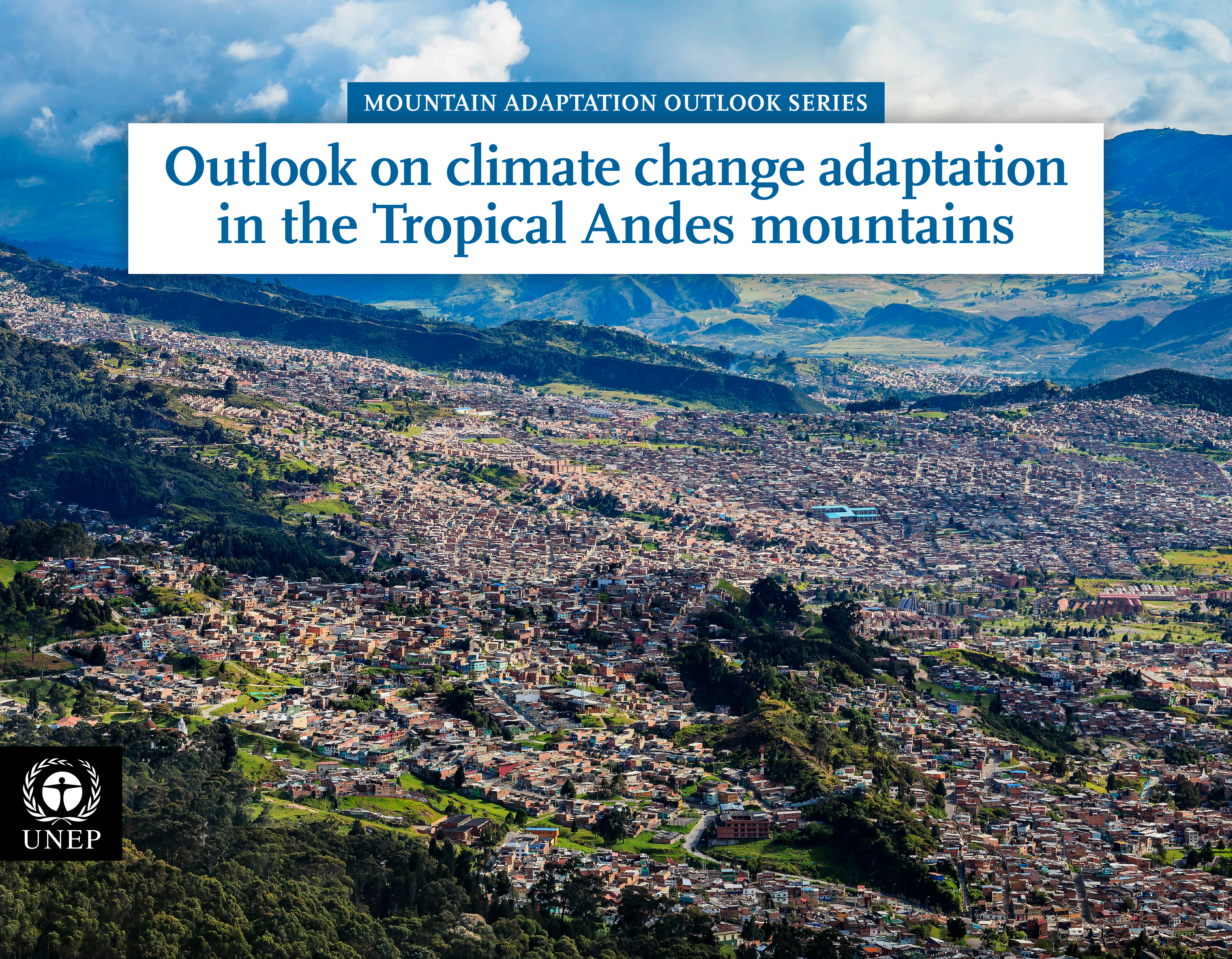
MOUNTAIN ADAPTATION OUTLOOK SERIES

Outlook on climate change adaptation in the Tropical Andes mountains



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Foreword

Mountain ecosystems enrich the lives of over half of the world's population as a source of water, energy, agriculture and other essential goods and services. Unfortunately, while the impact of climate change is accentuated at high altitude, such regions are often on the edge of decision-making, partly due to their isolation, inaccessibility and relative poverty.

That is why the United Nations Environment Programme and GRID-Arendal have partnered on a series of outlook reports about the need for urgent action to protect mountain ecosystems and to mitigate human risk from extreme events. Covering the Western Balkans, Southern Caucasus, Central Asia, (Tropical) Andes and Eastern Africa, the reports assess the effectiveness of existing adaptation policy measures and the extent to which they apply to mountain landscapes, going on to identify critical gaps that must be addressed to meet current and future risks from climate change.

The result of a broad assessment process involving national governments and regional and international experts, the reports offer concrete recommendations for adaptation. This includes sharing regional good practices with the potential for wider replication to improve cost efficiency and adaptation capacity.

While each of the regions is covered in a dedicated report, they all face similar issues. On one hand, rising temperatures and changing precipitation patterns affect a range of mountain ecosystems, including forests, grasslands and lakes. On the other, drivers such as pollution from mining and unsustainable agriculture erode their ability to cope with these changes. The combined impact is increasing vulnerability among the local and downstream populations who depend on mountain ecosystems – especially when they are isolated from markets, services and decision-making institutions.

By the end of this century, the coldest years in the Tropical Andes Mountains will be warmer than the warmest years to which humans and other species have adapted so far. A vast variety of ecosystems are found in these mountains, including the Amazon basin, snow-capped peaks and more arid areas like the Atacama Desert, the world's driest. These support the lives of tens of millions of people, so cooperation and information sharing among Andean countries are crucial for the health of these ecosystems, which is why assistance from the respective governments has been much appreciated in creating this report.

We hope that this report will serve as a practical companion for local, regional and national policy makers seeking to protect fragile mountain ecosystems and the people who depend on them.

Achim Steiner
UNEP Executive Director and Under-Secretary-General of the United Nations

H.E. Andrä Rupprechter
Austrian Federal Minister of Agriculture, Forestry, Environment and Water Management

Executive summary

The Tropical Andes are the home to many diverse communities, from remote farming villages to large urban centres and capitals, such as Merida, Bogotá, Quito, Cusco, El Alto and La Paz. In total, about 60 million people live at between 1,000 and 4,500 metres (Cuesta, 2012). The region has a tropical climate, with little seasonal variation in temperatures. However, there is strong seasonality of precipitation, in the Peruvian Andes in particular. In Colombia and Venezuela, the Andes are generally more humid, while the Altiplano and the Bolivian Andes are drier.

The Tropical Andes will experience some of the most drastic impacts of climate changes in South America. By the year 2100, the coldest years in the Tropical Andes Mountains will be warmer than the warmest years to which humans and other species have adapted so far. Different climate models all indicate warming everywhere, but there is far greater uncertainty when it comes to projections of precipitation and seasonality (Magrin et al. 2014). However, the general trend across the region is that precipitation will increase in the already wet north-west and decrease in the drier Altiplano area and north-east. The rainy season in the Altiplano area is already becoming more concentrated, and the dry season longer.

Farmer, Peru

The Tropical Andes are among the world's biodiversity hotspots most vulnerable to climate change (Malcolm et al., 2006). These mountains contain a wide spectrum of microclimates harbouring unique diversity of ecosystems. Glaciers, high mountain grasslands, mountain forests, rivers, lakes and wetlands provide essential services to society. Therefore, damage from climate change to these ecosystems can consequently harm society. If they are to adapt successfully to climate change, mountain ecosystem services and mountain communities must be recognized and protected.

Key risks from climate change

Change in the precipitation regime will have serious implications for the provision of water for drinking, sanitation, agriculture, energy and industry. Meanwhile, temperature increase will alter the biochemical composition of soil and vegetation, thereby changing its capacity to regulate water flows. Extreme events, albeit not caused by climate change alone, will further reduce the capacity of soil and vegetation to prevent landslides. Glacier melt can – in some cases – release heavy metals into water flows, which can pose health risks for those using the water. The increase and concentration of the demand for water and other resources will be amplified by population growth and urbanization.

Water availability is essential to all key economic activities in the Tropical Andes, especially hydropower, which generates the majority of electricity in the region. Mining is another key economic activity in the area, and relies heavily on water resources. In areas where water is becoming scarce, inclusive management systems are necessary to prevent conflict between stakeholders.

Agriculture is among the most important subsistence and economic activities in the Tropical Andes, and one of the sectors most affected by climate change. Tubers, such as potatoes and oca, are particularly vulnerable to warming. As the mountains become warmer, crops need to be moved to higher elevations, often with negative consequences for pastoralists and biodiversity. Warming is also threatening high mountain grasslands, which are particularly important for pastoral communities and water regulation (López-i-Gelats et al., 2015).

Agricultural problems affect some of the poorest and most vulnerable to food insecurity, with substantial negative effects on human health. Furthermore, insects and vector-borne diseases have moved higher as the climate has warmed (Siraj et al., 2014). Malaria, dengue fever and other diseases will therefore become more prominent in the mountains.

Extreme climatic events are predicted to increase in strength and can in turn cause floods, droughts and landslides. These events have the potential to cause enormous harm to humans, infrastructure and the environment. Socioeconomic indicators determine to a significant degree the outcome of such extreme events for different social groups. For example, poor people living in slums on the steep hillsides of Andean cities are more vulnerable to landslides.

Key findings

Mountain communities in the Tropical Andes are particularly vulnerable and exposed to climate hazards, partly due to their disproportionate poverty and the specific features of mountain environments. For example, geographic inaccessibility affects all industries and increases the costs of hazardous events and adaptation policies. Furthermore, remote mountain areas are often under-prioritized by central governments. Adaptation targeted towards mountain-specific environments is currently underdeveloped, despite being necessary to avoiding the abovementioned risks.

