerability and risk for Cusco. This is based on the evidence discussed in the *Climate-related hazard assessment*, the *Urban, social and economic adaptive capacity assessment*, and the I*nstitutional adaptive capacity assessment*.

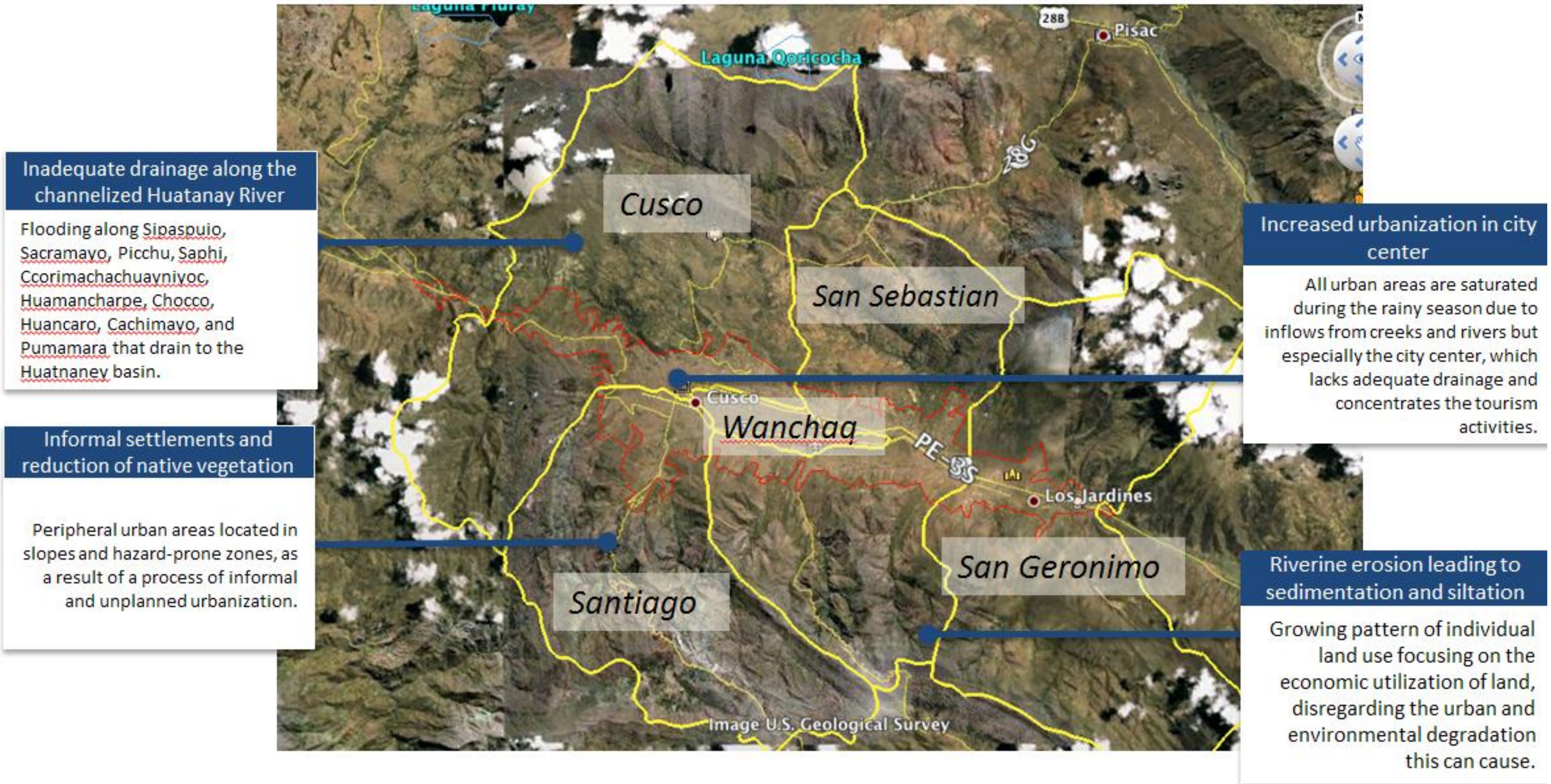


Figure 5.2 Predominant features of the built environment in Cusco that impact upon flood and landslide hazard risks.

5.2 Institutional vulnerability in Cusco

The institutional architecture of a city plays a central role in shaping the risk and vulnerability experienced by urban populations to natural hazards. It determines the distribution, accessibility and quality of critical services and physical infrastructure available to residents, and the provision of a safe and healthy environment. The institutional architecture refers to formal structures of government management such as legislation, planning guidance, and public organizations, as well as the more informal aspects of governance such as transparency and accountability, which characterise the social contract between citizens and the state.

In small and medium-sized cities such as Cusco, the capacity of urban management and governance institutions to identify and respond to current and future climate vulnerability defines not only the resilience of the urban system, but also its potential for future growth and sustainable expansion.

Climate change policy instruments

At the national level, Peru has a complicated and evolving policy framework for climate change adaptation, which is backed by an institutional structure that is increasingly being mobilized to reduce vulnerability and respond to risk. Currently there is a gap between policy initiatives for planning and adaptation, and the capacity of government agencies to implement, regulate, and enforce these measures. The recent reconfiguration of the institutional architecture of Peru's national, regional, and local governments (e.g., MINAM, Water Basin Councils, Environmental Councils, and the semiautonomous *Defensorías*) promises improved functionality and efficiency in the future, but the newly created organizations require time, revision and realignment, and clear channels for institutional coordination prior to an effective engagement with climate change risk. During this period of transition, a certain degree of uncertainty can be witnessed in the system for risk planning, as institutions try and establish their exact roles and responsibilities, and develop the capacity and skills to meet these goals.

The centralized nature of Peru's polity facilitates national planning. But the strength of climate change institutions at the national level has also resulted in weak local adaptation capacity as municipal governments await direction and budgetary resources from above. The secondary role played by local and regional level government institutions in decision-making for climate change planning and management strategies has created an imbalance between national priorities and local needs. Reconciling this difference and improving communication and information exchange between the three scales of government is a crucial gap in addressing vulnerability to climate change hazards in Peru.

Institutional capacity for adaptation

Cusco has a devolved system of governance at the regional, provincial, city and district level. Each district has its own mayor, civil defence, and planning unit, and experiences varying degrees of social and geo-physical vulnerability. This has resulted in an uneven application of risk management strategies across the entire urban conurbation of Cusco, with certain districts prioritizing risk management exercises to a greater degree than others. The political priorities and vision of every mayor are important in determining the amount of human and capital resources invested in risk reduction.

A devolved structure of municipal governance offers both opportunities and constraints for urban management. In order to take full advantage of the localized and democratic nature of municipal governance in Cusco, greater collaboration and coordination is required across all districts. There is a need for a platform or forum for regular exchange on risk management strategies across the various districts of the city.

One central challenge faced by municipal institutions in Cusco is the need to reconcile economic growth with a reduction in risk and vulnerability. Population growth, in-migration and tourism are a leading cause of uncontrolled building and construction activity in the city, placing increasing pressure on already stressed public services and infrastructure. It will be a daunting challenge for city officials to balance socio-environmental risk with economic priorities and the promotion of an expanding city that serves as a commercial and regional hub. Unless this balance is achieved, the potential for disaster loss remains high, with no clear strategy for long term growth and planning at the city level. Along with compliance to national directives for climate change adaptation planning, a strategic policy is needed for the city as an independent urban unit – with a necessary consideration of future trends in development and risk of the surrounding rural regions.

Risk management for natural hazards in Cusco is to a very large extent guided by the national policy framework for environmental management and disaster risk reduction in Peru. Although implemented through a devolved system of local government, efforts towards the integration of climate change risk and vulnerability in city level public policies are usually initiated and funded by national ministries and government departments. The system for disaster risk reduction in Peru has changed considerably over the past decade, with the creation of new laws and the ongoing restructuring of coordinating bodies for risk management at the national level.

The recent re-distribution of responsibilities between National Civil Defence Institute (INDECI) and the newly created National Centre for Disaster Risk Estimation, Prevention and Reduction (CENEPRED) promises greater engagement across government departments, but has also created gaps and overlaps in organizational functions at the local level in the short term. More staff and investment is needed at the regional and municipal level to carry out the functions of the newly created agency at the local level, including issues such as risk identification and planning. Currently, regional and municipal wings of Civil Defence in Cusco have to carry out the responsibilities of disaster planning and preparedness, even though their budgetary resources only allow for disaster management and response.

National initiatives to institutionalize the incorporation of risk analysis and climate change adaptation strategies in Peru have achieved a significant degree of success in transforming the policy of local level public institutions in Cusco. The National System of Public Investment (*Sistema Nacional de Inversión Pública* – SNIP) through the Ministry of Economics and Finance (*Ministerio de Economía y Finanzas* – MEF) offers monetary incentives for city level government departments to mainstream risk analysis in their strategic frameworks. Although there is evidence that such efforts are so far limited to policy and not practice, and that funds gained through this scheme are rarely invested back into risk management, it appears to be an important means through which risk awareness has infiltrated city level policies. Most government departments in Cusco now have plans that incorporate climate change adaptation and risk management.

Shortage of resources and qualified staff is a challenge faced by several city level institutions involved in risk management activities. Lack of financial resources and legislative capacity has resulted in weak implementation and regulation of risk management policies. For example, implementation of building controls and land use planning is limited due to a shortage of resources. This capacity deficit is exacerbated by a rapid rate of urbanization and hence population growth in Cusco, stressing a system for urban risk management that is already operating beyond capacity. Systems of sewage, drainage and river basin management are also missing in parts of the city. In addition to policy strengthening for climate change adaptation, there is likely the need for greater investment into capacity building for risk management and infrastructural strengthening at the city level.

There is a clear and urgent need among local government institutions for more and better climate data, as well as the mapping of socio-environmental vulnerabilities under conditions of climate change. There also is an interest and readiness to move forward on developing early warning mechanisms and adaptation measures to avert or mitigate climate-related conflicts. Capacity building and mechanisms for improved coordination need to be developed among the key players in Cusco to facilitate data collection and information sharing. For example, INDECI produced hazard risk maps for Cusco in 2005 but there was little public knowledge of the maps or how they could be utilised. Hazard maps created by INDECI in 2010 revealed that a large portion of the population was already resident in high risk areas and could not be relocated. However, since the implementation of risk zoning is beyond the mandate of INDECI, it is up to the discretion of municipal agencies and district mayors to determine the extent to which these maps are used as guidance in regulation and planning in each district. Increased availability of accurate and relevant data, disseminated through established systems of communication can provide for more informed and appropriate policy decisions on urban risk management by city institutions. This needs to be supported by organizational capacity for implementation and regulation.

Tourism is the biggest employer in the city and has played a very important role in the development of Cusco. The flooding in 2010 suspended travel to Machu Pichu and the Sacred Valley, and incurred heavy losses for the tourism industry. However, there is little evidence of cooperation or coordination between city level government agencies and tourism organizations in mediating future disaster risk through development and investment initiatives. No formal platforms for collaborative planning or public-private initiatives to address climate change risk have been initiated in the city. An alignment of tourism industry interests with urban risk management strategies can potentially result in greater local level action on adaptation and risk reduction.

Civil society organizations such as the Centre for Disaster Study and Prevention (PREDES) have played a significant role in affecting risk reduction and management practices in Cusco. PREDES influences changes in practice and capacities of district governments and civil defence organizations by providing assistance to local government units in developing early warning systems, preparing emergency plans, risk management strategies, and undertaking vulnerability assessments. Other local level institutions such as the Red Cross are also engaged in working with communities to reduce vulnerability. These two forms of civil society engagement – expert institutional input and community level participation – are important contributions if progress is to be made on the issue of climate change adaptation. Ideally, national level policy change initiatives need to be combined with practical work at the local level by such non-governmental organizations to develop more resilient systems for climate change adaptation and planning.

Although risk identification and disaster management capacities in Cusco have seen a relative improvement, risk reduction and adaptive governance remain weak. This points to a low level of institutional capacity, resources, and flexible management systems in the city. National policy frameworks have started to improve knowledge creation and communication on risk, and have helped establish efficient procedures for coordination during disaster situations. But implementation of procedures and regulations that require technical and human resources is poor due to a lack of funding and capacity, and will need to be improved to deal with increased risks associated with climate change.

Overall institutional assessment

Despite the institutional weaknesses discussed here, there are emerging opportunities and a variety of positive steps to build on, including the on-going work on climate change adaptation at the local level. There is considerable capacity in Cusco to take further action to not only increase resilience but also to operationalize planning in order to reduce vulnerability, climate-related and otherwise. Adaptive governance practices and flexible systems for change remain weak in the city, not least because of a lack of resources and low levels of continuous and critical engagement across municipal, district, and community scales. Most city-wide institutions such as the MPC and municipal Civil Defence have an operational mandate that functions beyond electoral cycles and can be used to ensure continuity of policy goals and long-term strategies in district organizations such as the Mayor's office and district civil defence forces.

As a start, joining the agendas of tourism and city level climate change adaptation would strengthen both sectors of activity. Engaging district mayors to undertake coherent action in collaborative adaptation and planning for risk under district level organizations will also enhance overall adaptive capacity in Cusco. Given the right resources and operational capacity, there clearly are new initiatives and partnerships that can be forged to promote strategic climate change adaptation in Cusco.

Table 5.1 lists policies, programs, projects and studies related to environmental management, urban development, disaster risk management and climate change adaptation.

Table 5.1 Available strategic plans

National and Regional Strategies	Overview
Estrategia Regional Frente al Cambio Climático – 2012	An extensive review of the climate change situation, inclusive development and regional strategic priorities.
Urban Development Projects	
Plan de Desarollo Urbano - 2006-2011 Municipalidad Provincial del Cusco, Gerencia de Desarollo Urbano y Rural - sub Gerencia de Gestión del Plan Director	Identifies key development and risk management challenges in the Municipality, highlights major institutions, and their relevant legislative roles, and develops three development scenarios for the city
Plan de Acondicionamiento Territorial 2006-2016	Describes development statistics for districts within the municipality and outlines development projects for each district based on urgent needs.
Disaster Preparedness, Prevention and Response	
Plan Nacional de Prevención y Atención de Desastres (PPAD 2004)	Extensive review of local government capacities and weaknesses in addressing disaster risks, ending with a prioritized set of recommended projects to improve disaster risk management at the local level
Regional Plan for Preventing and Responding to Disasters (Plan Regional de Prevención y Atención de Desastres), 2 007	A strategic, long term instrument that defines objectives, strategies, programs and sub-programs to orient and frame activities around risk reduction, prevention and emergency management in case of disasters
Sectoral Plans	
Plan Estratégico Nacional de Turismo (PENTUR) 2008-2018	Peru's Tourism development plan which mentions climate change in several areas – and makes special note of potential climate vulnerabilities in the tourism sector, but does not identify specific sectoral risks or adaptation strategies
Studies	
Risks in the City of Cusco (Sustainable cities project - PNUD-INDECI)	Geo-morphological study of landslide, seismic and flood risk in the city of Cusco ending with suggested investments and studies to reduce the risks to these hazards
Master Plan 2006	Identified most critical areas with respect to landslide and flood risks in the city of Cusco as a way of prioritizing investments

5.3 Landslides and floods vulnerability in Cusco

Changes in climate may already be impacting the city of Cusco. The sparse long-term records which are available over the last 40 years (1965-2008) suggest a strengthening of the hydrological and climate cycles, with more intense rain falling in shorter periods of time. Precipitation patterns are projected to change in the future, possibly resulting in greater frequency or intensity of floods and landslides during the rainy season. This could exacerbate the impact of the existing stressors on agricultural productivity, water availability and quality, and other local governance and management functions.[16]

This analysis considers which areas are exposed to floods and landslides, how that exposure may change in the future, and the associated vulnerability of the settlements in each of the districts to these hazards.

[16] Caracterización climática de las regiones Cusco y Apurimac. 2010. SENAMHI. PACC. Reference is missing

5.3.1 Approach

This section synthesizes information on Cusco's landslide and flood vulnerabilities, focusing on the current physical risk, urban social and economic conditions, and institutional arrangements. This is done by conducting a vulnerability analysis for each district in the study area. Due to the lack of available data, the results of this analysis should be viewed as an informative screening of which districts are more likely to be affected by landslides and floods by mid-century.

A vulnerability analysis of critical infrastructure is not possible as this would require an analysis by infrastructure category (e.g., inspection of building codes, damages associated with past events, and other indicators to determine how sensitive the infrastructure is when exposed to the hazard). This analysis does, however, overlay the critical infrastructure with the districts that are exposed to the hazards. This vulnerability analysis can then inform decision makers as they consider climate adaptation options and provide recommendations regarding the combination of hazards, districts, and facilities that would benefit from a more intensive risk analysis.

A vulnerability analysis considers the exposure, sensitivity, and adaptive capacity of the settlement to the hazard (see Figure 5.3). Each of these components is discussed in more detail below.

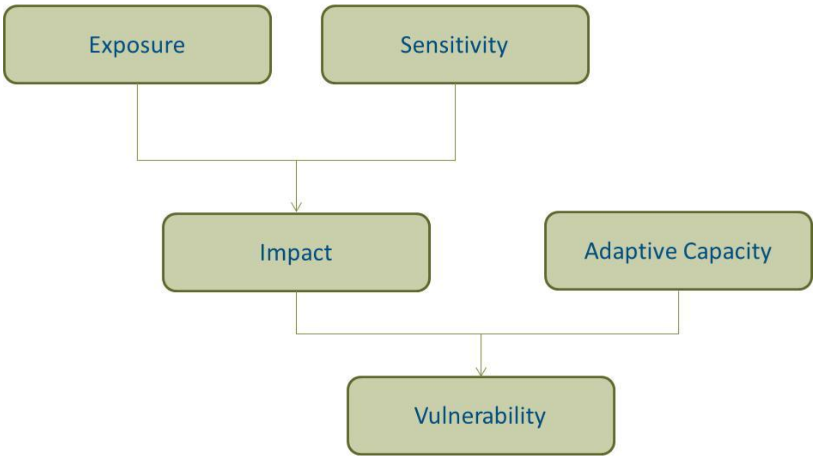


Figure 5.3 Schematic of the vulnerability analysis for landslides and floods, Source: The Authors.

Exposure. Exposure considers whether a settlement and/or facility is located in an area that is considered susceptible to the hazard. For this analysis, this is simply a "yes/no" determination based on the findings in the hazard analysis. The hazard analysis identified the regions and settlements that were exposed to a landslide and/or flood hazard and considered through the use of climate projections whether the exposure may increase or decrease by mid-century (see Box 8).

> **Box 8 Projected changes in hazards**
>
> Due to climate change, Cusco's exposure to floods and landslides during the wet season is projected to increase in the 2040s. The projections further suggest an increased chance of drought during the dry season which could affect the occurrence of landslides.

Given the hazard analysis does not include a more intensive modelling effort (e.g., new hydrologic and hydraulic modelling driven with projections of precipitation to investigate how exposure may change or drilled-down analysis of changes by precipitation event), this analysis is constrained to simply considering whether the existing hazard will worsen or reduce in areas already exposed to the hazard. Because of this, this analysis cannot provide a quantitative number describing the change in flooding or landslide exposure. However, it can provide a high-level description of which settlements are exposed to the hazard and a qualitative description based on quantitative data as to how climate change may impact future exposure. Climate projections were developed to reduce various components of uncertainty (e.g., an average from an ensemble of climate models was developed for two plausible socioeconomic futures). As with any projection, there is inherent uncertainty. In addition, new climate data that is shown to produce more rigorous results should be considered to augment the results presented in this report.

- **Sensitivity.** Sensitivity describes the degree to which a district that is exposed to the hazard might be affected. This step can rely on design standards, historical and geographic analogues, and/or expert opinion. The sensitivity of the settlements within each district was ranked based upon two available metrics: percentage of households with adobe and the density of the urban population. The percentage of adobe households was used as a proxy to suggest the proportion of housing that are less able to withstand landslides and may suffer more damage during a flood. According to the 2005 INEI census, more than 70 percent of the building stock in Cusco is made of adobe. Additional data was used to provide geographically disaggregated housing information at the district level. The density of the urban population suggests the amount of the population that might be affected by the hazard and/or areas more prone to affect population if the hazard were to occur (either directly or indirectly). Future work would benefit from the incorporation of detailed housing information (e.g., raised height of doorways) currently being developed by the municipality.
- **Adaptive capacity.** Adaptive capacity considers how an impacted settlement (i.e., a settlement that is exposed to and potentially harmed by the hazard) may be able to cope or adapt. This may include considering what technological, economic, and social means are available to help the settlement deal with the hazard. The adaptive capacity within the settlements was based upon two available metrics: poverty levels and households with unsatisfied basic needs (UBN). These metrics were used based upon the assumption that settlements that rank high will be less capable of responding to and/or protecting against the hazard.

Table 5.2 provides a description of the number of housing in each district that uses adobe construction.[17] In 2007, all districts are relatively similar in the percentage of adobe housing between 71 to 76 percent, except for Wanchaq which has about 39 percent of housing made of adobe construction.

Table 5.2 Total housing and proportion of adobe construction for each district

District	Total housing	Adobe housing	% of housing that is adobe
Cusco	26,710	19,368	73%
San Jeronimo	7,922	5,692	72%
San Sebastian	17,036	12,014	71%
Santiago	20,249	15,414	76%
Wanchaq	14,028	5,408	39%

Table 5.3 details the rankings used for sensitivity and adaptive capacity. The two metrics for sensitivity are ranked from 0 to 4 and averaged for a sensitivity score (likewise for adaptive capacity). For each district, the settlements in the Cusco study area are ranked according to the information provided in the *Urban, social and economic assessment*.

Table 5.3 The rankings of sensitivity and adaptive capacity.

Rank	Sensitivity	Adaptive Capacity
0	0 to 20% of housing is adobe; Urban density less than 10 pop/hectare	Poverty level less than 8%; UBN less than 8%
1	20 to 40% of housing is adobe; Urban density less than 50 pop/hectare	Poverty level less than 15%; UBN less than 15%

[17] Housing includes independent housing, apartment building, huts/cottages, makeshift housing, housing not meant for human habitat, and other as defined by the INEI Population and Housing Census, 2007. This information is additional detail to that provided in the *Urban, social and economic assessment.*

Rank	Sensitivity	Adaptive Capacity
2	40 to 60% of housing is adobe; Urban density less than 80 pop/hectare	Poverty level less than 20%; UBN less than 20%
3	60 to 80% of housing is adobe; Urban density less than 120 pop/hectare	Poverty level less than 30%; UBN less than 25%
4	80 to 100% of housing is adobe; Urban density greater than 120 pop/hectare	Poverty level greater than 30%; UBN greater than 25%

Vulnerability. The vulnerability analysis then applies the rankings of sensitivity and adaptive capacity from low (i.e., least vulnerable) to high (i.e., most vulnerable) for each settlement that are located in flood- and/or landslide-prone areas.

The rankings of sensitivity and adaptive capacity are then used to assess potential vulnerability, as shown in Table 5.5. The suggested responses to the potential vulnerabilities are as follows:

- Low ("L"): Stay attentive to the hazard but do not necessarily change current planning and management
- Medium ("M"): Consider developing strategies to curtail impacts and consider enhancing warning systems
- High ("H"): Develop strategies to curtail impact and consider hazard vulnerability in planning.

This evaluation is representative for both the landslide and flood vulnerability analyses. Additional discussion is provided regarding the number of facilities located in each settlement.

Table 5.4 Index of potential vulnerability for hazards based upon the rankings of sensitivity and adaptive capacity.

Sensitivity		Adaptive Capacity 0	1	2	3	4
	4	M	M	H	H	H
	3	M	M	M	H	H
	2	L	M	M	M	H
	1	L	L	M	M	M
	0	L	L	L	M	M

5.3.2 Vulnerability results

A number of climatic and anthropogenic factors play a role in whether and where a landslides and/or flood may occur (see Table 5.5). This report has considered how changes in climate may impact landslides and floods, but future changes associated with the settlement stressors will also play a key role in reducing or exacerbating the impact. For example, the slopes of Cusco started to be populated around the 1970s to 1980s as informal settlements. With time, these have been formalized, with roads constructed and other basic services provided. This urban development has occurred in areas prone to landslides which amplifies the susceptibility of slopes due to clearing of vegetation and other protective features. How this region continues to develop will have a direct impact on the susceptibility of the region to landslides and floods.

Table 5.5 Summary of anthropogenic and climatic stressors of landslides and floods, and a description of the projected change in climate by the 2040s.

	Stressors		Projected climate change
	Anthropogenic activities	Climatic	
Landslides	■ Activities which reduce soil absorptive capacity, including pavement and housing. ■ Slope loading with housing and infrastructure. ■ Deforestation and land clearing for urban expansion. ■ Diversion of streams and rivers.	■ Slope saturation from intense rainfall and snowmelt. ■ Prolonged intense precipitation ■ Freeze and thaw weathering ■ Flooding ■ Shrink and swell weathering	By the 2040s, the rainy season may be slightly prolonged and intensified, but with less intense rainfall episodes. Overall, the projected increases in precipitation will likely increase the possibility of landslides. In addition, there is an increased chance of drought during the dry season. The reduced soil moisture may reduce the threat of landslides for unaltered vegetation. However, drying soils may increase the threat of landslides where vegetation has been removed and/or covered by impermeable surfaces
Floods	■ Poor drainage infrastructure. ■ Deforestation and overgrazing of upstream areas in a watershed. ■ Obstruction of drainage structures. ■ Paving, construction, and activities which minimize the absorptive capacity of the soil.	■ Prolonged periods of rain ■ Intense rainfall ■ Rapid snowmelt	By the 2040s, the rainy season may be slightly prolonged and intensified, but with less intense rainfall episodes. Overall, the projected increases in precipitation will likely increase the possibility of flooding.

The discussion and results of the vulnerability analysis are presented by (1) settlements, and the (2) facilities and critical infrastructure

Settlements

All five districts in Cusco were found to experience an increase in future exposure to floods and/or landslides. Of these districts, the settlements located in Santiago and San Sebastian are considered the most vulnerable (see Table 5.6).

Table 5.6 Summary of districts that are potentially vulnerable to floods and landslides.

Settlement	Population	Potential Vulnerability

		Exposure Today	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Cusco	100,712	Y	↑	3	2	**M**
Santiago	84,097	Y	↑	4	4	**H**
Wanchaq	63,894	Y	↑	3	1	**M**
San Sebastian	45,287	Y	↑	3	3	**H**
San Jeronimo	18,966	Y	↑	2	3	**M**

The vulnerability of these districts is based on the most recent data. However, it is important to note the increase in adaptive capacity from 1993 to 2009 experienced by Cusco, San Sebastian, and Wanchaq. These districts all improved their adaptive capacity by the equivalent reduction of their respective rankings by one level (e.g., Cusco had an adaptive capacity ranking of 3 in 1993 to 2 in 2009). Given this change occurred over just a 15 year period, this suggests this region has a strong capacity to reduce its vulnerability.

For example, although Cusco in 2009 had similar poverty levels to San Jeronimo and San Sebastian, the latter districts have seen more rapid reduction of poverty over time (Table 5.8). In this sense, the vulnerability assessment needs to be more than just a 'snapshot' of the present situation and to consider the urban, social and economic dynamics. This will demonstrate how capable, in general, some districts may be in adopting measures that increase its adaptive capacity.