Because of the complex topography in mountainous regions, available climate models are often too coarse to provide precise and less ambiguous projections at the local level. This adds uncertainty to the development of adaptation policies, which are crucial to facing climate hazards both in the mountains and in the lowlands. There is also a lack of mountain-specific

Llamas, Altiplano, Bolivia

Nor Yauyos-Cochas Landscape Reserve, Peru data, and knowledge on how climate change affects social and biological systems, which both are key to developing and implementing effective adaptation strategies. Furthermore, insufficient technical capacity on mountains and adaptation is another barrier to successful policy development and implementation, especially at the sub-national government levels.

Since the impact of climate change occurs over decades and centuries, adaptation policies should ideally be based on long-term observations in combination with projections. However, current institutional designs favour actions with short-term gain. Too often stakeholders are forced to implement reactive policies instead of more cost-effective preventive action. A long-term perspective towards adaptation also involves the development of indicators to measure success and failure in order to improve policies and strategies.

The lack of technical knowledge and capacity on climate change issues that is prevalent among local stakeholders hinders their ability to adapt to changes. This could partly explain the lack of implementation of existing adaptation policies in mountain communities. Furthermore, effective adaptation calls for the coordination of climate change adaptation across policy sectors and places, but weak institutions currently hinder this. There are, however, some existing policy frameworks (e.g. for Risk Management and for Integrated Watershed Management) that, despite not having been created under the climate change label, could easily be used for adaptation purposes and have a complete set of policy instruments.

Problems caused by climate change in the mountains are often transboundary due to their importance in terms of hydrology, the location of basins and the continuation of social and biological systems. International cooperation and coordination on mountain policy could increase adaptive capacity. The tropical Andean countries share many challenges and opportunities, which could favour mutual cooperation and benefits, yet the lack of sharing of information and practical experiences between countries in the region hinders the effective development and implementation of adaptation policies.


Wax palms in Cocora valley, Colombia

Another barrier is the lack of effective participation of women and indigenous people from mountain communities and the lack of inclusion of traditional knowledge in the design and implementation of mountain adaptation policies. The highest numbers of indigenous people in the countries live in the high sierra in central Peru and in the Altiplano. Thriving in some of the world's most difficult environments demonstrates ingenuity and adaptability, yet these capacities are currently underutilized by society due to poverty, sexism and ethnic discrimination. Adaptation measures should build on traditional knowledge wherever available and involve women, indigenous people and vulnerable groups in their planning and implementation.

Recommendations

Monitoring and research

1. Increase the number of hydro-meteorological measurement stations and maintain existing stations to ensure long-term observations and accurate local projections in mountain areas. Efforts to maintain and expand on the existing hydro-meteorological measurement infrastructure would reduce costs of adaptation policies by allowing targeted and efficient measures to be implemented. More funding should be awarded to initiatives such as the Initiative on Hydrological Monitoring of Andean Ecosystems (iMHEA), which currently has more than 20 monitoring sites to respond to specific hydrological concerns of the communities and local authorities.

2. Fund and promote more research on mountain-specific impacts of climate change on social and biological systems; this is necessary for more efficient adaptation action. Particular attention should be paid to the locally specific challenges in the various settings. National data should be disaggregated geographically, to allow researchers to understand the different adaptation needs in different parts of countries. Enhance the monitoring of mountain-specific biodiversity, such as through the Global Observation Research Initiative in Alpine Environments (GLORIA-Andes) adapted for the Andes and the Andean Forest Monitoring Network.

Key risk sectors

3. Address key risks threatening water resources, land resources, loss of biodiversity and ecosystems, food security and health. Mountain communities are particularly vulnerable and exposed to climate hazards. Policies addressing food and water availability in these communities are important to prevent poverty and associated ills. Water resources provided by mountains are also crucial to the vast majority of the population living downstream. There is no one-size-fits-all adaptation strategy possible for the entire Tropical Andes; hence the need for both mountain-specific adaptation measures relevant at the local level and specific adaptation plans for each different setting/case. Prudent water management and the development of sustainable water storage solutions should be considered.

4. Implement Ecosystem-based Adaptation (EbA) measures. Mountain ecosystems are threatened not only by climate change but also by other stressors, including pollution and changes to land use. To successfully combine economic development with preservation of the ecosystems in vulnerable mountain communities, it is important to strengthen and properly manage ecosystems, and sustainably increase the benefits gained by society. EbA encompasses a range of low-cost options that promote the sustainable use of natural resources while planning for and adapting to changing climate conditions. EbA can benefit mountain communities as well as communities in downstream areas.

5. Expand measures to prevent and manage extreme events driven by climate change. The design of tools, mechanisms and technologies to address climate-driven events (such as floods or wildfires) must be forward-looking and preventive in nature to increase the resilience of people, ecosystems and infrastructure. The development of early warning systems would be very valuable to reducing casualties, especially in the case of flooding. In some cases, it would be beneficial to use the policy instruments of other frameworks (e.g. those of Risk Management) for climate change adaptation purposes.

Governance

6. Move from reactive to preventive action. A long-term approach focused on prevention is needed to adapt to climate change. Many effects to which society must adapt occur over decades and centuries. Efficient adaptation must acknowledge where long-term preventive measures are preferable to short-term reactive measures, and efforts must be made to ensure continuity both in policy as well as policy-implementing institutions. The institutional basis for long-term monitoring and observations should also be guaranteed.

7. Promote Result-Based Management. Complementary policy instruments are required to allow policies to be implemented: policy alone is not enough. Adaptation policies should be designed with inbuilt indicators and mechanisms to measure their degree of implementation success, effectiveness and failure. Policy monitoring and evaluation is especially important in remote areas and in areas where there is little prior experience. Such measures are central to a long-term approach to adaptation action.

8. Enhance technical capacity on climate change adaptation. Climate change affects all aspects of society and government. To reach the goals of climate change adaptation, it is therefore important that decision makers and implementers at all levels are educated about climate science and adaptation policy. This could be advanced by including information about climate change adaptation in the training of government actors at all scales, from central agencies to local governments - especially within mountain areas. Awareness-raising is generally valuable to ensuring that local people, private companies and governments work towards shared goals in climate change adaptation.

9. Build from existing traditional knowledge and strengthen women's role. Andean mountain communities have been dealing with an adverse and changing environment since they first colonized the mountains more than 10,000 years ago. Their experiences should be used for local adaptation action and their knowledge to complement current research. The inclusion of traditional knowledge in the design and implementation of mountain adaptation policies has proved successful and should be further encouraged. Women have a profound knowledge of their environment and often play a greater role than men in the management of natural resources. Through their experiences, responsibilities and strength, women are a primary resource for adaptation and their roles should be strengthened by government.

Regional cooperation

10. Create an Andean data-sharing platform for adaptation. As the tropical Andean countries share many challenges and opportunities in the mountains due to climate change, there is potential for mutual benefit. Both natural and social scientific research and measurements, as well as lessons learned from implemented adaptation policies, should be shared to reduce costs, improve all countries' adaptive capacity, and avoid the unnecessary duplication of research, policy efforts and other measures. Facilitating interdisciplinary discussions among experts on mountains and climate change could be an important part of the knowledge-sharing process.

11. Improve coordination between Andean countries on sustainable development in the mountains. International cooperation and coordination on mountain policy would be of mutual benefit to all Andean countries in order to strengthen their adaptive capacity and jointly take advantage of opportunities. The benefits of an Andean data-sharing platform could be further enhanced by regional coordination on the establishment and standardization of indicators and monitoring systems. Regional coordination could also ensure demand-driven research and monitoring. Mutual commitments in the region on adaptation policies, including joint objectives and programmatic priorities, could also facilitate a long-term approach.

Introduction

Mountains are unique and threatened systems where changes due to climate change are among the best-demonstrated. The higher the mountains, the more temperature-sensitive these regions are, and often extreme impact events such as glacier lake outburst floods – due to glacier recession and subsequent formation of unstable lakes – can be directly attributed to the effects of long-term warming.

In this outlook, mountain environments are areas with an elevation and slope angles that meet the UNEP (2002) definition.[1] The Tropical Andes region is the area of the Andean Mountain range from their northernmost point at 11°N in Colombia until 23°S on the southern border of Bolivia (Cuesta, 2012). This definition is based on national borders since the assessment focuses on policy instruments. However, the tropical mountain environment stretches until 27°S in the north-east of Argentina (Ibid.). The Tropical Andes pass through five countries: Venezuela, Colombia, Ecuador, Peru and Bolivia.

The Andes are approximately 7,000 km long and are the world's longest terrestrial mountain range, running parallel along the entire west coast of South America. It is the second highest after the Hindu Kush-Himalaya mountain system. From northern Chile and Argentina, the Andes widen out to 700 km, with high valleys and a high plateau called the Altiplano. This area marks the start of the Tropical Andes and dominates Bolivia and southern Peru. Wide, high mountain valleys are prevalent in Peru before the range narrows from Ecuador and into Colombia. Valleys are generally parallel to the range. The range splits into three branches, one of which reaches Venezuela.

The Andes mountain range has a profound impact on the climate and environment of the South American continent. The range acts as a barrier between the coast to the west and the extremely humid Amazon basin to the east. Moisture from the rainforest is not able to move across the range, thereby creating the continent's unique environment. The climate also changes drastically throughout the region and is greatly influenced by latitude and altitude, giving way to the world's driest desert, Atacama on the western slopes of the Central Andes and rainforests along the eastern foothills.

The countries of the Tropical Andes are all parties to the United Nations Framework Convention on Climate Change (UNFCCC) as Non-Annex I countries. The Convention serves as an important platform for international action on climate change mitigation and adaptation. Most of the Andean countries (except Venezuela) have announced Intended Nationally Determined Contributions (INDCs) as their national commitments to mitigate climate change. These targets will be reached by mobilizing their own resources and also by requesting donor support for their climate actions. The impacts of climate change, however, continue to grow and are felt throughout the entire region. Rising temperatures and changing precipitation patterns are leading to more frequent and intense weather events, clearly highlighting the need for immediate adaptation measures.