Table 5.7 Percentage of poverty and poverty reduction over time in Cusco

Year	Cusco	Santiago	Wanchaq	San Sebastián	San Jerónimo
1993	35.5%	49.3%	17.4%	43.6%	58.8%
2009	25.5%	30.1%	4.8%	25.7%	25.1%
Percentage change between 1993 & 2009	**-10%**	**-19.2%**	**-12.6%**	**-17.9%**	**-33.7%**

The results of the vulnerability analysis by district are provided in Figure 5.4. All districts in the Cusco study area are considered moderate to highly vulnerable to floods and landslides.

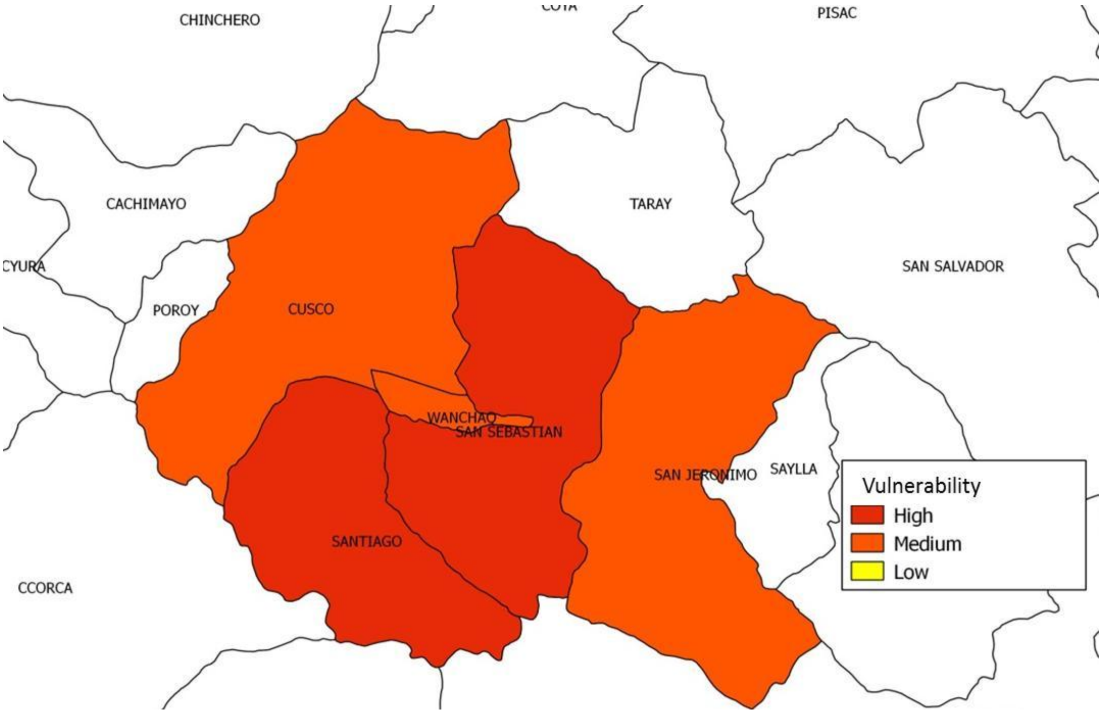


Figure 5.4 Potential vulnerability of settlements within each district prone to flood and landslide hazards.

Facilities and Critical Infrastructure

A facility-by-facility vulnerability analysis was not conducted for this analysis. This would require producing vulnerability scores for each facility by establishing a relevant series of rankings of the adaptive capacity and sensitivity, preferably based on characteristics of the facility location, engineering designs and standards. Instead, this section provides an identification of facilities that may be exposed to the landslide and flood hazards (see Box 9). Facilities considered include schools, hospitals, police stations, recreational areas, and airports. This was done by overlaying the exposure of the hazard zones with the critical facilities (see Figure 5.5 and 5.6). The vulnerability of each district was also provided to consider which facilities are located in the most vulnerable and most populated settlements.

Box 9 overlaying infrastructure and settlement vulnerability

Flood and landslide events can damage infrastructure, leading to financial losses. It is important to realize that two similar types of infrastructure may suffer differently in response to an event. This is because the potential damage and associated costs to infrastructure – particularly infrastructure built to last many decades or more – is affected by many complex factors such as building materials and design, maintenance, age of the infrastructure, past damage, and the strength and dynamics of the particular event. Therefore to analyze infrastructure vulnerability, a detailed database of these factors for each critical infrastructure is needed. Additionally, discussions with infrastructure stakeholders can assist in understanding the level of difficulty in building protective resilience into the infrastructure.

The overlay figures provided identify which infrastructure is located in an area prone to landslides and/or floods. The settlement vulnerability to the event is also included in the figures to demonstrate the potential 'social' severity if an event were to occur. For example, if a flood were to occur in a settlement highly vulnerable, there is a higher potential need for specific infrastructure – e.g., a hospital – to support the affected population compared to a settlement ranked at lower vulnerability. In addition, considering the criticality of the hospital to the local population is also important; Is it the only hospital within a given radius of the settlement? Are other hospitals not vulnerable to the event reachable during an event? Will necessary staff be available to support the hospital needs? These types of overlays can provide key talking points for decision makers when considering how to identify which infrastructure is critical to the local population and thereby warrant further study.

The airport and a number of critical facilities in each district are exposed and potentially vulnerable to floods (see Figure 5.5). These findings are somewhat equally spread across the five districts suggesting all districts have critical facilities that should be considered in a future facility-scale risk assessment.

There are significantly less critical facilities exposed to landslides (see Figure 5.6). Of the five districts, Santiago and Cusco have the greatest number of exposed facilities. A future facility-scale risk assessment should consider the physical characteristics and industrial standards for each critical facility through a site assessment.

In addition to these maps, the data presented earlier in the report suggests that flooding poses a greater hazard to transportation infrastructure than landslides, and disruption of the transportation networks can have significant impacts on the city and region's economy. Little information exists on past damage to energy and water infrastructure by floods and landslides. There is a significant lack of sewage infrastructure in Cusco, which has caused water contamination and increased the health impacts of flooding. Improving sanitation infrastructure and services will improve the resilience of Cusco to climate change.

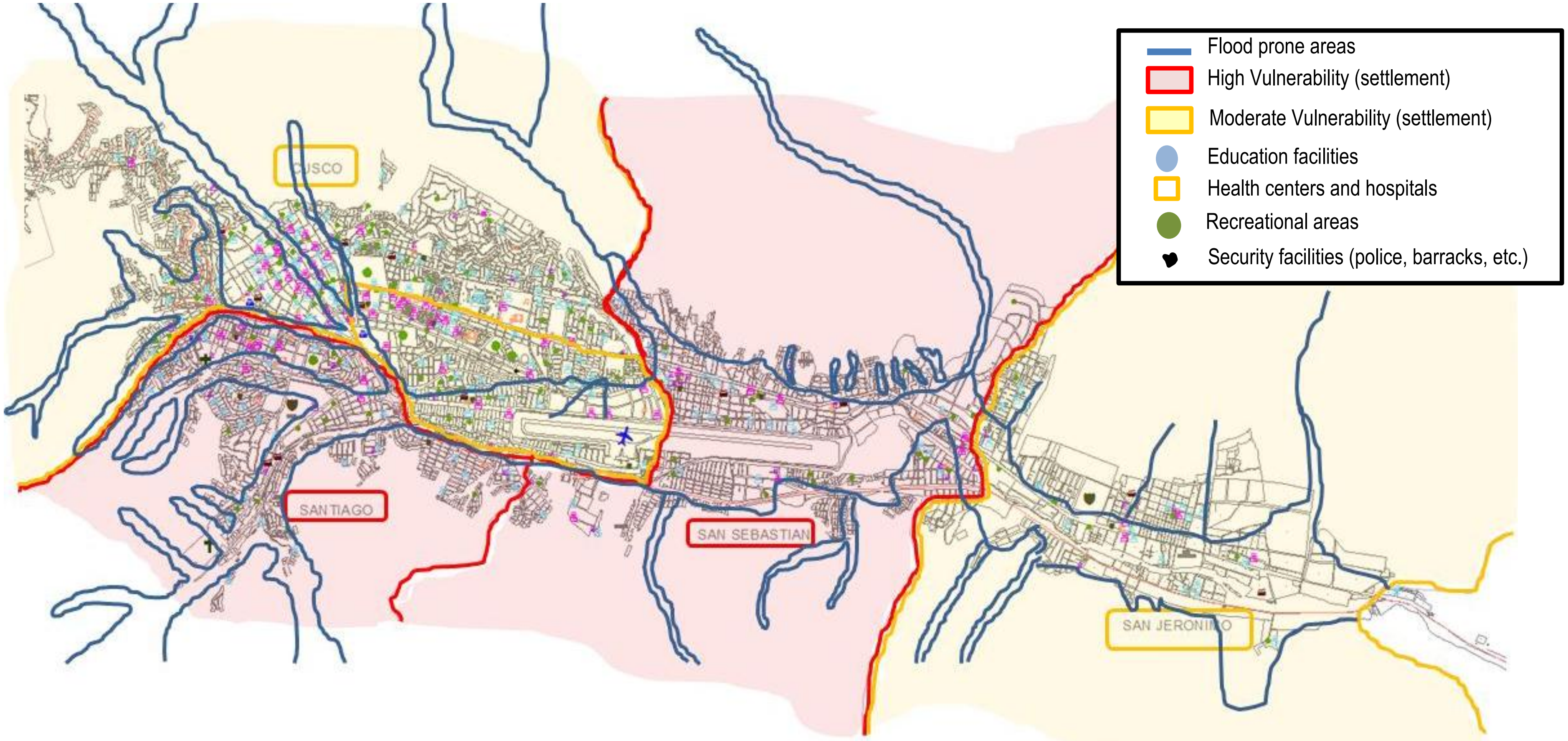


Figure 5.5 Vulnerability by district to floods and landslides in the 2040s with an indication of areas prone to flooding.

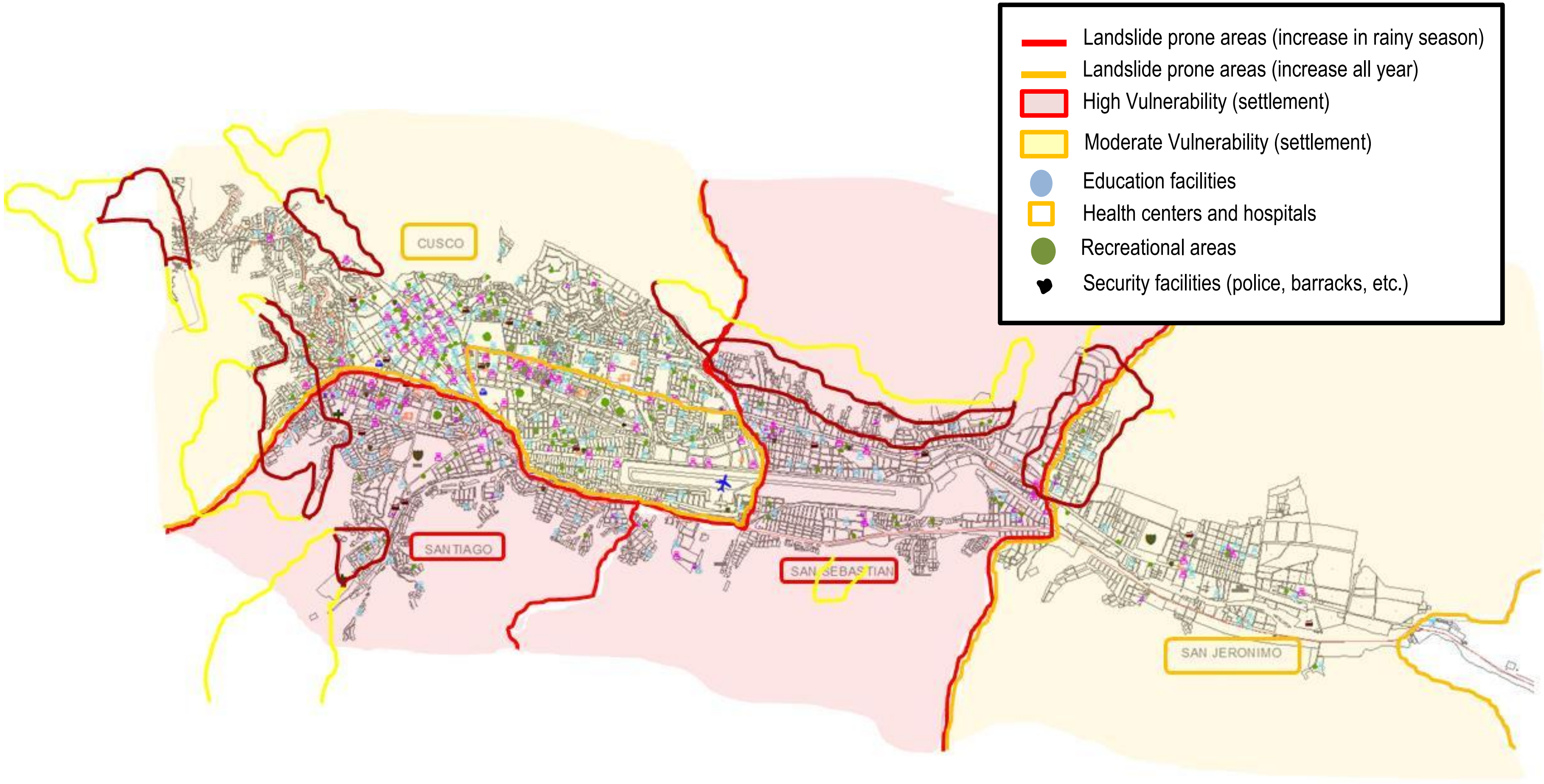


Figure 5.6 Vulnerability by district to floods and landslides in the 2040s with an indication of areas prone to landslides. Dark red line denotes areas that are currently prone to landslide events and are projected to increase while the yellow line denotes areas that are currently prone to landslide events and are projected to increase in frequency in the rainy season and decrease in the frequency in the dry season.

Table 5.8 provides a summary of the settlement vulnerability scoring, population, the number of facilities in each district. For planning purposes, it is recommended to develop adaptation options for those densely population settlements with critical infrastructure located in potentially "high" vulnerable areas. Hence, adaptation planning could initially focus on Santiago and San Sebastian.

Table 5.8 Summary of settlement flood and landslide vulnerability and the population and facilities within each district.

Score	Settlement	Population	Facilities
High	Santiago	84,097	■ 28 Schools ■ 2 Hospitals and health centers ■ 5 Recreational areas ■ 4 Municipal government institutions ■ 2 National and regional government institutions ■ 1 Bus terminal ■ 6 Police stations ■ 1 Army barrack
High	San Sebastian	45,287	■ 27 Schools ■ 3 Hospitals and health centers ■ 9 Recreational areas ■ 5 Municipal government institutions ■ 2 Police stations ■ 1 Army barrack
Medium	Cusco	100,712	■ 51 Schools ■ 2 Hospitals and health centers ■ 16 Recreational areas ■ 22 Municipal government institutions ■ 6 National and regional government institutions ■ 12 Police stations ■ 1 Army barrack
Medium	Wanchaq	63,894	■ Airport ■ 23 Schools ■ 3 Hospitals and health centers ■ 7 Recreational areas ■ 9 Municipal government institutions ■ 22 National and regional government institutions ■ 5 Police stations ■ 1 Fire brigade
Medium	San Jeronimo	18,966	■ 12 Schools ■ 1 Hospitals and health centers ■ 6 Recreational areas ■ 4 Municipal government institutions ■ 3 Police stations ■ 1 Army barrack

5.3.3 Considering risk

A risk assessment considers the likelihood of a hazard event occurring (typically expressed in terms of probability) and the magnitude of the consequence if the hazard event occurs. Some studies define likelihood use the probability of the occurrence of a climate hazard (NYCPCC 2009). Our vulnerability analysis incorporated limited primary and secondary data. In order to expand this analysis to consider risk, additional data is needed to develop a quantifiable baseline understanding of the frequency, severity, and triggers of landslides and floods and how these hazards may change over time. In addition, no information was available to consider the impact of these hazards on specific critical infrastructure.

The following studies are suggested for the Cusco to continue its development of pertinent risk information:

- Future work could further define relevant precipitation thresholds and environmental conditions that are responsible for flooding. This would require access to daily precipitation observation data and an analysis between past flood events and the associated meteorological conditions that lead to the event.
- A limitation to our analysis is that the current identification of areas prone to floods does not explicitly describe the magnitude of precipitation events associated with each flood event. Future flood analysis would benefit from the development of a flood susceptibility or vulnerability map describing today's and future conditions. The region would benefit from hydrologic and hydraulic modelling describing current flood conditions that could then be driven by future climate projections to assess future flood-prone areas.
- The development of flood hazard maps for specific return periods would be a useful tool for connecting the threat of flooding to extreme events and further defining the level of threat to flooding (e.g., the distance river flooding travels over the river banks under an extreme event of a given return period).
- It would be beneficial to define the magnitude of impact and the associated costs with historic landslide and flood events. These could be binned into ranges of similar damage/costs and then cross-referenced with the respective underlying precipitation events and thresholds. If the relationships are statistically sound, this would provide another source of information for considering how future change in these precipitation events could then impact the region.
- The development of an early warning system could be developed in a way that provides additional precipitation threshold(s). How these precipitation threshold(s) are projected to change can then be considered when assessing the impacts of future climate change.
- An analysis of precipitation thresholds and indicators associated with historic floods and landslide events could be conducted by: (1) developing these thresholds and indicators based on historic events, (2) projecting how these thresholds and indicators may change in the future, and (3) considering how these future changes may impact the frequency and intensity of future landslides and floods.
- Future work could incorporate stream gage data that was not available for this study to further investigate the relationship between precipitation and runoff. In addition, stream gage data is useful for calibrating monthly water balance models that can then be used to project how the stream gage parameters may change in response to future changes in monthly temperature and precipitation.
- The vulnerability assessment could be enhanced by incorporating additional metrics describing sensitivity and adaptive capacity. For example, the height of the doorway floorboard may be useful in determining susceptibility to floods. In addition, considering how the values of these metrics changed with future time would create a more dynamic analysis.
- A selection criteria could be developed to determine which of the infrastructure that is exposed to the hazards is critical (e.g., is the roadway an emergency evacuation route). Of the critical infrastructure, a drilled-down vulnerability analysis specific to that infrastructure could then be developed.

The choice of which activities to undertake depends on the concerns and stakeholder understanding of the hazards within Cusco.

6 Strategic climate adaptation investment and institutional strengthening plan

6.1 Introduction

Cusco is exposed to both floods and landslides. Flooding regularly occurs during the rainy season. Landslides also represent a major hazard, as a large part of the population is settled on steep slopes. Although there is a degree of uncertainty associated with the climate projections undertaken during the assessment, the results indicate that by the 2040s, the rainy season may be intensified and extended by a few months, which would slightly increase precipitation. This would thus also result in an increased possibility of floods and landslides. However, projections also suggest that there could be a reduction in the intensity of rainfall during precipitation events: i.e., there could be more frequent, yet less severe rainfall events, which might ultimately moderate the possibility of floods and landslides.

Uncertainty is further complicated by Cusco's variable terrain, which can lead to large differences in precipitation received in one location versus another. Therefore, the findings presented here should be carefully applied to the municipal planning within the context of this uncertainty. Concerning floods, the analysis performed reveals that the areas identified as prone to flood events are projected to continue to cause concern to Cusco in the 2040s. The change in landslide hazard is less clear; some regions may experience an increase in activity while others experience a decrease.

Landslide and flood hazard are closely related to the way urban expansion takes place in Cusco. The city is characterized by a long-run expansion and settlement pattern, which has configured its urban structure and layout following a linear, horizontal and low-density pattern covering all available space in the valley. Cusco is nowadays still going through a strong phase of urban expansion, acting as a hub for in-migration, and attracting people from the surrounding rural regions. Urban growth occurs in an unplanned manner and a considerable group of newly-arrived migrants locate in areas not designated for habitation, including hazard risk areas. Poverty intersects with this, as at-risk neighbourhoods are also often marked by high levels of poverty and low access to basic services.

Although Cusco's local DRM system benefits from its sound structure, challenges persist. The city's devolved governance system can complicate the coordination of DRM strategies. In particular, each district has its own mayor, civil defense and planning unit, which has resulted in an uneven application of risk management strategies across the entire urban conurbation.

The purpose of the *Cusco strategic climate adaptation investment and institutional strengthening plan* is to identify and then to prioritize short-, medium- and long-term adaptation interventions aimed at enhancing resilience to flooding and landslides in Cusco.

6.2 Approach and tools for adaptation planning

The preceding *Climate-related vulnerability and assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon in the short and medium term.

Engagement with national and local level stakeholders and decision-makers during the execution of the assignment was a very important feature which helps ensure coherence with national and local priorities and to tailor measures to fit needs.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Cusco in March 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be linked or incorporated into existing priorities, sectoral plans and planning instruments, and form part of an overall climate change adaptation strategy for Cusco.

Climate change adaptation planning is a key element of urban planning since it sets out a range of responses that can be implemented to enable communities to 'adapt' and become more resilient to climate-related change. Resilience is broadly defined as the 'ability to absorb or off-set damage and so avoid lasting harm and recover to pre-disaster status.' (da Silva et al., 2012) In the context of climate change, a more resilient system (i.e., a city) has the ability to withstand higher threshold limits in specific events, such as floods and landslides.

The steps taken to develop the *Strategic climate adaptation investment and institutional strengthening plan* for Cusco were:

6. Identification of urban planning, physical, socio-economic and institutional challenges and shortcomings related to flooding and landslides, drawing from the four assessments carried out under the project.
7. Definition of planning themes that create the foundation for a climate change adaptation strategy.
8. The planning themes lead to specific structural and non-structural measures which can be implemented in Cusco to manage and reduce flooding and landslide vulnerability and risk. These measures are presented in Table 6.1 and Table 6.2. Table 6.3 positions the measures within the disaster risk management (DRM) cycle.
9. Finally, a set of specific actions that can be undertaken to implement adaptation measures are proposed. These actions are presented in Table 6.4, which specifies:
   - The targeted area in the city: the area/s where the action can be enacted.
   - The institution responsible for enacting the action: this identifies the institution or institutions that have a responsibility for the proposed action.
   - The timeframe for its implementation: this allows providing a prioritization spectrum. Short-term actions are the issues with the highest priority; long-term actions are the issues with lower priority, or with high priority but with longer-roll out times.
   - An estimation of its relative cost: this is meant to give estimation on the resources to be allocated for the implementation of the action.

In the process of planning and implementation, the uncertainty associated with climate projections and its implications requires addressing, as Box 10 below describes.

Box 10 Dealing with uncertainty: addressing the risk of maladaptation

Ranger et al (2011) point out that as a degree of uncertainty is incorporated in climate projections, uncertainty is also embedded within the climate change adaptation process.

If policy-makers need to make investment decisions that will have a direct impact in the future capacity of a city to adapt to climate change, and uncertainty is embedded within the decision-making process, policy-makers face a significant challenge: *How to plan and decide on what will best help in constructing the city's resilience to climate change when the information available to advise on decision-making is limited and/or unclear?*

The major risk of not taking uncertainty into account is to take decisions that expose a society to maladaptation. This occurs when unsuitable investments are made for addressing the climate changes that actually do happen.

There are two forms:

- Under-adaptation: when the actions and adjustments made are not enough to deal with the climatic changes that do occur. For example, needing significant financial resources for replacing infrastructure built prematurely and found unsuitable to address climatic changes can be regarded as under-adaptation.
- Over-adaptation: when the adjustments made initially prove to be unnecessary, but later on they

are either not adaptive or counter-adaptive. For example, when considerable financial resources are put into building a sea defense meant to withstand a sea level rise of 4 meters, but this change does not happen and the infrastructure is found unsuitable.

In dealing with maladaptation, the integration of adaptation considerations into existing planning and policy priorities can be seen as a major asset. Incorporating adaptation into the overall development process can allow the proper addressing of the existing needs of a city. The rationale is to focus on principles rather than projections. If adaptation is integrated not as an independent characteristic but as a constitutive element spanning across an integrated development strategy, the possibility of delivering an appropriate strategy taking into account present uncertainties is increased.

Furthermore, a core feature of integrated planning is to build flexibility into adaptation strategies by prioritizing long-term adaptive capacity while avoiding inflexible decisions: here, the need to have a decision support tool allowing stakeholders to make “robust” investment choices in a context of uncertainty has been advanced (Lempert et al., 2010).

“Optimal” solutions stand in contrast to “robust” ones. An “optimal” solution is only adapted for an expected future, but might be inappropriate if conditions change. “Robust” solutions might not be optimal, but they are appropriate no matter the conditions that are encountered in the future. Allowing the incorporation of new information to guide decision-making allows the effective design of an adaptation strategy in which flexibility and robustness are embedded as core elements.

6.3 Strategy and adaptation measures

Overreaching goal

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Cusco. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process.

From goal to planning themes

The planning themes that create the foundation for a climate change adaptation strategy to help Cusco build its resilience against floods and landslides, both now and in the future, can be outlined as follows:

- **Coordinated risk management and planning across all districts of Cusco:**
  - Consolidation of district administration and municipal risk management functions
  - Consider urban expansion and future demographic trends, as well as physical and climate vulnerabilities in land use management for the city
  - Development of an integrated approach that considers drivers of economic and environmental change in surrounding regions needs for a more sustainable and long-term approach to understanding climate vulnerabilities.
- **Capacity building in national and city level government institutions engaged in climate change planning and risk management:**
  - Improvement of human resources capacity and infrastructure for the successful implementation of climate adaptation practices and policies.
- **Mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing:**
  - Improvement of information, communication and policy relevant technical knowledge for assisting local actors to identify and understand impact, vulnerability and adaptation responses in order to effectively select and implement practical and high priority adaptation measures.
- **Improved budgetary resources and climate financing for long-term recovery and building resilience against climate change hazards:**

- Improved funding capacity and financial resources to enable strengthening of the institutional capacity of risk management organizations.
- Formalized structures of cooperation with the private sector in planning and risk reduction phases for sustained and meaningful engagement.

■ **Cross-scale integration of risk management practices:**

- Promotion of local level participation in climate change adaptation and risk reduction.
- Initiatives to engage the public and local stakeholders in adaptive actions and to improve citizen awareness regarding floods and landslides to consolidate institutional and local adaptation and provide a more holistic approach to climate change planning.

■ **A shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance:**

- Supporting efforts towards mainstreaming climate change adaptation from policy into development practice and programmes.

From planning themes to measures

An integrated strategy requires the use of both structural and non-structural measures for “getting the balance right” (Jha et al., 2012).

Flood and landslide risk management measures can be either structural or non-structural. In broad terms, structural measures aim to reduce risk by controlling physical processes – such as the flow of water – both outside and within urban settlements. They are complementary to non-structural measures which aim at keeping people safe from flooding or landslides through better planning and management of – in this case, urban – development. More narrowly:

■ **Structural measures:** refer to physical investments that a city can institute in order to prepare its built environment for the expected effects of climate change. Structural measures are often costly investments in hard-engineered infrastructures.

■ **Non-structural measures:** refer to investments other than the improvement of physical infrastructure. These measures are often less costly than structural measures, and span a wider spectrum, covering urban (for example, planning), socio-economic (for example, poverty reduction) and institutional (for example, educational campaigns) dimensions.

Tables 6.1 and 6.2 which follow present a series of disaster and climate change-related adaptation measures which can be implemented in Cusco to manage and reduce flooding and landslide risk and vulnerability to these hazards – and, in so doing, enhance overall urban resilience.