Against this background, this outlook has been prepared by UNEP, its collaborating centre GRID-Arendal and the Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), involving a number of national and international experts. This outlook synthesizes and analyses existing climate change adaptation responses in the mountainous regions of the Tropical Andes and the extent to which they address key climate risks.

In doing so, the authors and contributors have followed the definitions set out in the IPCC's Fifth Assessment Report (Oppenheimer et al., 2014). The outlook has taken three main steps: 1) the determination of the main climate hazards, vulnerabilities and key risks. Once identified, these key risks are considered priorities to be addressed by adaptation policy; 2) the identification of existing policies and strategies for climate change adaptation, and 3) the analysis of the extent to which these existing measures can respond to the key risks (gap analysis).

Risks are considered key if there is a combination of vulnerability and likelihood of exposure to hazards (Oppenheimer et al., 2014). Climate hazards are the physical events or trends resulting from climate change that can threaten society or natural systems. For example, there is a high likelihood of increased temperatures in the high mountains, which will have negative consequences for local farmers. These farmers are generally vulnerable (predisposed to harm) due to their extreme environment, remoteness from services and markets, poverty and other social inequalities. The resulting high risk of decreased income and malnutrition is therefore considered to be key. This methodology is applied to describe the key risks to climate change in the Tropical Andes Mountains.

This synthesis publication has used the following information sources: peer-reviewed journal articles; grey literature sources (e.g. those available from NGOs and international organizations); government reports including the National Communications submitted by countries to the UNFCCC); and extensive expert input through stakeholder consultations.

Socioeconomic background

The risk of climate change to society varies both with the magnitude of the expected climate hazards and with the society's exposure and vulnerability to these hazards. Vulnerability arises both from the sensitivity and susceptibility to harm, and from the limited capacity to cope and adapt. Many social factors such as poverty, gender discrimination and education levels are relevant to determine degrees of vulnerability. People with limited funds, access to government institutions or social safety nets have fewer adaptation options and are more likely to suffer from the impact of climate change. The high Andes, particularly in Ecuador, Peru and Bolivia, have some of the most widespread poverty in South America. Furthermore, poverty-related problems in the mountains are often exacerbated by remoteness from markets and services. The effects of climate change could therefore exacerbate existing social inequality and suffering, including gender, ethnic and economic inequalities, all of which are significant in the Tropical Andes region.

Despite significant economic growth and other improvements achieved in the region during the late 1990s and the first decade of 2000, these countries face other common issues, including poverty, poor literacy and health care. Weak governing institutions and high levels of corruption also limit sustainable development and adaptive capacity in the region. Furthermore, illegal activities, such as the drug-industry, environmental crime and illegal mining, place additional stress on people and the environment, which increases their vulnerability. A new wave of extractive industries in the Andean region (e.g. large-scale, open pit mining) also poses challenges for local people and high elevation systems, including on water resources, livelihoods and social relationships (Bebbington & Bury, 2009).

While several governmental policies have favoured rural and indigenous communities in Bolivia over the last decade, discrimination of ethnic minorities still constitutes a significant barrier to adaptation. The highest numbers of indigenous people in the Tropical Andes live on the steep valleys of the high sierra in central Peru and in the Altiplano. Among the many and diverse indigenous groups in the mountains, Quechua and Aymara are the largest. A significant proportion of these groups are small-scale farmers, who are particularly vulnerable to climate change. However, traditional ecological knowledge is a significant capacity for adaptation (Berkes et al., 2000). Thriving in some of the world's most difficult environments demonstrates ingenuity and adaptability; capacities that are underutilized by society due to social structures, including poverty and ethnic discrimination. For example, a study showed that indigenous people living in the northern part of the Altiplano are particularly vulnerable to climate change due to poverty and lack of education (Valdivia et al., 2013). Furthermore, for many people, mountains and glaciers also have a deep cultural and religious significance.

Due to sexist social structures, women often have fewer tools available for adaptation, such as access to education, financial credit and participation in local and national governance. Sexism and other forms of discrimination, such as racism and poverty, combine to make many women in the high Andes particularly vulnerable to climate change. In a study on particular Aymara communities in the Altiplano, about 30 per cent of women and 10 per cent of men did not speak Spanish (Valdivia et al., 2013). This was partly due to unequal educational levels and access to external services. However, recent years have seen an improvement, as women become both more educated and more included in local decision-making. To succeed, adaptation policies must target such social barriers by considering the needs and opinions of women, especially in areas with high levels of emigration.

Some social causes of vulnerability not only increase the vulnerability of the underprivileged, but also enhance the capacity of the privileged. For example, the overrepresentation of men in parliament could mean that their issues are given disproportional weight; and the entitlement of the rich is enhancing their adaptive capacity by reducing that of the poor. The representation of women in parliament differs substantially along the range, from Bolivia at 52 per cent and Ecuador at 42 per cent to the less representative 17 per cent in Venezuela, 20 per cent in Colombia, and 22 per cent in Peru (World Bank, 2015a).

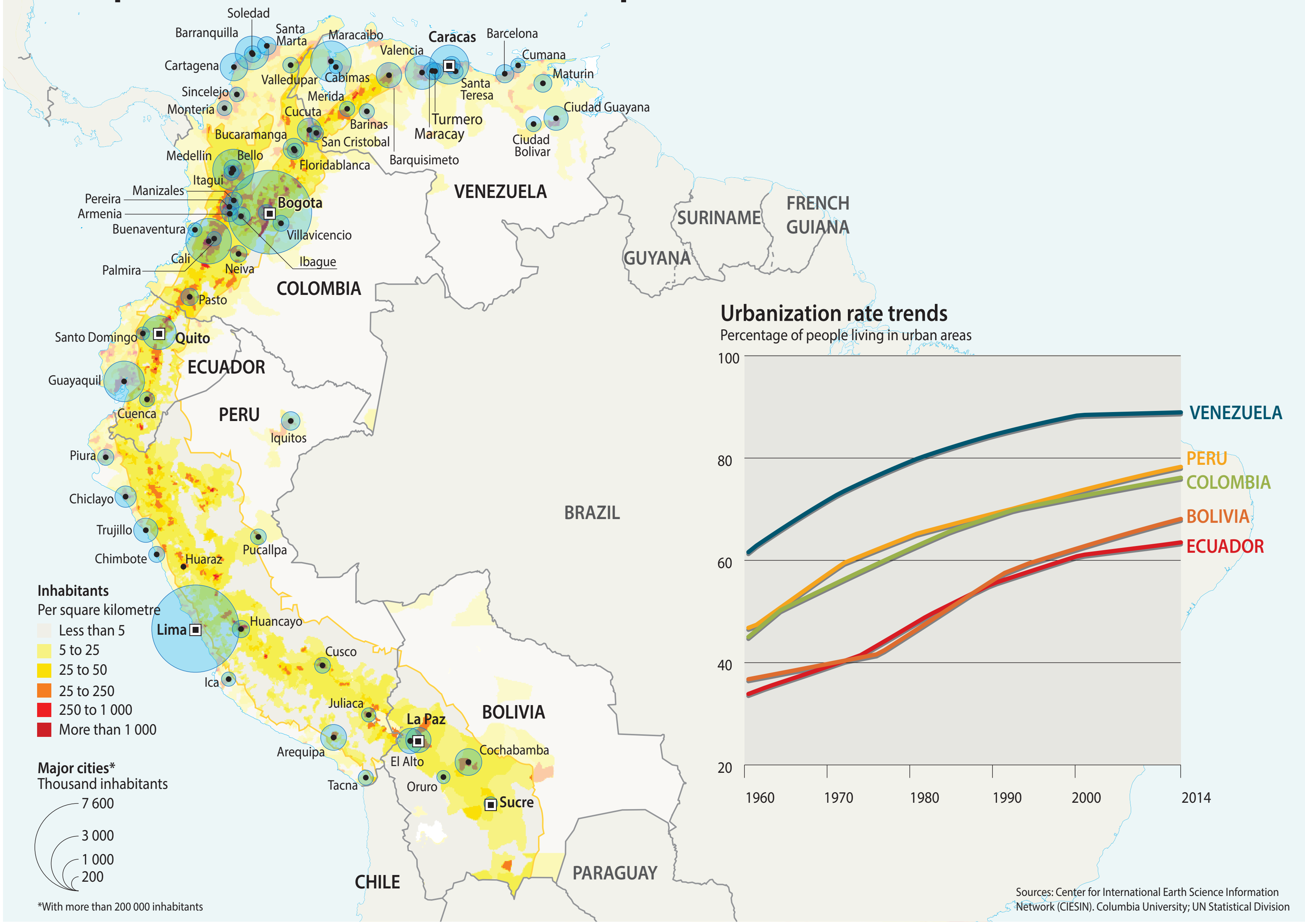
Multiple capitals and large cities are located in the Tropical Andes. Bogotá is the most populated, with approximately 9 million inhabitants. Other big cities include Medellín, Quito, Cusco, El Alto and La Paz. Sixty million people live on the range at between 1,000 and 4,500 m.a.s.l. About half of these live in Colombia. Bolivia is the country with the highest percentage of its population living in the mountains (90 per cent). Population growth and international and internal migration are key factors in determining vulnerability to climate change. Migration (including temporary) often constitutes an essential element of adaptation for families and communities. Meanwhile, changes in land use, population growth and unsustainable exploitation of resources are, in combination with climate change, threatening the capacity of the Andes Mountains to provide ecosystem services needed in both the high- and lowlands.