Each measure is briefly described and the anticipated co-benefits over and above their flood and landslide management role are sketched.

In order to present a forward-looking view and allow the prioritization of adaptation options, two ratios are also considered:

■ **Benefits relative to costs:** to allow an understanding of how the costs inherent to the measure compare with the expected benefits.

■ **Robustness to uncertainties:** robustness refers to the way in which the benefits of an adaptation measure might vary with climate projections. It can be regarded as the risk of maladaptation. For example, on the left hand-side of Figure 6.2 are found “no-regret measures” (measures that will have a positive effect on adaptation, no matter the accuracy of climate projections, as for example, with awareness campaigns). On the right hand-side are located “higher-regret” measures, whose benefits are dependent on the accuracy of climate projections (for example, drainage systems or flood defences).

It is important to highlight that the robustness and cost-benefit ratios of measures are established on a case-by-case basis. It is also acknowledged that costly, long-term projects should seek “no-regret” ways to build in flexibility in order to address potential uncertainty.

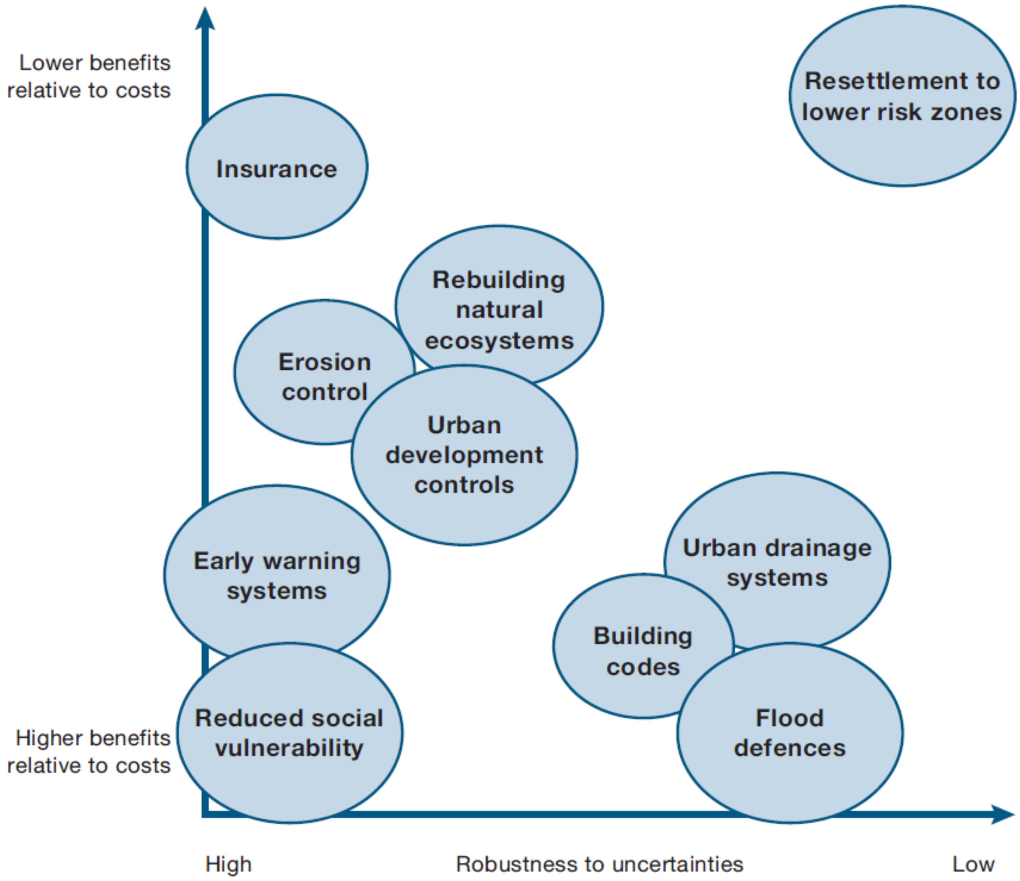


Figure 6.1 Relative costs and benefits of flood management options (based on findings for Guyana, Mozambique and UK). Source: Adapted from Ranger and Garbett-Shields 2011, in Jha, A., Bloch, R., and Lamond, J. (2012).

Table 6.1 Structural measures

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ Intensified and extended rainy season ■ Reduction in the intensity of rainfall during precipitation events: more frequent, yet less severe rainfall events	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk due to intensified precipitation	**Seek additional financing for the public investment project (Proyecto de Inversion Publica – PIP) for the head waters of the Saphy river**	Stakeholders acknowledged the need to improve land use management in the upper part of the Valley in order to enhance control of the watershed system in the city. Physical infrastructure to guide water flows in the Saphy is a priority. During the workshop, stakeholders raised the need to seek additional budgetary resources to support the public investment project aiming to regulate head waters of the Saphy river. Given that the project is located in the San Sebastián District, efforts should be put into closely working with it to secure cooperation, feasibility and investment.	■ Increased control of the watershed system ■ Risk reduction	Moderate	High

Table 6.2 Non-structural measures

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ Intensified and extended rainy season ■ Reduction in the intensity of rainfall during precipitation events: more frequent, yet less severe rainfall events	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk due to intensified precipitation	**Enhance the implementation of zoning and land use planning instruments**	Zoning is defined as land use regulations and planning. As a planning instrument, zoning is meant to guide urban expansion: it can orient urban development away from high-risk areas. Cusco is going through a strong phase of urban expansion. Growth is most often the result of rural-urban migration from the adjacent region in the Cusco area as well as other areas in Peru. Urban development occurs in an unplanned manner: newcomers frequently settle in areas that are not designated for habitation, such as archaeological or ecologically protected zones, as well as zones in slopes or in proximity to water streams. It is estimated that informal growth has accounted for around 80 per cent of the total urban expansion in recent years. Stakeholders identified various measures to be advanced in order to enhance land use planning and zoning regulations, with the ultimate aim of establishing a more sustainable pattern of urbanization:	■ Structured urban growth ■ Better provision of public services ■ Increased liveability and quality of life ■ Institutional strengthening ■ Urban resilience	Moderate	High

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
			■ Actors mentioned the need to accurately **identify the areas that are at risk of flooding and landslides**. This would be the first step to **design appropriate land use and expansion strategies**: knowing which the at-risk areas are would allow to **incorporate risk into land use planning**, thus contributing to establish a sustainable and resilient pattern of urban expansion. ■ In order to control expansion and avoid the settlement of population in flood-risk areas, stakeholders advanced the idea of **planting vegetation along the margins of rivers and the tributaries of the Huatanay and Saphy rivers**. This would both help **enhance environmental protection as well as planning regulations and direct expansion away from risk areas**. ■ Stakeholders mentioned the need of having **stronger institutional mechanisms for the enforcement of planning regulations and control**. This would **imply capacity building measures** for the local authorities in charge of planning strategies in Cusco. In this, designating protected areas surrounding the city that are not fit for urbanization could prove essential. ■ In the medium run, stakeholders acknowledged **the potential need of relocation planning for settlements in areas where the risks cannot be mitigated**: there was consensus that legitimize informal settlements with the provision of basic public services could be counter-productive in risk management in the long run. However, implementing a relocation initiative is challenging and costly, as it involves identifying areas and populations at high-levels of risk and elaborating housing strategies for them. Relocation needs to be incorporated in long-run planning processes, and form part of complimentary strategies, such as housing and masterplanning initiatives.			
■ Intensified and extended rainy season ■ Reduction in the intensity	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk	**Improve data collection**	Stakeholders saw as a challenge the **improvement of data collection and dissemination**: critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is still missing in El Progreso. Without this information, it is impossible to undertake local	■ Better assessment of risk ■ Increased accuracy of data to inform decision-making	High	High

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
of rainfall during precipitation events: more frequent, yet less severe rainfall events	due to intensified precipitation		adaptation activities that rely on the downscaling of climate change models and climatic data. Various points were raised to address these shortcomings: ■ **The creation of an Urban Observatory linked to the University** meant to advance innovative studies and practice in climate change adaptation. The Observatory would act as a knowledge hub bridging data collection, research, and various stakeholders in the understanding of climate change challenges. Through this, appropriate adaptation measures, incorporating sound data, could be derived. ■ In order to improve data collection, stakeholders mentioned the need to expand the network of rain meters, both within the city and in the surrounding areas, and particularly the basin to the north-west of the city. This would allow the improvement of climate monitoring and the study of subsequent changes over time, and appropriately. Ultimately, decision-makers would strongly benefit from the access to this information when designing adaptation strategies. ■ **Concentrate efforts in the dissemination of existing tools.** Stakeholders recognized that useful and detailed instruments, such as technical maps prepared by PREDES, were available and could be used for planning purposes. The diffusion of these tools and their incorporation when designing adaptation strategies could be of the most importance for the success of risk mitigation measures. ■ Stakeholders acknowledged that specific reports were missing, in order to have an accurate picture of risk. It was mentioned in the workshop the need to produce historical hydrological studies of Cusco, notably integrated studies of underground drainage systems within the historic core. This would help understand the interrelation between hazard and the hydrological characteristics, and how this has progressed over time. ■ Producing **studies assessing the economic impact of climate chang**e in Cusco could help **trigger action and decision-making**: quantifying the costs of inaction or inappropriate action can act to raise awareness and have an accurate picture of the consequences if appropriate adaptation measures are not implemented.	■ Increased awareness of risk and the potential impacts of climate change		

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ Intensified and extended rainy season ■ Reduction in the intensity of rainfall during precipitation events: more frequent, yet less severe rainfall events	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk due to intensified precipitation	**Introduce improved waste management measures and incorporate risk management considerations into solid waste projects.**	Stakeholders acknowledged that Cusco **faced severe challenges in solid waste management**, and the attached consequences this had in risk mitigation. It is estimated that in 2004, only 37 per cent of the total waste produced was disposed in landfllills: the remaining waste stayed in streets, riverbanks or was discharged into water streams. This not only creates pollution and environmental issues; it also contributes to the exacerbation of risk as the accumulation of waste can impede the circulation of water, and thus result in increased flooding. As such, stakeholders agreed on the need **to improve solid waste management measures**. This improvement would need to **incorporate risk management considerations**: city authorities, as well as the population, would need to understand that the betterment of solid waste collection is necessary not only for the enhancement of quality of life but also for hazard risk mitigation. The improvement could occur through the **strengthening of authorities in charge of waste collection in the city, involving improved budgetary allocations and institutional capacity**. An **educational component** is thus included: efforts should be put into introducing a better system for solid waste management, but this should also include an awareness exercise for the general public. The population would need to understand how it can contribute to this matter, and the actions it could take in this.	■ Reduction in risk ■ Raise awareness ■ Environmental protection	Moderate	Moderate
■ Intensified and extended rainy season ■ Reduction in the intensity of rainfall during precipitation events: more frequent, yet less severe rainfall events	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk due to intensified precipitation	**Work towards establishing an Integrated approaches to reducing risks**	The workshop raised the need of working in **the improvement of coordination activities between stakeholders** engaged in climate change adaptation initiatives. This would involve the advancement of an integrated approach in risk reduction. The **formulation of an integrated approach in risk reduction** would be of the most importance, notably due to the governance issues raised in Cusco: the city is marked by a fragmented system in DRM, as each district is responsible for the coordination of local strategies. In this, stakeholders mentioned that a specific programme, The "Pact for the City" (El Pacto por la Ciudad) had been launched by the MCP as part of the update of the Urban Development Plan. The aim of such an initiative is to generate commitment amongst local governments as well as civil society organizations to guarantee the advancement of an integrated planning approach in Cusco.	■ Increased cooperation between stakeholders ■ Institutional strengthening ■ Shift towards an integrated approach to disaster risk reduction and climate change adaptation	High	High

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
			During the workshop, it was mentioned the possibility of capitalizing on such initiatives to work towards the establishment of an integrated approach to risk reduction and climate adaptation: already existing platforms could be utilized to facilitate communication amongst stakeholders, create consensus and a coordinated vision in adaptation strategies. Engaging district mayors and district level institutions in a broad initiative would therefore improve overall adaptive capacity.			
■ Intensified and extended rainy season ■ Reduction in the intensity of rainfall during precipitation events: more frequent, yet less severe rainfall events	■ Increased flooding risk due to intensified precipitation ■ Increased landslide risk due to intensified precipitation	**Put efforts into linking tourism and adaptation priorities**	Stakeholders recognized the need of conciliating tourism and economic growth strategies with climate adaptation initiatives. Given that tourism is a major resource in Cusco, aligning tourism and economic development priorities with climate change adaptation challenges is essential for the long-term sustainability of the urban area: the city needs to find a way to promote economic expansion through tourism while incorporating environmental and climate concerns into an overall development strategy. The main task would thus be to find a balance between socio-environmental risk and the assertion strategy of a city operating as a commercial and regional hub. Unless this balance is achieved, the potential for disaster and loss remains high, with no clear strategy for long term growth and planning at the city level. Cusco could capitalize on revenues from tourism to advance the adaptation agenda and conciliate economic growth with environmental concerns: the income generated from tourism could be used to fund adaptation activities. Local authorities could make as such to allocate a designated percentage of the resources coming from tourism for institutional strengthening and/or capacity building measures meant to build adaptive capacity. This would create an ecosystem service payment system through which money would be channeled back from the recipient of the service, with the overall purpose to finance environmental preservation activities. The establishment of a payment link could therefore create a platform for starting bridging the tourism and climate change adaptation agendas: linking resources for both activities would also bond policy and implementation priorities.	■ Efforts towards the establishment of an integrated approach in climate change adaptation ■ Increased resources for climate change adaptation options ■ Better coordination between stakeholders	Moderate	High

Proposed measures and the disaster risk management (DRM) cycle

Under the disaster risk management (DRM) cycle, the structural and non-structural measures above can also usefully be classified as: (i) risk reduction, (ii) risk transfer or share, (iii) preparedness, and, (iv) response and recovery (Mitchell and Harris, 2012). Table 6.3 below locates the proposed structural and non-structural measures in the DRM cycle.

Table 6.3 Risk management options

Risk reduction (preventing hazard/shock, reducing exposure and vulnerability)	Risk transfer or share	Disaster preparedness	Disaster response and recovery
Seek additional financing for the public investment project (Proyecto de Inversion Publica – PIP) for the head waters of the Saphy river		Improve data collection	Put efforts into linking tourism and adaptation priorities
Enhance the implementation of zoning and land use planning instruments		Work towards establishing an Integrated approaches to reducing risks	
Introduce improved waste management measures and incorporate risk management considerations into solid waste projects			

6.4 Action plan

Table 6.4 presents a set of specific actions that can be undertaken to implement climate change adaptation measures. It illustrates the areas targeted by the action, the institution/s responsible for putting it in place and giving it life, the expected time-frame (short, medium, or long-term), as well as the relative costs. The purpose of this is to present planning initiatives that the city could consider and how these could be implemented.

Table 6.4 Cusco action plan

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
Seek additional financing for the public investment project (Proyecto de Inversion Publica – PIP) for the head waters of the Saphy river	Improve land use management in the upper part of the Valley in order to enhance control of the watershed system in the city	Upper part of the valley	■ MPC ■ Water Administration Authority (Autoridad Administrativa del Agua – AAA) ■ San Sebastián District ■ IMA (Institute of Water and Environmental Management)				Very high
	Work as necessary with the MCP, other regional and municipal governments to seek additional budgetary resources to support the public investment project aiming to regulate head waters of the Saphy river						
Enhance the implementation of zoning and land use planning instruments	Identify the areas that are at risk of flooding and landslides	**Floods:** Margins of the Saphy and Huatanay rivers. **Landslides**: nort-west slopes of Pichu and Ayahuico, San Sebastian district.	■ MPC ■ Committee of Civil Defense				Moderate to high
	Plant vegetation along the margins of rivers and the tributaries of the Huatanay and Saphy rivers						
	Enhance institutional mechanisms for the enforcement of planning regulations and control						
	Organize relocation planning for settlements in areas where the risks cannot be mitigated						
Improve data collection	Creation of an Urban Observatory, linked to the University, to advance innovative studies and practice in climate change adaptation	City-wide	■ MPC ■ Committee of Civil Defense; Scientific Committee of Disaster				Low to moderate

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
			Prevention (COCIPREDE) of the UNSAAC (Universidad Nacional de San Antonio Abad del Cusco) ■ National Meteorological Service (Servicio Nacional de Meteorología e Hidrología – SENAMHI) ■ Centre of Studies in Disaster Prevention (Centro de Estudios y Prevención de Desastres – PREDES)				
	Expand the network of rain meters, both within the city and in the surrounding areas, and particularly the basin to the north-west of the city						
	Concentrate efforts in the dissemination of existing tools, such as technical maps						
	Produce studies assessing the economic impact of climate change						
Introduce improved waste management measures and incorporate risk	Strengthening of authorities in charge of waste collection in the city, involving improved budgetary allocations and institutional capacity	City-wide	■ MPC				Moderate

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
management considerations into solid waste projects	Launch an awareness exercise for the general public: the population would need to understand how it can contribute to waste collection improvement, and the actions it could take in this						
Work towards establishing an Integrated approaches to reducing risks	Improvement of coordination activities between stakeholders engaged in climate change adaptation initiatives through existing platforms such as "Pact for the City" (El Pacto por la Ciudad)	City-wide	■ **Public institutions:** MCP; Committee of Civil Defense; COPESCO ■ **Civil society organizations:** PACC Peru (Programa de Adaptación al Cambio Climatico); ITDG (Soluciones Prácticas); Centro Guamán Poma de Ayala ■ **Academic institutions:** Scientific Committee of Disaster Prevention (COCIPRED) of the UNSAAC (Universidad Nacional de San Antonio Abad del Cusco)				Moderate
Put efforts into linking tourism and adaptation priorities	Find a balance between socio-environmental risk and the assertion strategy of a city operating as a commercial regional hub	City-wide	■ COPESCO ■ MPC				Moderate
	Create an ecosystem service payment: allocate a designated percentage of the resources coming from tourism for institutional strengthening and/or capacity building measures meant to build adaptive capacity						

6.5 Conclusion

Climate change adaptation is a continuous process: the adaptive capacity of a city can be constructed and enhanced over time, through various measures in different time-scales (short-term, medium-term, long-term). The *Cusco Strategic Climate Adaptation Investment and Institutional Strengthening Plan* presents an overview of the strategies that the city can adopt to strengthen its capabilities in climate change adaptation planning.

Cusco is a complex urban area marked by high levels of poverty and exposure to floods and landslides. The city benefits from a sound DRM system, with the presence of a Committee of Civil Defense, in charge of disaster preparation and response. Despite having a strong DRM system, the recurrence of hazard risk marks the urban area. This can severely affected the long-term sustainability of the local economy, mostly based on tourism. Acknowledging this challenge, local authorities and stakeholders have identified as a major issue the conciliation of the local economic development agenda with climate change adaptation and disaster risk reduction priorities.

The World Bank has been innovator in this effort, through the Vilcanota Valley Protection and Development Project (Vilcanota II). The Vilcanota II project is a regional development project aimed at enhancing local economic development through promoting tourism and increasing environmental and historic preservation efforts while also addressing disaster risk management in the Cusco area. This is an attempt to tackle simultaneously the economic needs of a growing regional centre and the environmental risks stemming from expansion.

As a start, joining the agendas of tourism and city level climate change adaptation would strengthen both sectors of activity. Engaging district mayors to undertake coherent action in collaborative adaptation and planning for risk under district level organizations will also enhance overall adaptive capacity in Cusco. Given the right resources and operational capacity, there clearly are new initiatives and partnerships that can be forged to promote strategic climate change adaptation in Cusco.

Framing adaptation in line with overall development priorities can prove to be crucial. If adaptation is mainstreamed within the existing institutional structures and developing objectives, notably poverty reduction, vulnerability to climate hazards can be significantly reduced. The main challenge for policy- and decision-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term climate risks and embraces uncertainty, as the timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments and action. In the end, the ability and willingness of key actors to address climate change impacts will be of utmost importance.

7 References

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ANNEXES

Annex 1 Methodology of climate-related hazard assessment

This analysis utilizes existing tools used by the Cusco city government to consider how flood and landslide hazards may change by mid-century (2040s). To effectively inform future urban planning, it is important our approach be appropriately aligned with the available local data and tools. The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events include:

1. Reviewing available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collecting and investigating data on past landslide and flood events in Cusco to assess the degree of impact per event and the conditions that precipitate events.
3. Assessing available resources used by the municipality to describe zones vulnerable to landslides and floods, and inform emergency planning.
4. Assessing available future precipitation and temperature data for the 2040s.
5. Assessing and performing the application of three distinct approaches that consider how climate change may impact the resources investigated in Step 3.

Each step is discussed in greater detail below.

Step 1: Review the physical system. It is important to first understand the environmental system specific to Cusco that affects the nature and location of landslides and floods. To do this the thematic maps of local terrain, soils, and hydrology developed by the municipality were reviewed. To investigate local climate, two data sources were analysed:

- To consider how meteorological conditions vary month by month in the Cusco region, observed precipitation and temperature data from WorldClim (Hijmans et al., 2005) were collected. Worldclim data was generated through the interpolation of average monthly climate data from weather stations at a 1 km^2 resolution.[18] Figures are included in this analysis to illustrate the large variability in temperature and precipitation across the mountainous region.
- Monthly observational data for five local stations provided by the National Meteorology and Hydrology Service (SENAMH) were used to construct climatic averages of temperature, precipitation, and extreme events for 1965 to 1990. This time period was selected as it is consistent with the baseline years used in developing the climate projections.[19]

The results of this step are presented in Section 2.3.

Step 2: Catalogue past events. A collage of past flood and landslide events was compiled based on: (1) discussions with stakeholders during the field visit; (2) government reports; and (3) online material including local newspaper reports. This includes the use of the DesInventar database. This information was collected to explore answers to these specific questions: Do floods and/or landslides occur concurrently? Is the hazard more apt to occur during specific times of year? Is there regularity to the occurrence of the events or is the time series of events punctuated by a few events over a long time period? What type of rainfall patterns lead to floods and landslides? Answers to these questions help illuminate the flood and landslide trends in Cusco.

Two case studies of regional storm events were selected to suggest the potential impacts related to significant regional flooding and landslides that could become more common under future climate

[18] For observation data, this dataset uses a number of major climate databases such as the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, among others. It also uses the SRTM elevation database. The ANUSPLIN program interpolates noisy multi-variate data using thin plate smoothing splines (using latitude, longitude, and elevation as independent variables). At a minimum, averages were calculated for 1960 to 1990 where at least 10 years of data where available. After removing stations with errors, WorldClim used precipitation records from 47,554 locations.

[19] The baseline years for the climate projections are 1961 to 1990; however, given the observation stations do not provide complete records from 1961 to 1964, the averaging across this time period is from 1965 to 1990.

change. Regional storm events were chosen because they provide a regional signal of precipitation that is at approximately the same spatial resolution as the projected changes in climate used in this analysis. More localized storm events may be influenced by physical processes that are at too small a resolution to be well represented by global climate models.

The results of this step are presented in Sections 2.4 and 2.5.

Step 3: Review flood and landslide resources. As this analysis is to inform municipal planners, planning and emergency management resources were collected which are used by the municipality to gauge landslide and flood hazards. Using these resources allows this analysis to be developed drawing from sources of information that local planners are intimately knowledgeable with and already use for decision-making. In addition, these resources may have entry points for including changes in climate- and weather-related variables. How these variables may change in the future may then indicate how the potential future impact may change. Further, these entry points (e.g., precipitation threshold used to trigger an emergency response) may have defined spatial and temporal scales for the precipitation data that were deemed acceptable, and, as such, replicating future projections as close to the scales of data as possible ensures the results of this analysis are within an acceptable scale of uncertainty to inform future plans (understanding that working with climate projections introduces additional uncertainty as discussed in Step 4). A review was conducted to investigate if precipitation informed these collective resources. For example: Is the flood and/or landslide early warning system triggered by a specific precipitation threshold? Were the flood and/or landslide hazard maps developed based on precipitation metrics?

Discussion of the application of the methodology and the findings of this step is presented in Sections 2.4 and 2.5.

Step 4. Assess climate projections. We reviewed sources that provide precipitation and temperature projections. For replicability across other cities and as no locally tailored data was available, data sources that provide global projections of climate were considered.

Considerations in identifying and developing appropriate projections. The following approach was adopted to develop robust projections to inform this analysis (see Box 11 for term definitions and additional discussion of uncertainty in climate projections):

- **Time period:** The 2040s were chosen as the relevant time period for this study.
- **Spatial scale:** Cusco is located in mountainous terrain with low observation station density which represents an area of great uncertainty with regards to the climatic projections (Hijmans et al. 2005). Downscaled projections were used to reduce this uncertainty.
- **Natural Variability:** To reduce this uncertainty, 30-year averages were used from 2030 to 2059, centered at the 2040s.
- **Model uncertainty:** To reduce the contribution associated with model uncertainty, projected change is calculated as an average for the climate model ensemble (i.e., the average values across all climate model results for a given emission scenario). This is consistent with the approach recommended by the broader community of climate scientists as the most robust indication of how climate may change in the future when considering adaptation responses (Knutti et al. 2010). To illustrate the range of values projected across the climate models, the maximum, minimum, 25-percentile, and 75-percentile were also provided.
- **Scenario uncertainty:** Given it is unclear how global society may evolve over the coming decades, this analysis considers low (B1) and moderately-high (A2) greenhouse gas emission scenarios for developing potential futures.

Given the disagreement amongst climate models regarding the direction of future precipitation (i.e., will precipitation increase or decrease), additional tools were used to assess confidence in the climate model ensemble mean used in this analysis. The following ranking was applied (this example is based on a total of 15 climate models) to consider how many of the models agreed in the direction produced by the climate model ensemble average: “very high” if 13 or more climate models were in agreement, “high” if 11 or 12 climate models were in agreement, “medium” if between 6 and 10 climate models were in agreement, “low” if between 3 and 5 climate models were in agreement, and “very low” if less than 3 climate models were in agreement. This ranking was applied in our evaluation of precipitation projections in the 2040s where there can be strong directional disagreement across the models.

Box 11 Uncertainty in Climate Projections

There is considerable confidence in the capability of climate models to simulate temperature projections particularly at the continental scale, but less confidence in climate models' ability to project precipitation. This difference in confidence should be qualitatively considered when incorporating vulnerability and risk assessments results into future planning.

There are three main sources of uncertainty in climate model simulations:

1. Natural variability (the unpredictable nature of the climate system)
2. Model uncertainty (the ability to accurately model the Earth's many complex processes)
3. Scenario uncertainty (the ability to project future societal choices such as energy use)

The relative contribution of each uncertainty component to the climate model simulation's overall uncertainty varies with time. In the near term, Hawkins and Sutton (2009) suggest scenario uncertainty is relatively minimal while model uncertainty and natural variability are dominant contributors by near-term and mid-century. These uncertainties also change relative to each other for projections on different spatial scales. Natural variability becomes a greater source of uncertainty at finer scales. This is one reason why incorporating downscaled projections expands the potential uncertainty in climate projections.

There are a few methods adopted within the climate modelling and impact science community to capture the breadth of uncertainty associated with each of the three main sources. To understand the uncertainty associated with natural variability, climate model results may be averaged over long-term periods of time (e.g., 30 years) or driven with variations in input data to simulate various sources of natural variability differently. A collection of results across climate models that rely on variations in parameterizations and other components within climate models can provide some breadth of the uncertainty component associated with climate models. And considering various emission scenarios reflecting differences in how our society may change in the future provide some degree of quantification of the scenario uncertainty.