Urbanization and international migration, to both large and smaller cities in the region, affect migrants and those left behind. Migrants often receive increased wages, improving both their own situation and helping their dependents and community. Remittances from migrants play an important role in providing adaptability and resilience in rural communities, while migration from the mountains reduces strain on vulnerable ecosystems. On the other hand, emigration can erode local institutions and governance arrangements that influence access to resources. Emigration also leaves rural communities with a reduced labour force, and migrants often face significant difficulty establishing themselves in a new area. Dependency relationships with urban centres could also prove problematic if remittance levels were to go down.

All countries in the region have high levels of urbanization and population growth. These trends will significantly increase and concentrate the demand for services and resources, which are already often threatened by climate change, such as water resources and agricultural goods (Buytaert and De Bièvre, 2012). Demographic trends and social challenges must be considered in combination with climate change to develop successful adaptation policies across all policy sectors.

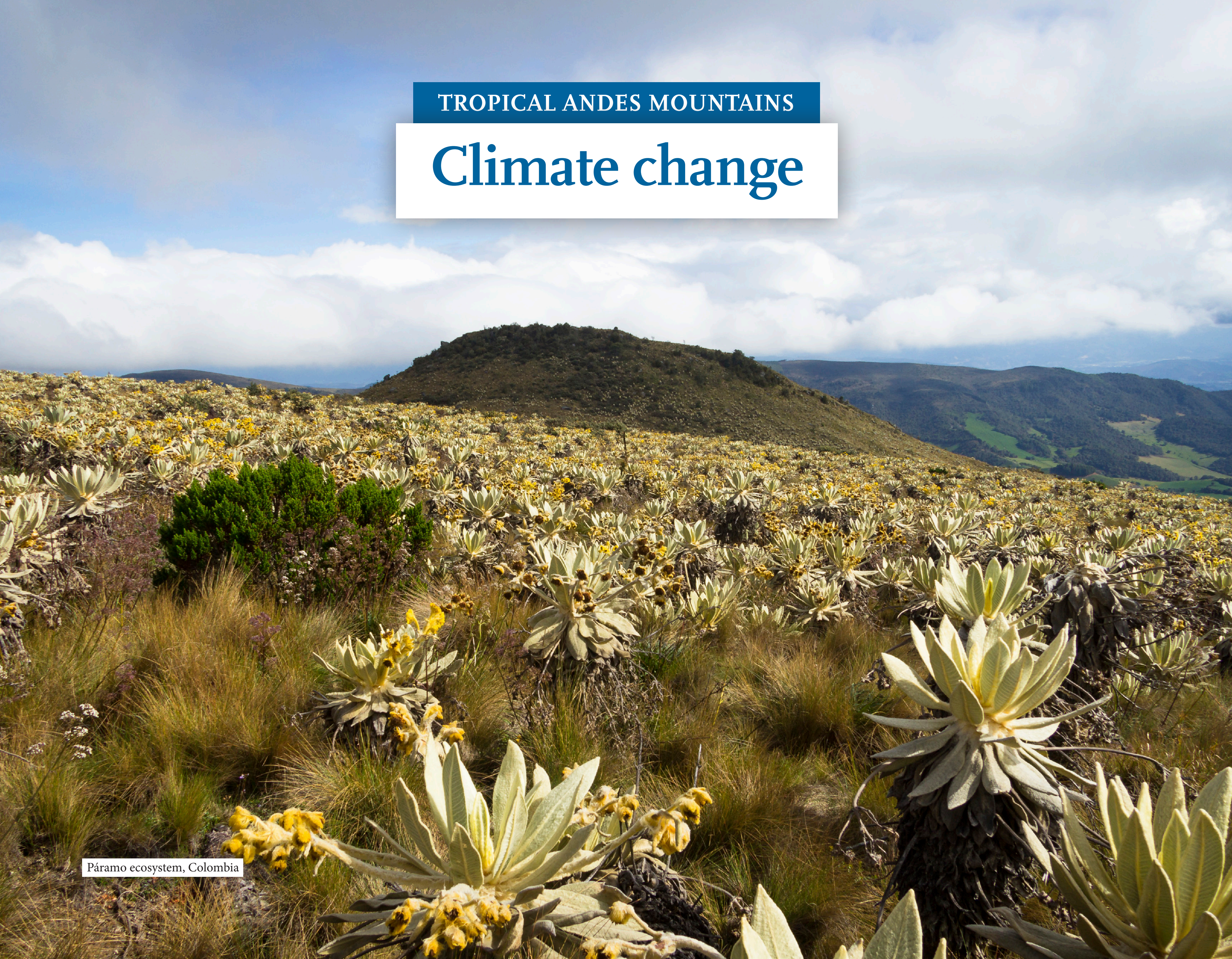
Miraflores, Peru

Population distribution within the Tropical Andes countries



TROPICAL ANDES MOUNTAINS

Climate change



Páramo ecosystem, Colombia

Climate change hazards and trends

Climate hazards are the physical events or trends resulting from climate change that can threaten society or natural systems. For example, increased temperatures, extreme precipitation events, glacial melting and landslides can be climate hazards. The degree to which areas and policy sectors are susceptible to damage from hazards is termed their vulnerability. Vulnerability to climate hazards is dependent on varied characteristics of the society or natural system exposed. This includes the presence of key infrastructure, environmental and socioeconomic factors, as well as governments' and peoples' willingness and capacity to adapt. Hazards become risks when society is both exposed to the hazard and is vulnerable to its effects.

There is uncertainty about both observed and predicted climate change due to insufficient data and the complex topography of the region, which requires a high density of long-term hydro-meteorological measurement stations. This lack of measurements represents a significant barrier in the development of adaptation policies.


Nor Yauyos-Cochas Landscape Reserve, Peru

In the Tropical Andes, projections of future climate change often appear to exacerbate climate events already being observed: wetter areas become wetter, drier areas become drier, leading in turn to more dramatic precipitation events and more dramatic droughts (Magrin et al., 2014). In other areas, projections show that some very dry areas may also become wetter (Hijmans et al., 2005).

Temperature

Numerous studies confirm that the Tropical Andes have undergone significant warming in the last century (Magrin et al., 2014), yet the degree of warming in different locations differs significantly, partly because of the rugged landscape and the increase in warming with increasing elevation. From the information available, some broad trends have been observed. Mean warming of about 0.7-1°C was recorded in the Tropical Andes in the latter half of the 1900s. From 1939 to 2006, the increase was about 0.1°C per decade (Vuille et al., 2008). The rate of warming accelerated in later years: from 1980 to 2005 the rate of warming was about 0.33°C per decade (Barry, 2005). Only two out of the 20 last years have been below the average recorded from 1961 to 1990 (Vuille et al., 2008). However, the increase varies greatly within the region and at the local level. The highest warming has been observed in parts of the Colombian Andes (Ruiz et al., 2008) and in the Central Andes of Peru and the Altiplano (Valdivia et al., 2013; Vuille, 2013).

Mindo Nambillo Forest Reserve, Ecuador

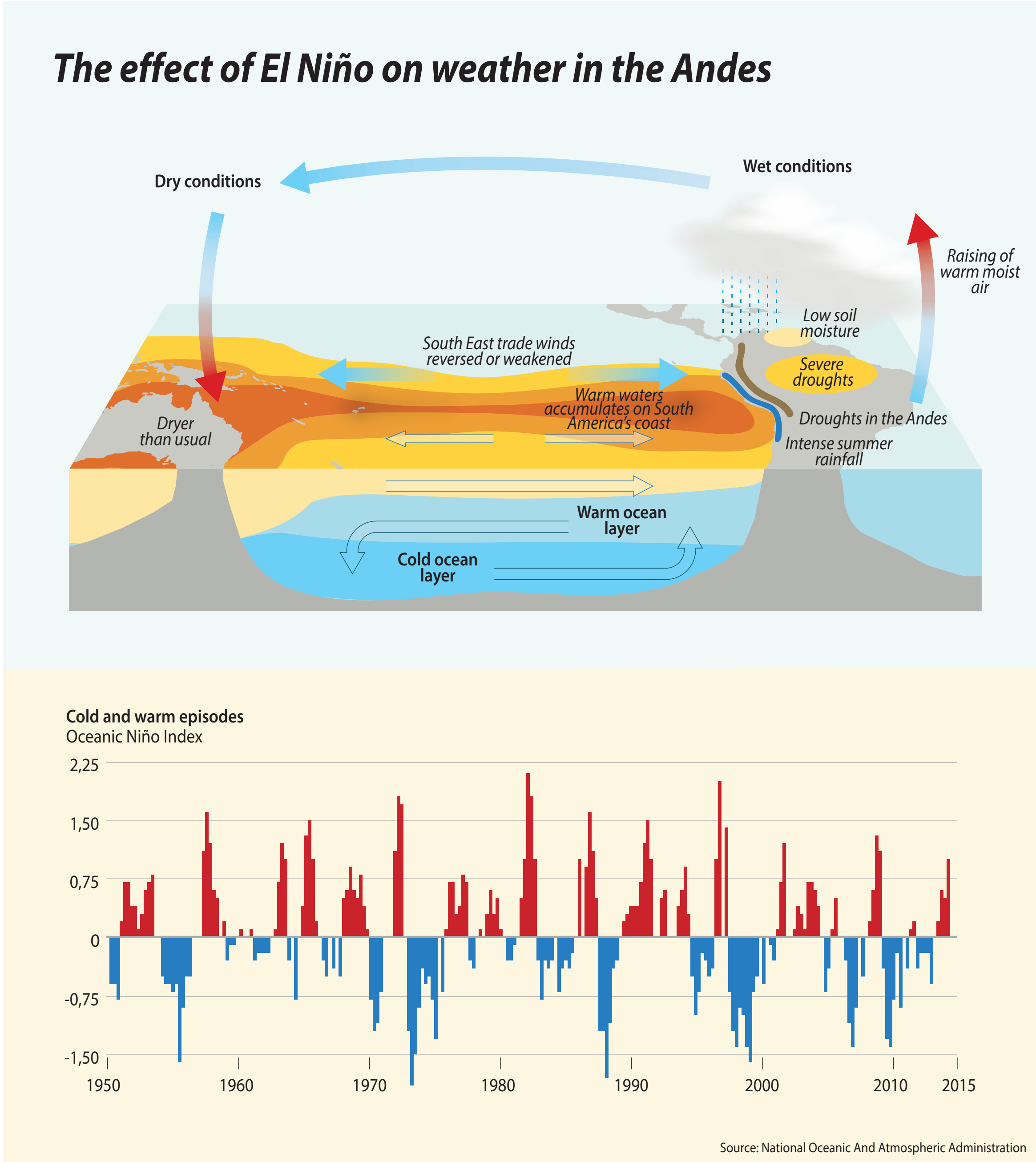
Precipitation

Rainfall varies substantially with time and location in the Tropical Andes. It is therefore particularly important to recognize that trends of annual total precipitation in the region do not represent the trends in specific places or times of the year. In the Central Andes, Bolivia and Peru have highly differentiated rainy and dry seasons. Approximately 50 to 80 per cent of the yearly total precipitation falls in the rainy season in the Central Andes (Vuille et al., 2000). In the Altiplano area, more than 60 per cent of precipitation falls in the rainy period (Thibeault, 2010). The northern Andes and surrounding areas are generally more humid and have less seasonally differentiated precipitation.

Changes in total annual precipitation over the last century in the Tropical Andes have been less clear overall than changes in temperature, as the rugged topography of the Andes influences the generalizability of precipitation measurements. Most importantly though, the internal variability (such as year-to-year differences) is very large for precipitation, and therefore any climate change signal must be very strong to be visible in this variability (and it isn't). The trends observed are that precipitation has increased in the inner tropics but decreased in the outer tropics (Magrin et al., 2014). Bolivia and southern Peru have the biggest problems with water shortages. The north-western coast of Peru and the hyper-humid Ecuadorian Choco have experienced an increase in precipitation, while the drier Altiplano area has observed a decrease.

Changing seasonality is perhaps the most important change in precipitation patterns observed so far. In the south in particular, there are indications that the rainy season has become more intense and more seasonally concentrated, while the dry season has become longer (Seth et al., 2010).

Precipitation in the Tropical Andes also has great yearly and decadal variation. This is mainly due to the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) climate systems. It is important to remember that ENSO events have spatially and temporally different and asynchronous effects in different parts of the Tropical Andes. Along the lower slopes of the Tropical Andes, El Niño events generally cause heavy rainfall. However, this rainfall does not reach above 2000 m.a.s.l. In fact, El Niño events generally lead to warm and dry weather in the high elevations of the Tropical Andes and along the eastern slopes. La Niña events, on the contrary, generally cause cold and wet conditions in the high mountains. In the Central Andes, this influence is less significant and less uniform (Chevallier et al., 2010).



Projections

The clearest trend in the Tropical Andes is the increase in air temperature. The Tropical Andes are expected to experience some of the most drastic change in climate in South America (Urrutia and Vuille, 2009; Hijmans et al., 2005). However, projections of future climate change using different models in the Tropical Andes are highly uncertain, particularly for rainfall. For temperature there is a higher degree of agreement between the different models. This is partly because the topography of the region is too rugged to be captured by low-resolution global models. In addition, there is not a high density of meteorological stations, which would be needed for validating and calibrating climate models. Climate models, therefore, differ more from observations in the Andes than in other parts of South America. This is true for both models on temperature and precipitation projections. While especially in short-term projections internal variability ("noise") of the modelled processes is often larger than any trends, for longer time scales the signal-to-noise ratio improves and allows for deriving robust trends (in particular for temperature).

El Niño and la Niña events have strong, though varying, effects on both precipitation and temperature in South America and the Tropical Andes. The overall frequency of El Niño events is expected to decrease slightly. Extreme El Niño events, however, are in recent studies predicted to increase in frequency due to global warming (Cai et al., 2014). El Niño events are also associated with extremely warm years, thereby adding to the predicted warming.

Temperature

Future warming is predicted to be highest in the mountains (Urrutia and Vuille, 2009; Bradley et al., 2004). In all medium emission scenarios, by 2100 the coldest years in the Tropical Andes Mountains will be significantly warmer than the warmest years people have adapted to over the centuries (Vuille, 2013). This means that by 2100, temperatures will be unprecedented for current social and ecological systems. It is important to remember that climate variability, such as by ENSO events, will also affect how climate change manifests at particular times in the future.

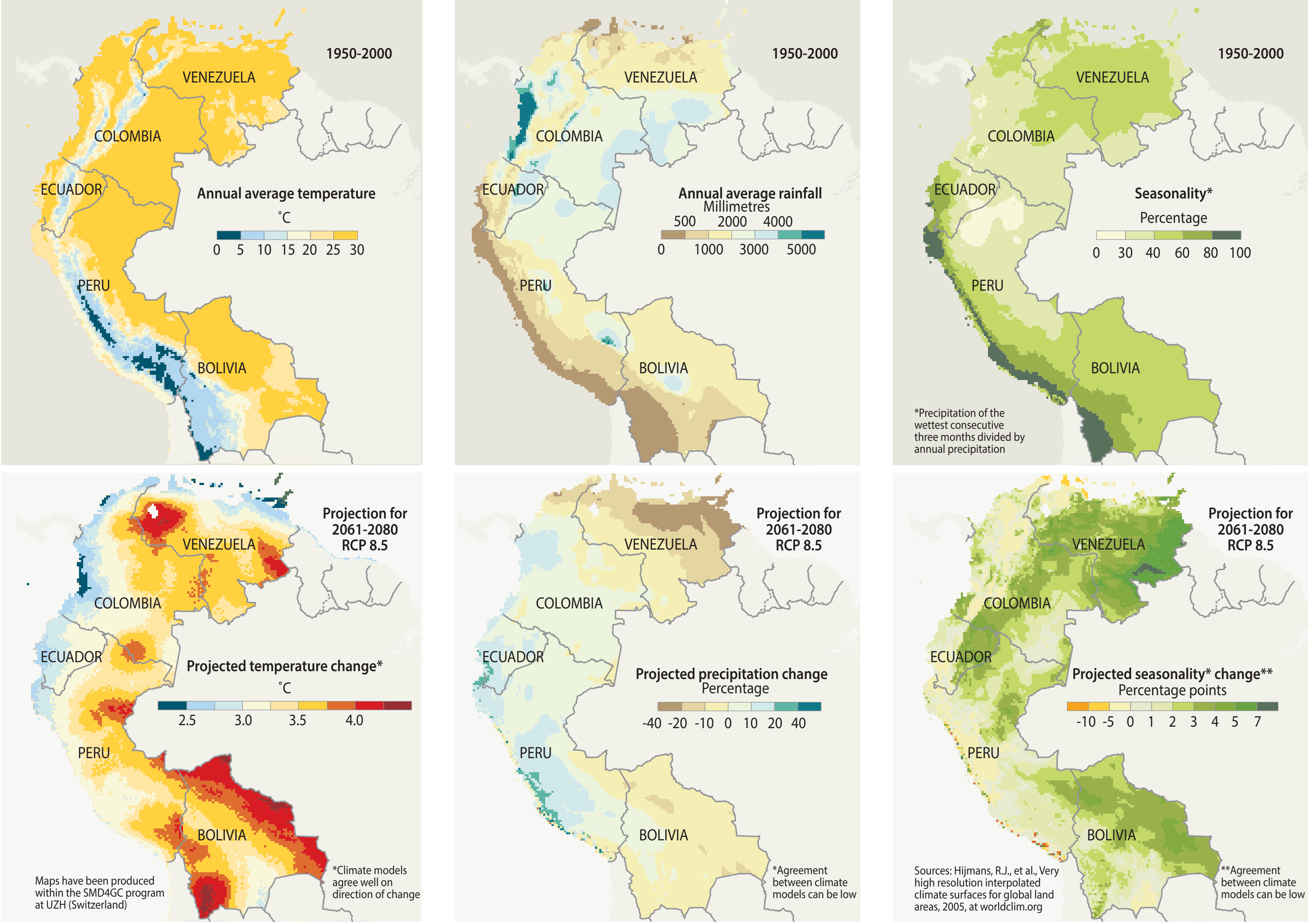
In a high-emission scenario (RCP8.5), temperatures in the Tropical Andes are expected to increase by 4.5-5°C by 2100 (Bradley et al., 2009; Hijmans et al., 2005). It should be noted that models vary greatly in their projections for the regions, and are particularly uncertain in mountain regions, but all models agree that temperature will increase (Valdivia et al., 2010). In some models, the Bolivian Altiplano is expected to experience 3-4°C warming (Anderson et al., 2011, Minvielle and Garreaud, 2011). A high-resolution model projects significantly greater warming at higher altitudes, from 3.5°C warming at 500 m to 4.8°C warming above 4,000 m on the western slopes (Urrutia and Vuille, 2009). In low emission scenarios, the expected warming has about half the amplitude. Available models also project a higher frequency of warming than today's average in the years approaching 2100.

Precipitation

Most studies on precipitation focus on changes in total annual precipitation. However, for the Tropical Andes the main change may be in seasonal variability. In southern Peru and Bolivia, for instance, climate models predict more intense and concentrated rainy seasons and longer dry seasons (Seth et al., 2010). However, it is important to recognize the high variance of precipitation patterns within these areas. The expected changes in total annual precipitation are generally low and uncertain in South America as a whole. However, models predict that in a high-emission scenario there will be significant changes for some sub-areas (Magrin et al., 2014). In general, wet areas will get wetter, and dry areas will mostly get drier. The north-western Andes of Colombia, Ecuador and Peru will experience increased rainfall, while a decrease is expected in the north-eastern Andes of Venezuela and Columbia, in southern Peru and in the Bolivian mountains (Vuille et al., 2008; Magrin et al., 2014; Hijmans et al., 2005).