Climate datasets used in the analysis. Two scenarios were developed for this analysis. For simplicity, this analysis refers to the climate model ensemble mean under the B1 emission scenario as Scenario 1 and the climate model ensemble mean under the A2 emission scenario as Scenario 2 (see Box 11).[20] These emission scenarios were chosen as they provided projections for low and moderately-high emission scenarios and were readily available from a number of sources across a number of climate models. For this analysis, all projections are considered equally plausible.

Box 12 Scenarios for this Analysis

Scenario 1: The climate model ensemble average under the low (B1) emission scenario

Scenario 2: The climate model ensemble average under the moderately-high (A2) emission scenario

The available climate projection data were assessed by applying the following criteria: Are projections available to reflect changes in the 2040s? Are projections available at a monthly and/or daily resolution? Given Cusco is located within mountainous terrain, are downscaled projections available? Are projections available that indicate changes in precipitation and temperature under high and low future greenhouse gas emission scenarios?

For this analysis, we collected two sets of projection data (see Table A1.1)[21]:

[20] The A2 emission scenario family has population that continuously increases and regional economic development with technology change more fragmented than other scenarios. The B1 emission scenario describes a global population that peaks in mid-century and declines thereafter, and an emphasis on global solutions to economic, social, and environmental sustainability. (IPCC, 2007)

[21] The WorldClim data[21] were considered, but Climate Wizard provided an easier interface for accessing projections in the 2040s and applies a more sophisticated downscaling technique. The data that is used to support Climate Wizard is also available at daily resolution which, with some effort, could be analyzed to construct

- Statistically-downscaled monthly projections for temperature and precipitation from ClimateWizard for the 2040s relative to 1961 to 1990 (Girvetz, 2009).[22] This data provides downscaled projections of 15 climate models.[23] We considered two emission scenarios for this analysis, including B1 and A2.
- Dynamically-downscaled monthly projections of daily precipitation rates from PRECIS-Caribe for the 2040s relative to 1961 to 1990.[24] This data provides downscaled projections under B1 and A2 emission scenarios.

Table A1.1 Catalogue of climate projections (2040s) used in this analysis.

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
PRECIS-Caribe[25]	Monthly change in precipitation rate per day	Yes	50 km	■ B1 ■ A2	Regional climate model, HadAM3P, driven with global climate models that were used to inform the IPCC Third Assessment
Climate wizard[26] (Girvetz, 2009)	Monthly Precipitation	Yes	50 km	■ B1 ■ A2	Statistically downscaled 15 global climate models used to inform the IPCC Fourth Assessment

For our analysis, we assume all projections provided by climate model and emission scenario are equally plausible rather than assigning ranks or weights to a given climate model or emission scenario. Further, we apply the guidance provided by the scientific community in developing two scenarios for use in our study. For a given emission scenario, we average across all climate models to obtain a climate model ensemble average.

The projected changes in climate based upon these two datasets for the two scenarios described in Box 11 are provided in Section 2.6.

Step 5. Assess approaches to consider climate change impacts on floods and landslides. As described below, we considered three approaches and tested the viability of implementing each one based on available information:

- **Approach 1.** This approach identifies and investigates the development of flood and landslide maps used by the municipality in planning and emergency management. Any precipitation metrics used to develop the flood and landslide maps are identified. An analysis is done to quantify how these precipitation metrics may change in the future and a discussion of the implications of these changes on the frequency and/or intensity of future flood and landslide events is provided.

additional precipitation indices such as threshold indices (e.g., precipitation above a given amount) and return periods. This additional effort is recommended for future work.

[22] Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003). This dataset is for the 2040s (averaged from 2030 to 2059) compared to a 1961 to 1990 baseline.

[23] As recommended by the scientific community, this analysis considers the average across model grid cells around Cusco city (i.e., not just at the grid cell that overlays Cusco). This increases the statistical confidence of the results (Girvertz 2009).

[24] The Providing Regional Climates for Impact Studies (PRECIS) is a regional climate model developed by the Hadley Centre of the Meteorological Office of the United Kingdom to investigate projected changes in climate for non-Annex I Parties to the United Nations Framework Convention on Climate Change. The projections presented here are scaled by the data providers from results of two time slices, 1961-1990 and 2071-2100, under the A2 emission scenario to estimate projected changes in the 2040s under the A2 and B1 emission scenarios.

[25] http://precis.insmet.cu/eng/datos.html

[26] http://www.climatewizard.org

- **Approach 2.** Using regional meteorological events that have caused floods and/or landslides can be a useful approach in developing precipitation event thresholds. How floods and/or landslides may change in the future can then be investigated by looking at future daily precipitation projections to see how often these thresholds might be crossed in the future.
- **Approach 3.** When observational data and/or records are very limited, global datasets of precipitation projections can provide insight as to how changes in the nature of precipitation may impact future floods and landslides in Cusco.

Table A1.2 provides a succinct discussion of each approach along with a description of the data requirements, the assumptions and limitations for applying the approach in the Cusco study area. The level of detail in the findings for use by the municipality reduces from the first approach to the third approach, moving from a more quantitative analysis to one that is more qualitative. Given the constraints on the available information as detailed in the “limitations” column in Table A1.2, we largely adopted approach 3 to investigate how landslides and floods may change in the future.

Future work should develop flood and landslide precipitation indicators based on today’s relationships using daily observations; the projections of these indicators would provide some insight regarding potential changes in floods and landslides.

Table A1.2 Description and considerations of approaches to investigate how changes in precipitation may impact floods and landslides in Cusco.

Approaches to Investigate Future Changes in Floods and Landslides				
Approach	Description	Requirements	Assumptions	Limitations
1. Identify precipitation metrics used in developing local flood and landslide hazard maps for local planners. Consider how these precipitation metrics may change in the future.	Investigate the methodology used to develop local flood and landslide hazard maps that inform local planners (e.g., 100 year flood, maps that identify areas that are prone to flooding, etc.). Determine what precipitation metrics were used in the map development. Identify appropriate source(s) for the projections of the precipitation metrics within the temporal and spatial resolution required and use these data to consider future change in hazard. In addition, through stakeholder discussions determine if additional anecdotal information or emergency flood and/or landslide warning systems are used and tied to precipitation thresholds.	■ Local flood hazard maps ■ Local landslide hazard maps ■ Emergency flood warning systems ■ Emergency landslide warning system ■ Local expertise in flood events ■ Local expertise in landslide events ■ Projections of identified precipitation metrics	The findings of this approach describing future conditions would not create new flood and landslide hazard locations. This method is constrained to consider whether the flood and landslide hazard locations identified by the flood and landslide maps are projected to intensify or lessen; though qualitative reasoning can be applied to broaden the identified future hot spots. As this analysis is intended to separate the climate change component from other influencing factors to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static such as changes in land use, construction and maintenance in sewage/drainage systems, and housing.	The Cusco municipal government uses the flood and landslide maps as described in Sections 2.4 and 2.5 to identify areas prone to floods and landslides. These maps are based on cataloguing past events and revised based on stakeholder expert knowledge. These maps are not linked to precipitation events. Given this, these maps do not provide precipitation metrics that can be used in this analysis. The maps simply indicate the locations of flood-prone and landslide-prone areas.
2. Identify precipitation thresholds. Consider how these precipitation thresholds may change in the future.	Use past events described in research/academic/government literature and local newspapers to identify the dates of past flood and/or landslide events. Using these identified dates, construct a table with the daily precipitation observed at a local weather station. If there are enough events to consider, investigate the strength of the precipitation threshold(s) in predicting flood events (e.g., construct a scatterplot between precipitation and flood, investigate whether there were other days that crossed a specific precipitation thresholds but did not lead to flooding); similarly for landslide events. Use daily downscaled precipitation projections to consider how the frequency of the precipitation threshold(s) may change in	■ Collection of past flood events ■ Collection of past landslide events ■ Local meteorological data ■ Daily downscaled precipitation projections	This approach assumes that the identified precipitation thresholds represent a consistent indicator for floods and landslides. For example, if cumulative rainfall over a 5-day period is considered a reasonable indicator for a given hazard in today's climate, it is assumed it will still be a reasonable indicator under a potentially changed climate (i.e., the future stressor/impact relationships remain constant). As this analysis is intended to separate the climate change component from the other influencing factors to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static such as changes in land use, construction	Cusco municipality provided observation stations for the Cusco area. This data is not at a daily resolution but monthly creating difficulty connecting events to local meteorological data. Because of this, this option can only be implemented drawing from the information available in newspaper articles and reports. There is significant spatial heterogeneity in precipitation amounts across the Cusco area for a given storm event, this makes it inherently challenging to construct robust relationships between precipitation amounts and flood/landslide events. This option also is difficult to apply as it assumes daily downscaled precipitation data is available in a ready-to-use format for

Approaches to Investigate Future Changes in Floods and Landslides

	the future.		and maintenance in sewage/drainage systems, and housing.	this analysis - this is not the case for Cusco.
3. Construct / leverage future precipitation projections and qualitatively consider the impact on local flood hazard maps.	Identify sources of recent precipitation projections for Cusco (i.e., projections developed ideally using modelling of IPCC AR4 or later) and the associated metrics (e.g., time periods, emission scenarios, climate models). Construct a catalogue of precipitation projections and determine the best projections to use for the flood and landslide analysis. Ideally, the data would include changes in annual, monthly, and daily precipitation. If daily is not available, then 'processed' projections that are available should be considered (e.g., changes in the 5-percentile of precipitation; changes in the 100 year precipitation return period).	■ Precipitation projections	As this analysis is intended to separate the climate change component from the other influencing factors to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static, including: land use, construction and maintenance in sewage/drainage systems, and housing.	The precipitation projections will not be developed specifically focusing on precipitation flood and landslide drivers in Cusco.

Annex 2 Inventory of flood events

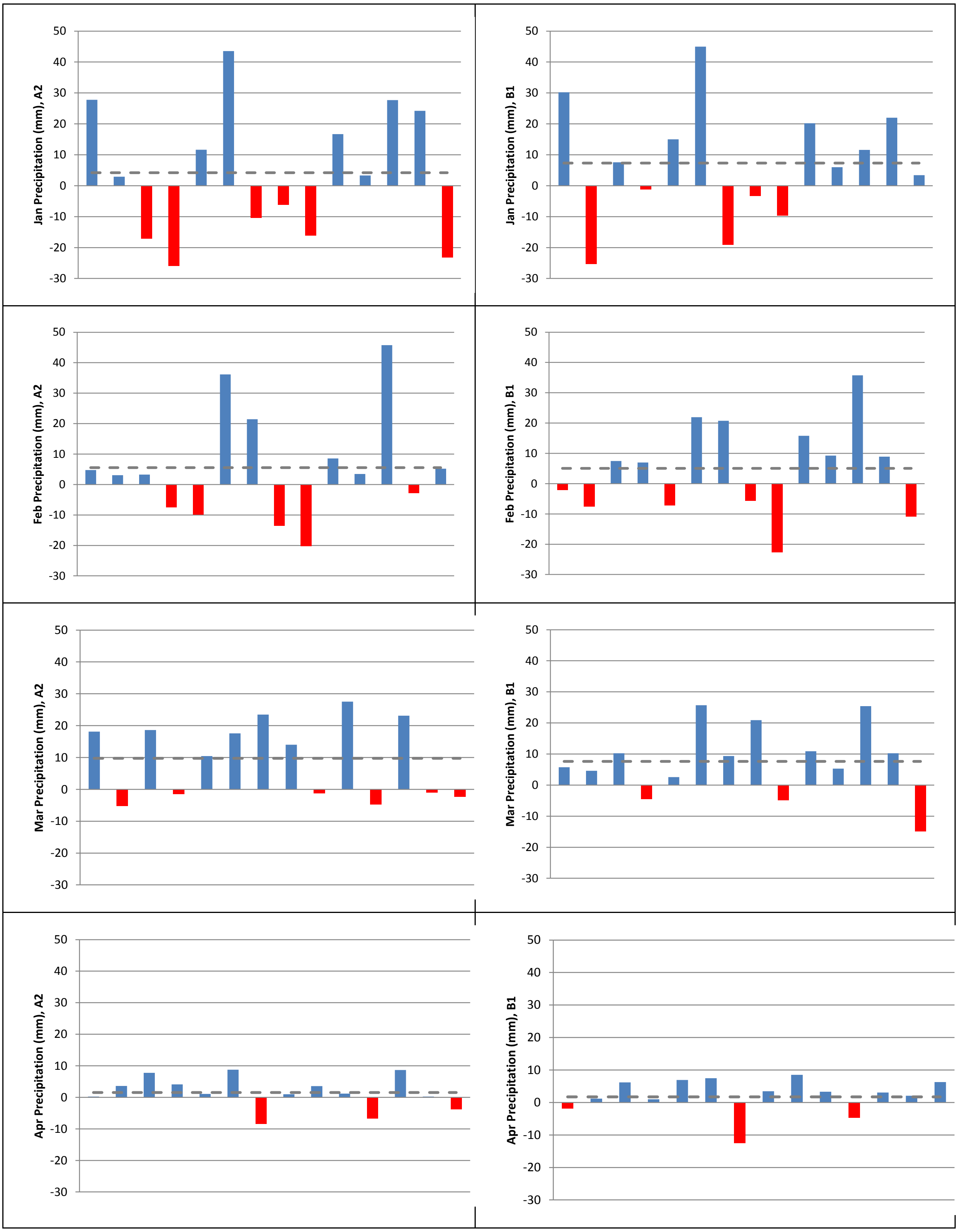
Table A2.1 Flood locations in and around the city of Cusco