Girl, Peru

Climate change in the Tropical Andes



TROPICAL ANDES MOUNTAINS

Impact of climate change on natural and human systems

Patchwork countryside, Ecuador

Loss of ecosystem functions and biodiversity

Mountain environments provide a wide range of ecosystem services, from the cycling of nutrients, water and greenhouse gases to disease regulation and protection from landslides and floods. The Tropical Andes contain a wide spectrum of microclimates, harbouring a unique diversity of ecosystems, such as glaciers, high mountain grasslands, mountain forests, rivers, lakes and wetlands. The ecosystems in the most tropical parts of the Andes, the north and along the eastern slopes, have particularly diverse and populous wildlife. The whole region is one of the biodiversity hotspots most vulnerable to climate change (Malcolm et al., 2006), partly due to its low inter-annual variability, which means that ecosystems are not adapted to long-term climate variability (Williams and Jackson, 2007). Therefore, many of the expected impacts of climate change will come indirectly through affecting these ecosystems and their services to society.

A biome-based model, using a high-emission scenario, predicts a potential 25 per cent change in ecosystem distribution in the Andes by 2050, based on preferred climatic conditions (Tovar et al., 2013). Glaciers, cloud forests and páramos are most vulnerable to climate change (Young et al., 2011), with the highest relative loss of area being predicted for these ecosystems and tropical mountain forests such as Yungas (Tovar et al., 2013). These losses can be explained by the direct impact of climate change on hydrology, and also by the high altitude of these ecosystems. Their altitude implies difficulty for species to migrate, a high rise in temperature and other factors resulting in fragility. However, this model does not take into account land-use change, which is the most damaging stressor on regional ecosystems (Magrin et al., 2014).

To adapt successfully to climate change, mountain ecosystem services must be recognized and preserved. Climate change, in combination with other stressors such as land-use changes, invasive species, poaching and pollution, puts significant pressure on fragile mountain environments. Reduction of these other stressors will increase the capacity to adapt. Human activities directly determine the landscape in large parts of the Tropical Andes. One study estimates that human activity – in varying degrees – has transformed on average 22 per cent of the area directly (Josse et al., 2009).

Flora in the Altiplano, Bolivia

Vicuñas, Peru

Retreating glaciers

Glaciers, recognized as a good indicator of climate change due to their sensitivity to temperature increase, are already experiencing its drastic effects. Climate change is expected to cause increased melting in the future, especially for tropical glaciers (Rabatel et al., 2013) such as those in the Tropical Andes, which range from about 4,000 to 6,500 m altitude. To date, melting has been most prominent in small and low-lying glaciers. The significant melting of tropical glaciers is possibly due to high radiation and moist tropical climate dynamics (Ibid.). Beyond the direct warming of the glaciers by air temperature, precipitation falling as rain instead of snow contributes to melting by reducing the albedo of the glacier surfaces. El Niño events are also associated with reduction in glacier mass, due to the higher temperature and reduced precipitation (Francou et al., 2003; Jeschke, 2009).

FIGURES

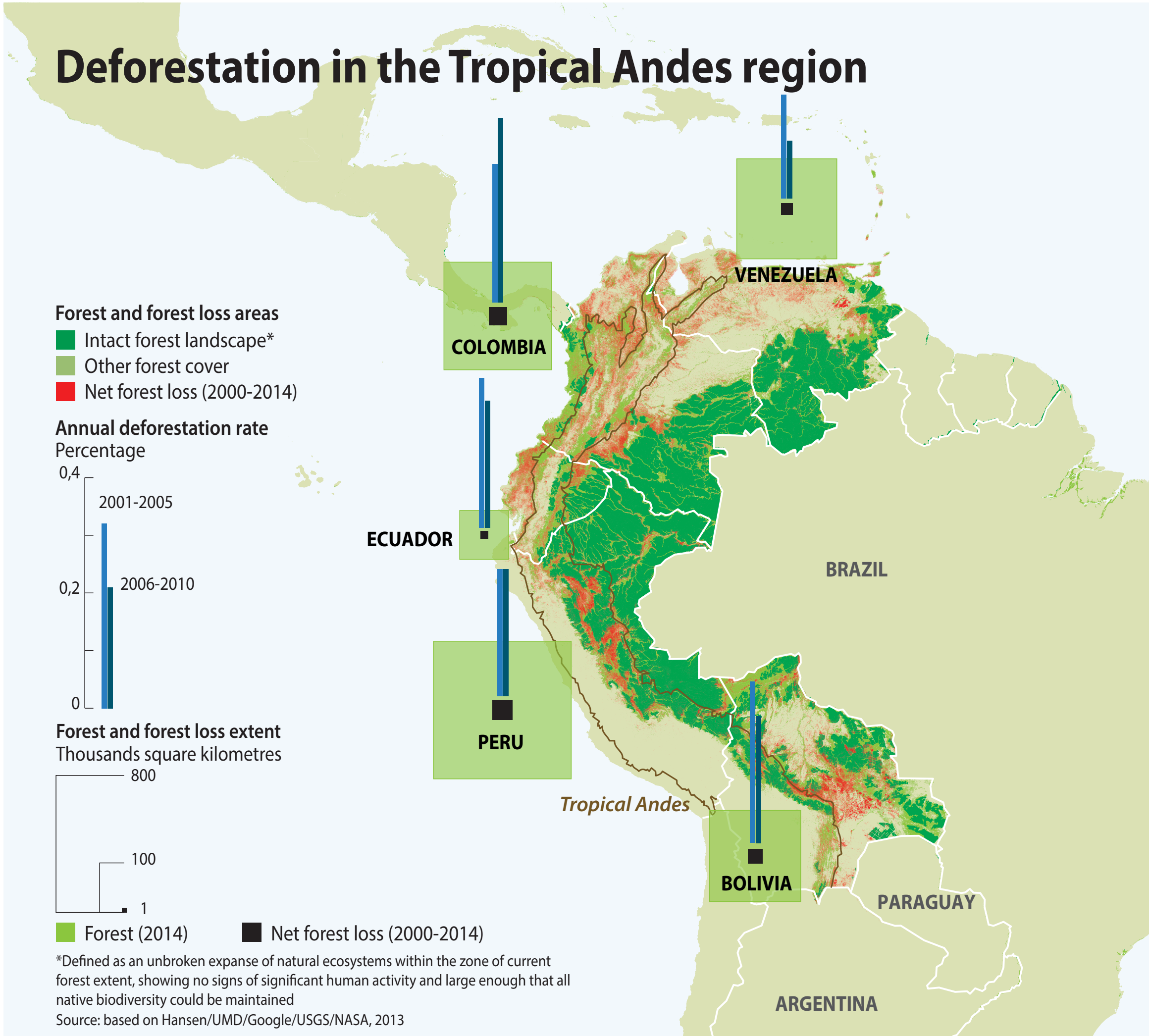
Glaciers in the Tropical Andes

The Andes contains 99 per cent of the world's tropical glaciers (Chevallier et al., 2010). This amounts to 0.8 per cent of the world's glacial area (not including Antarctica) (NCIDS, 2008). The remaining tropical glaciers are located in Africa and New Guinea, with a total area of less than 10 km². The total area of glaciers in the Tropical Andes was 1,920 km² about 10 years ago (Francou and Vincent, 2007), with 71 per cent in Peru, 20 per cent in Bolivia, 4 per cent in Ecuador, and 4 per cent in Colombia-Venezuela (Rabatel et al., 2013). The overall area of glaciers in the Tropical Andes has diminished further since 2007.

Glaciers play an important role in the hydrology of the Andes by storing water in the rainy seasons and releasing it throughout the year. The proportion of glacial meltwater in rivers is substantially higher in the dry season and in dry years (Buytaert et al., forthcoming). This is due to the lack of rain and not because of increased melting in the dry season. Glaciers have a particularly significant effect downstream in rivers that move into arid areas towards the Pacific after leaving the mountains. One extreme example is the Santa River in Peru, which receives water from glaciers on the Cordillera Blanca. On average, the contribution of glacial water in this river is between 4 and 8 per cent (Ibid.). However, in years with little precipitation the contribution can be as high as 80 per cent in the dry season. The compensation effect of glaciers is particularly important in Bolivia and Peru, where most tropical glaciers are located: here, there is the highest difference in seasonal precipitation and annual precipitation totals are low. In the short term in the Tropical Andes, diminishing glaciers cause increased water flow, but in the long term there will be reduced dry season compensation (Vuille 2013), which is mainly important for local ecosystems and mountain communities.

High mountain grass- and wetlands

Grass- and wetlands cover the areas of the high Andes from the treeline and up to the edge of the snow. These unique ecosystems include the neotropical alpine grasslands, known as páramos, dry and wet puna grasslands and other wetlands. Páramos cover the upper part of the northern Tropical Andes and wet punas occupy a similar niche in the Central Andes. These grasslands, containing millions of streams, rivers, lakes, and various kinds of wetlands, are crucial to the hydrology of the mountains, providing water to tens of millions of people downstream. They are also important for biodiversity and provide carbon storage (Myers et al., 2000). Carbon stocks in Andean ecosystems are comparable with those in tropical lowland forests, especially when organic carbon stocks in the soil are considered (Spracklen and Righelato, 2014). Anthropogenic pressure, from agriculture and climate change in particular, threatens the capacity of these ecosystems and their services. Páramos are among the ecosystems most threatened by climate change, with one biome-based model predicting a loss of 31 per cent of páramos by 2050 (Tovar et al., 2013), without including the added threat of land-use change.



Lake Titicaca

Lake Titicaca – Cooler as it becomes drier?

Adaptation policies must be designed to acknowledge the local variation in both hazards from climate change, and the vulnerabilities of local people and ecosystems. Lake Titicaca is the largest lake in South America in terms of volume. Due to its size and depth, it has a substantial effect on the local climate. The immediate areas around the lake today are about 4-5°C warmer and are also wetter than comparable areas at the same altitude. Palaeological records have shown that as water levels of the lake lowered during warm, dry, interglacial periods, a regional cooling effect took place and even reversed the trend towards warming. In a warming world, species are generally expected to migrate upward in order to stay within their optimal temperature range. This has already been observed on tropical mountains (Feeley et al., 2011). However, Lake Titicaca may be an example where such general assumptions do not apply and where the upward migration of forests will be halted abruptly (Bush et al., 2010). However, a reduced Lake Titicaca would have a huge impact on irrigation and agriculture downstream and Lake Titicaca has an impact on the whole endorreic (closed drainage system) Titicaca-Desaguadero-Poopó-Salares watershed.

Tropical mountain forests

With warmer temperatures, ecosystems often respond by moving upslope to colder climates (Feeley and Silman, 2010). This trend has been observed for decades as some species of trees are attempting to out-climb the heat (Feeley et al., 2011). The aforementioned biome-based model predicts that areas currently covered by páramos will become suited to tropical mountain forests (Tovar et al., 2013). The model also predicts a reduction of evergreen forests, in favour of more seasonally dry forests. However, the predicted rate of warming requires forests to migrate by more than 9 m in altitude per year (Feeley and Silman, 2010). This is much lower than observed migration rates and it is likely that most species will lose substantial proportions of their population.

Variance in ability to migrate partly determines the implications of climate change on species and ecosystems. Cloud forests, for example, have been unable to migrate into the high grasslands while being diminished in lower elevations (Rehm and Feeley, 2015). Features of both species themselves and their environment can limit migration. For instance, insurmountable peaks and steep valleys represent migration borders. Land use can also reduce the ability for tropical mountain forests to migrate. Studies show faster upward migration in protected than in non-protected areas (Lutz et al., 2013). However, the rate of migration is still too slow to match the predicted changes in climate.

Lakes and rivers

The aquatic ecosystems of the Tropical Andes include a great number of lakes, rivers and wetlands occupied by fish, microinvertebrates, plankton, algae and plants. The diversity of fish species declines with altitude, while algae and aquatic plants show the greatest diversity above 3,000 m (Maldonado et al., 2011). Lake Titicaca, with its numerous endemic species of fish, plants and algae, is an exception. The highly vulnerable aquatic ecosystems could be an early indicator of climate change in the region. However, few studies exist on the topic. Studies from Europe suggest a substantial decrease of cold-water species in favour of more warm-water species. Rivers and lakes depending on water from vulnerable areas such as páramos and glaciers could experience the largest impact.

Water

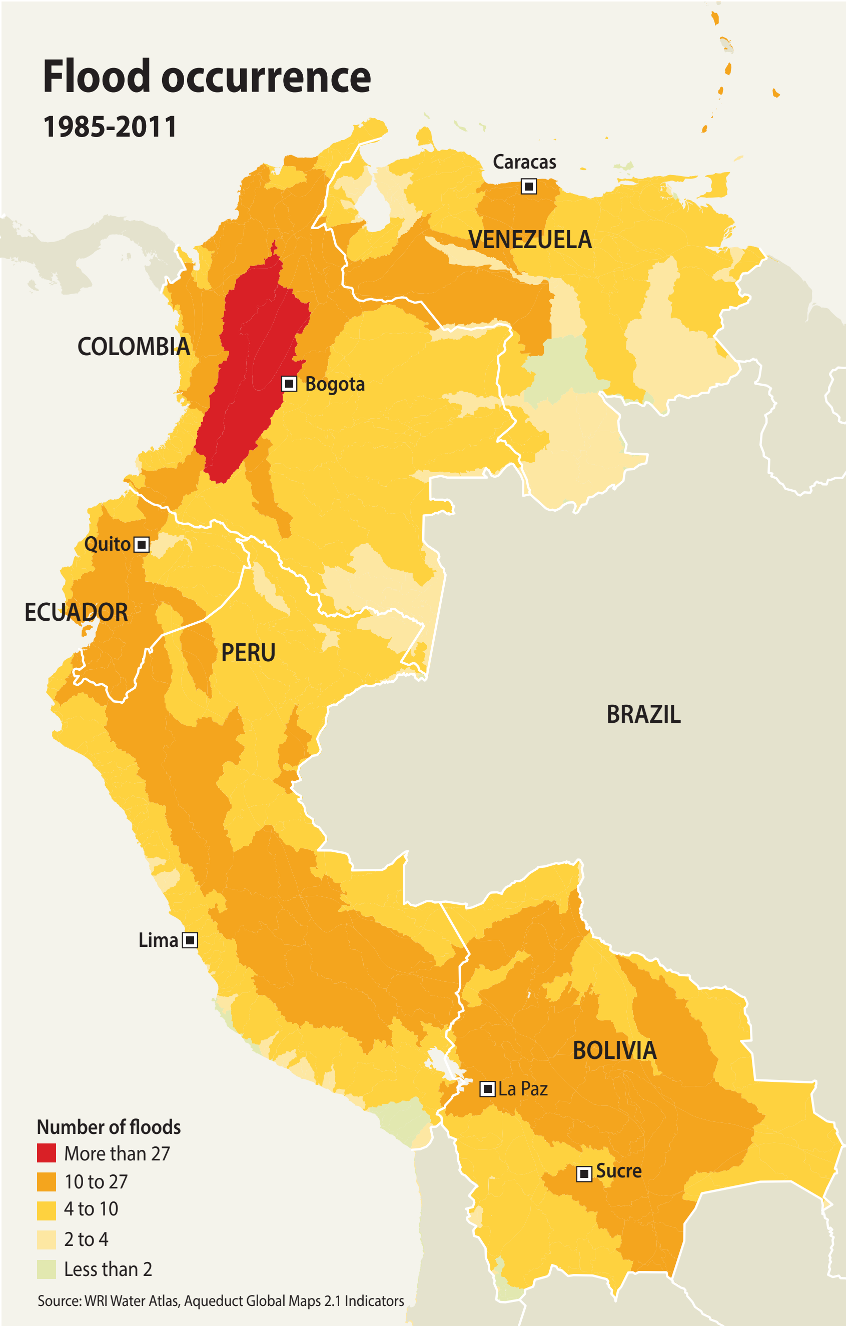
Climate change in the Tropical Andes Mountains will affect the availability of water for millions of people across the continent, including most major cities in the region. Population growth and urbanization will dramatically increase the amount and concentration of demand for already unequally distributed fresh water resources. The observed and predicted changes in precipitation discussed above, with more in the north-west and less in the south, will exacerbate the existing problems of water availability. Additionally, higher temperatures will increase evaporation rates across the region, thereby reducing available water resources. This applies in particular to the western slopes of the southern Tropical Andes. Climate change will dramatically reduce the capacity of mountain environments to provide water for drinking, sanitation, industries, mining, agriculture and energy. Temperature increase, precipitation patterns changes, glacial retreat as well as damage to wetlands and páramos will change the amount, timing and purity of water supply.

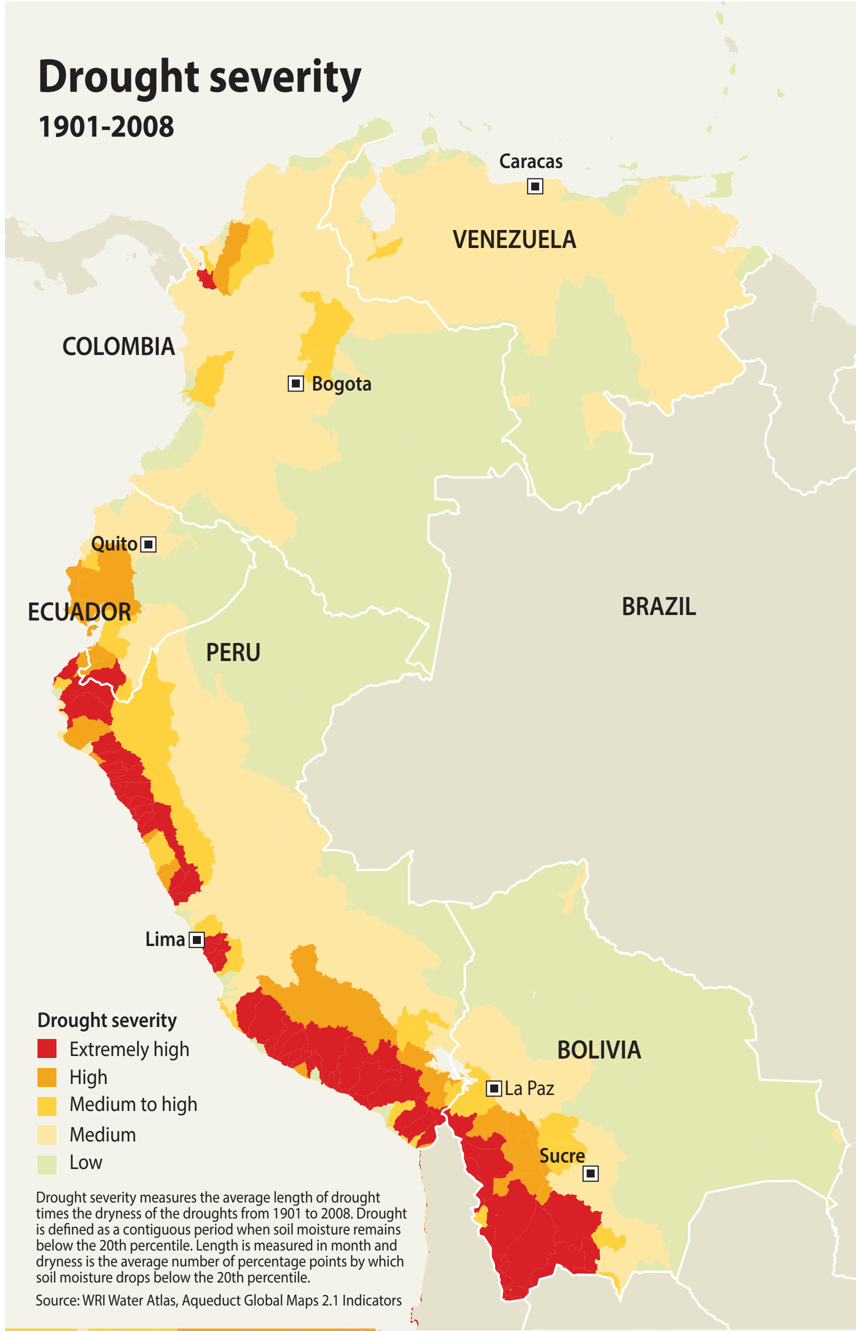
In the long term, tropical glacier loss threatens to reduce the water and electricity supplies of large cities and hydropower projects, as well as the agricultural and tourism sectors. Glaciers, wetlands, aquifers, páramos and other ecosystems provide services that are essential for water supply particularly in dry periods (Urrutia and Vuille, 2009). Wetlands and aquifers are most influential at lower elevations and in the north. Páramos in the high mountains are particularly important in Venezuela, Colombia and Ecuador, where millions rely on them for their water supply (Buytaert et al., 2006). Bogotá, for example, relies on the páramo of Sumapaz. In addition to climate change impacts, human activities such as mining, pine plantations, grazing livestock, hydropower and tourism have had a negative impact on páramos and their capacity to provide clean and sufficient water. In the Central Andes and in the south, glaciers, wet puna and wetlands serve a similar purpose of compensating for lack of precipitation in the dry season.