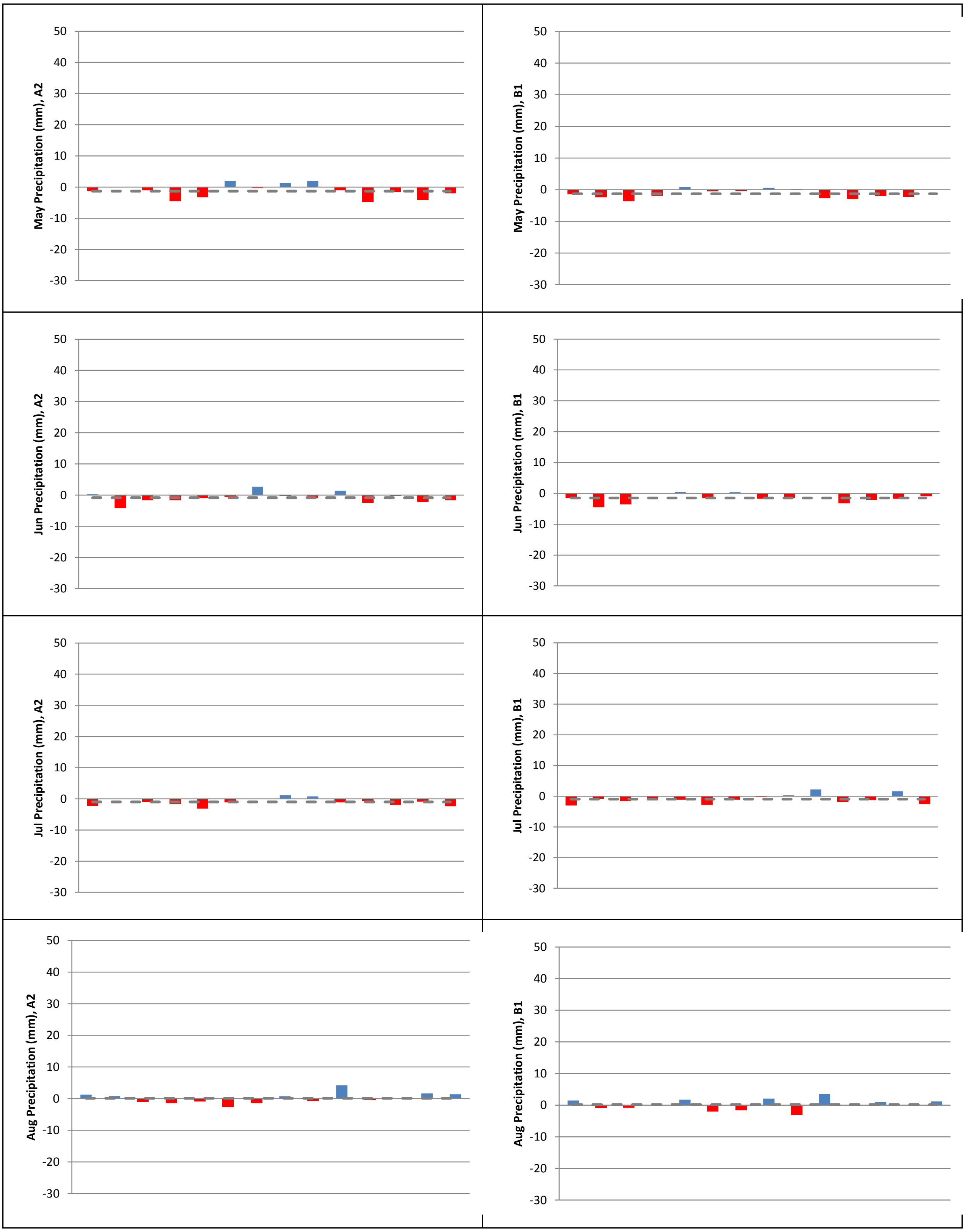
District / Area	Flood locations
Quebrada Ucchullo	Small rivers such as Quebrada de Lucrepata, Balconcillo, Ucchullo and Primero de Mayo discharge to Av La Cultura flooding down to where it meets the Cachimayo river. Previously flooded at Universidad Nacional San Antonio Abad del Cusco, Hospital Regional, Av La Cultura y Barrio de Mariscal Gamarra. Drainage channels were improved and possibly constructed for Av. Collasuyo, Av Universitaria, Av. Victor Raúl Haya de la Torre and the drainage of Av. de la Cultura. Risk has diminished but it is considered that urban expansion, soil cover with houses and pavement has increased the volume of water over time and these works might not be enough to avoid future floods.
Saphy Basin	Flood areas prior to river channelization, campamento Municipal, Urb Villa las Mercedes, Saphy river channelized area, Saphy Street, Plateros Street, Plaza de Armas, Paraninfo Universitario, Avenida el Sol. Threat of flooding is roughly 30 meters inland along each side of the river up until it discharges at the Huancaro River.
Quebrada Choquechaca	Flooding has been observed at the Sapantiana sector; Choquechaca, Tullumayo and Limacpampa streets down until Av. El Sol.
Quebrada Ayahuayco	Flooding areas identified at San Benito y Villa María sectors; Av Arcopata down to Avenida del Ejército.
Sipaspuquio and Picchu micro-basin	Flooding areas identified at Independencia sector; Av. Ejército down to Av. Alameda, and Óvalo de Pachacuteq.
Quebrada Sacramayo	Flooding areas include lower áreas of 1 de Diciembre, Hermanos Ayar, El Bosque, APV Independencia y la APV Amauta; and Av. El Ejercito.
Quebrada Korimachahuayniyoc	Flooding areas include APV Dignidad Nacional, APV Ruiz Caro y La Villa Militar Urb., and Huancaro. This waterway drains to the Huancaro river.
Micro-basin Chocco	Flooding areas include Comunidad Campesina, Chocco, APV Juan E. Medrano and APV Villa Cesar.
Micro-basin Huancaro	Flooding areas include the lower areas of: APV Villa Primavera, Los Pinos, Barrio de Dios. Other areas that could potentially be flooded include: Chocco, APV Las Américas, APV Juan Medrano, Urbs. Nueva América y Vallecito. This micro-basin drains at the Saphy river channelization.
NE Cusco	Flooding areas include streets in the area of Ucchullo: Calle Retiro, Av. Comercio 41, Av. Universitaria and Av. Victor Raúl Haya de la Torre, leading to Av. de la Cultura, partially flowing towards Av. Diagonal Angamos y la Quebrada de Huamantiana to finally reach a wide plain where Urb. Ttio Norte, Kennedy and Parque industria are located. Flood hazard includes those streets and surrounding buildings and streets and all the lower plain.
Micro-basin Cachimayo	Flooding areas located close to the river are prone to flooding until it discharges into the Huatanay river at APV Naciones Unidas: Urb. Los licenciados, APV Victoria, APV Las Salineras, Urb. Vallecito, APV Carlos Mariátegui, APV Kantu, Villa Mercedes, Vista Alegre, APV Manantiales

District / Area	Flood locations
	The natural river flow has been altered towards the east parallel to the Airport Velazco Astete at Urb. José Carlos Mariátegui
Cárcavas del Sector San Sebastián Norte	There are 10 main gullies located N of Av de la Cultura. Urb Los Licenciados y Conafovicer that may be prone to flooding. These gullies are dry with water filtering into the soil; however, with settlements (both into the gullies and on top) run-off could be changes affecting future floods.
Micro-Basin Pumamarca - Teneria	This micro-basin starts in the higher areas of Yuncaypata, and continues to the lower areas down to where it discharges to the Huatanay. Areas susceptible to flooding include: Urb Villa los Próceres. Urb Tenería, Santutis Chico (school Pukllasunchis and Instituto Superior Tecnológico Arco Iris)
Av. Principal Santa Maria - Larapa	The Avenida Principal Santa María starts at Picol Mountain. This area lacks space for a natural drainage flow; hence, areas along side are susceptible to flooding as it reaches the Av de La Cultura.
Quebradas De Llocllapata y Romeritos	Located at St Jeronimo, all households on either sides of the rivers can be flooded, as well as the Vinocanchon market.
Kayra Micro-basin	Flood areas starts at cerro Huanacaure, down towards Granja Experimental Kayra - Universidad Nacional San Antonio Abad del Cusco. Areas close to the Huatanay river, at the discharge of this basin, is susceptible to flooding.
Huacoto micro-basin	Flood area starts at Cerro Huaccoto Lower areas in the micro-basin are susceptible to flooding nearby the water treatment plan Seda Qosqo (San Jerónimo) close to its discharge to the Huatanay river
Huatanay basin	The basin starts at the intersection of the Huancaro river and the channelized Saphy river. During the rainy season the river floods all households along either side of the rivers. Among sector affected are: Terminal Terrestre, Centro Comercial El Molino, APV Herrera Farfan, Rosaura, San Judas Chico, Santa Lucila, Urb. Sol Naciente, APV Señor de los Milagros, Urb. Kenyi Fujimori, Urb. San Luis, Surihuaylla, APV San Antonio, Las Joyas, Naciones Unidas, Urb. Mollepata, Santa Rosa, Urb. Picol, Los Pinos, Versalles, La Kantuta, San Juan de Dios, Virgen del Rosario, part of Chimpahuaylla, APV Angostura, and down to Saylla. All locations are in Huanchaq, San Sebastián, San Jerónimo and Saylla districts. 25-30 meter mean flood and up to 50 meter in the upper area and until the area near the airport Velazco Astete. There are 2 areas that may be severely affected: APV Angostura and between the Huatanay River and the trainline entering Saylla maximum flood of 450 meter.
Poroy basin	Located NW of Cusco Flooding occurs along both sides of the river and its tributaries. The flooding limit is at the railway and includes Cruz Verde and Poroy sectors.

Source: Adapted from information provided in Benavente Velasquez, 2004.

Annex 3 Precipitation projection figures

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May Precipitation (mm), B1
Jun Precipitation (mm), A2
Jun Precipitation (mm), B1
Jul Precipitation (mm), A2
Jul Precipitation (mm), B1
Aug Precipitation (mm), A2
Aug Precipitation (mm), B1
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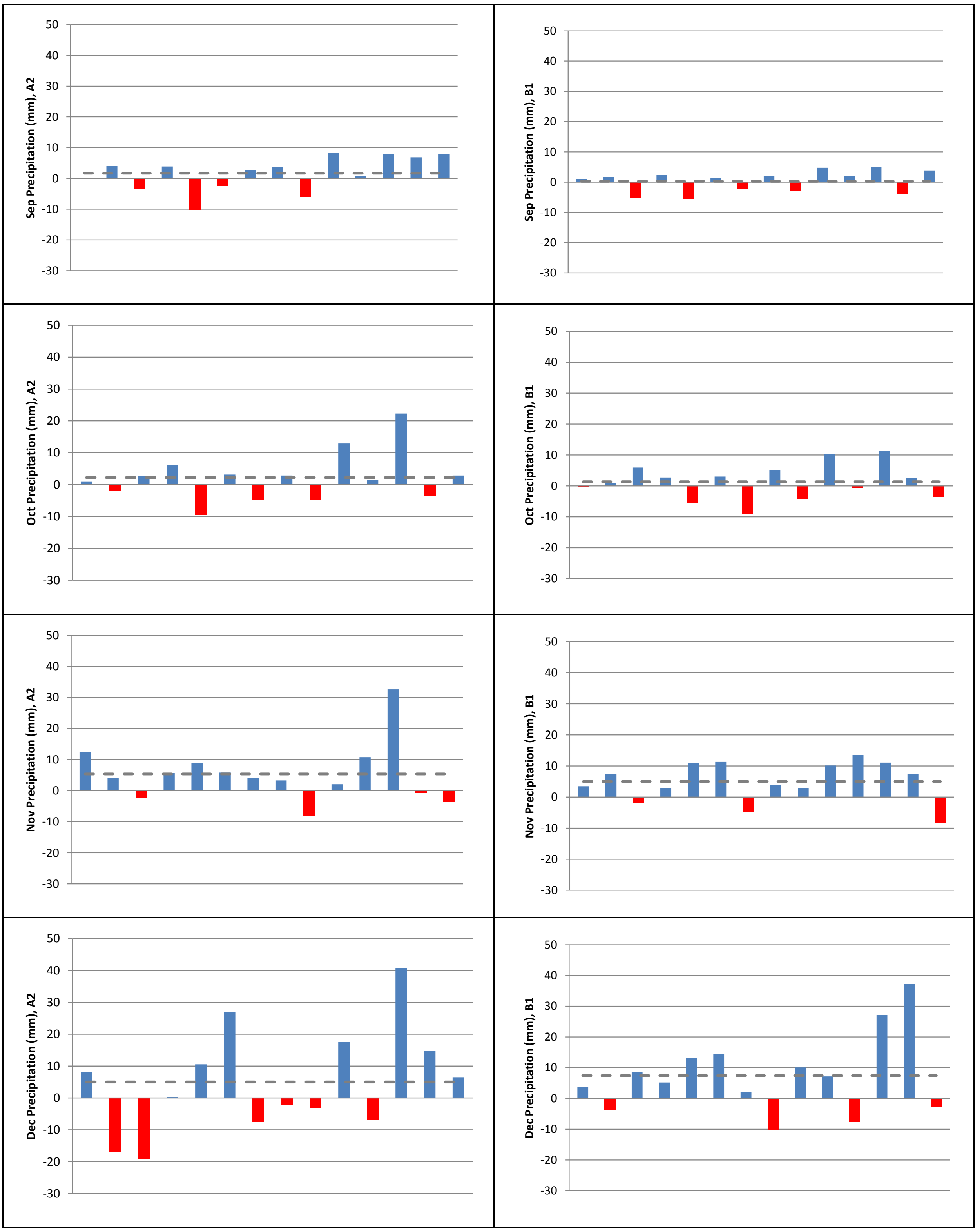
20
10
0
-10
-20
-30


Sep Precipitation (mm), A2
Sep Precipitation (mm), B1
Oct Precipitation (mm), A2
Oct Precipitation (mm), B1
Nov Precipitation (mm), A2
Nov Precipitation (mm), B1
Dec Precipitation (mm), A2
Dec Precipitation (mm), B1
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