As described above, climate change has caused a drastic retreat of tropical Andean glaciers. Glacial meltwater is proportionally most important to communities just beneath them in the Central Andes of southern Peru and Bolivia. However, glaciers are also important to specific communities in the north, such as in Quito, Ecuador. In an average year, about 570,000 people, primarily in the high mountains, rely

Importance of Glaciers to La Paz and El Alto

Glaciers are important to the water availability for millions of people living in and below the tropical Andes. Their role is mainly to compensate for lack of other water sources by slowly releasing water in dry periods. The Central Andes around the Altiplano are characterized by highly differentiated dry and rainy seasons. Ninety per cent of Bolivia's total rainfall is concentrated in a period of roughly four months (December-March). The urban areas of La Paz and El Alto, located at around 3,600 m and 4,100 m altitude respectively, are particularly dependent on the compensation effect of glaciers. The yearly average contribution of glacial meltwater to the water flow in the cities is estimated to be around 18 per cent. Between 12 and 40 per cent of the potable water is currently provided by these glaciers, depending on yearly fluctuations in precipitation. The area relies on rainfall during the rainy season, a time when glacial meltwater comprises only a small proportion of the total water flow. Towards the dry period, however, the proportion of glacial meltwater in the available water increases as other sources dry up (Buytaert et al., forthcoming). At the peak of the dry season, the contribution is on average 57 per cent. In a drought year, the city relies almost exclusively on glacial meltwater in the driest period (93 per cent). Since the rainy season is expected to be more concentrated in the future, and overall precipitation is expected to go down, the relative importance of dwindling glaciers for the areas water supply will increase. Glacial melting is causing increased water flow in the short term. However, as the glaciers shrink the flow will be reduced and the compensatory effect of glaciers providing water flow in the dry season will cease. More than 80 per cent of the glaciers in Cordillera Real are small (< 0.5 km^2). This means they are particularly vulnerable to the high warming predicted in their altitudes (Rangecroft et al., 2013). Already between 1963 and 2006, Cordillera Real in Bolivia has lost about 48 per cent of its glacier mass.


Flood occurrence
1985-2011
Caracas
VENEZUELA
COLOMBIA
Bogota
Quito
ECUADOR
PERU
BRAZIL
Lima
BOLIVIA
La Paz
Sucre
Number of floods
More than 27
10 to 27
4 to 10
2 to 4
Less than 2
Source: WRI Water Atlas, Aqueduct Global Maps 2.1 Indicators


Drought severity
1901-2008
Caracas
VENEZUELA
COLOMBIA
Bogota
Quito
ECUADOR
PERU
BRAZIL
Lima
BOLIVIA
La Paz
Sucre
Drought severity
Extremely high
High
Medium to high
Medium
Low
Drought severity measures the average length of drought times the dryness of the droughts from 1901 to 2008. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile.
Source: WRI Water Atlas, Aqueduct Global Maps 2.1 Indicators

Lake Poopó – officially declared "evaporated" in December 2015

Lake Poopó is located in the Altiplano mountains of Bolivia, at approximately 3,700 m altitude. It was formerly the second-largest lake in Bolivia after Lake Titicaca. The lake reached its peak in 1986 with an area of 3,500 km^2 (Quinn and Woodward, 2015). The area of the lake has always fluctuated and is sensitive to even small changes in precipitation and river inflow (inflow is mainly provided through the Rio Desaguadero, which itself flows from Lake Titicaca) (Zola and Bengtsson, 2006). In 1996, the lake completely disappeared and reverted to a salt flat status, and it took several years before water reappeared. However, by January 2016 water had almost completely disappeared apart from a few marshes.

The main reason for its disappearance is the strong drought caused by El Niño, but other contributing factors include the diversion of the lake's resources for water and agriculture.

Satellite images courtesy of NASA Earth Observatory, http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=87363

Lake Poopó, Bolivia, April 2013

Lake Poopó, Bolivia, January 2016


Laguna Churup, Huascarán National Park, Peru

on glacial meltwater for more than 25 per cent of their water needs (Buytaert et al., forthcoming). However, by melting throughout the year and storing water from the rainy season, glaciers in the Tropical Andes spread water supply to dry periods, which is important for a much higher number of people: about 800,000 rely on it for more than 25 per cent of their water in the driest months. Currently, during extreme droughts, this figure rises to more than 5 million people.

Rural communities without sufficient water storage are particularly vulnerable to the diminishing glacial compensation effect (Buytaert et al., forthcoming). One possible solution to increased seasonality and decrease in precipitation is to expand water storage systems in cities and in rural communities. For centuries, human-built water management systems have allowed people to thrive in the Andes. This Mamanteos in Huamantanga in Peru, for example, have been rebuilt to provide water for the local community as well as improve water availability for the lower basin, including the city of Lima. In creating these water management systems, it is important to acknowledge the possible social conflict arising from some groups being able to control water resources. This was observed near Lake Parón in Peru, where conflict arose between local communities and the hydropower company due to the latter's control over the water flow (Carey et al., 2012).

CASE STUDY

Accelerated Impact of Glacier Retreat in the Tropical Andes (PRAA)

The PRAA project, implemented in parallel in Bolivia, Colombia, Ecuador and Peru between August 2008 and March 2014, was a pioneering initiative to adapt to the effects of climate change in tropical glaciers and other fragile high mountain ecosystems, especially for local economies dependent on the water and conditions historically provided by glaciers. The project aimed to monitor glacial melting and its effects on the local environment and communities as well as to develop local adaptation measures, such as improving hydrological infrastructure and restoring páramos. The project was financed by the Global Environmental Fund (GEF) with the World Bank as the implementing agency; the General Secretariat of the Andean Community (CAN General Secretariat) acted as the administrator of the resources, and each country's national environmental authority lead and coordinated its implementation in each country.

In Ecuador, the Ministry of Environment carried out this function through the National Office for Adaptation to Climate Change of the Undersecretary of Climate Change. The PRAA in Ecuador implements pilot measures in neighbouring watersheds: Antisana and Papallacta on the Amazonian side of the continental watershed (Napo River basin) and Pita on the pacific slope (Esmeraldas river basin). These areas are important because they supply water for about 3 million Ecuadorians living in the Metropolitan District of Quito and the surrounding area. The areas also constitute a natural laboratory for applied research on the impacts of climate change on glaciers and water resources. The predominant ecosystem in these areas is páramo, which through its characteristic soil, flora and fauna, has an extraordinary capacity for storage and regulation of water. However, the páramos are also particularly sensitive to natural or anthropogenic pressures, such as overgrazing and climate change.

Huayna Potosi, Bolivia

The most direct beneficiaries of the pilot measures in Ecuador were the residents and members of the community of Tambo Valley, the Cooperativa San Jose del Tablon Alto, and the community of Papallacta. The high Andean ecosystems in which restoration has begun have also benefitted directly. In addition, institutions were also strengthened with equipment, training, research and capacity building. This includes the GADs (Decentralized Autonomous Governments) Papallacta, Napo and Quijos; National Institute of Meteorology and Hydrology (INAMHI); The Quito Water Fund (FONAG); Metropolitan Public Company of Water Supply and Sanitation (EPMAPS) and the Ministry of Environment of Ecuador.

At the end of PRAA-Ecuador, there was a change in people's attitude to climate problems and the opportunities available for adaptation; a significant amount of information was also gathered, not only on the climate, glacier dynamics and vulnerability to climate change for specific communities, but mainly on the potential of initiatives such as those undertaken by the project. This data and experiences is stored and used by institutions such as INAMHI, EPMAPS, FONAG and local GADs. The latter have prepared climate change plans and incorporated climate change considerations into their PDOTs (Plan for Territorial Development and Organization), even before the issuance of the new guidelines of the Ministry of Environment or the latest provisions of SENPLADES. The PDOT for Papallacta in particular is known for its scope, thoroughness and for its pioneering character.

Food

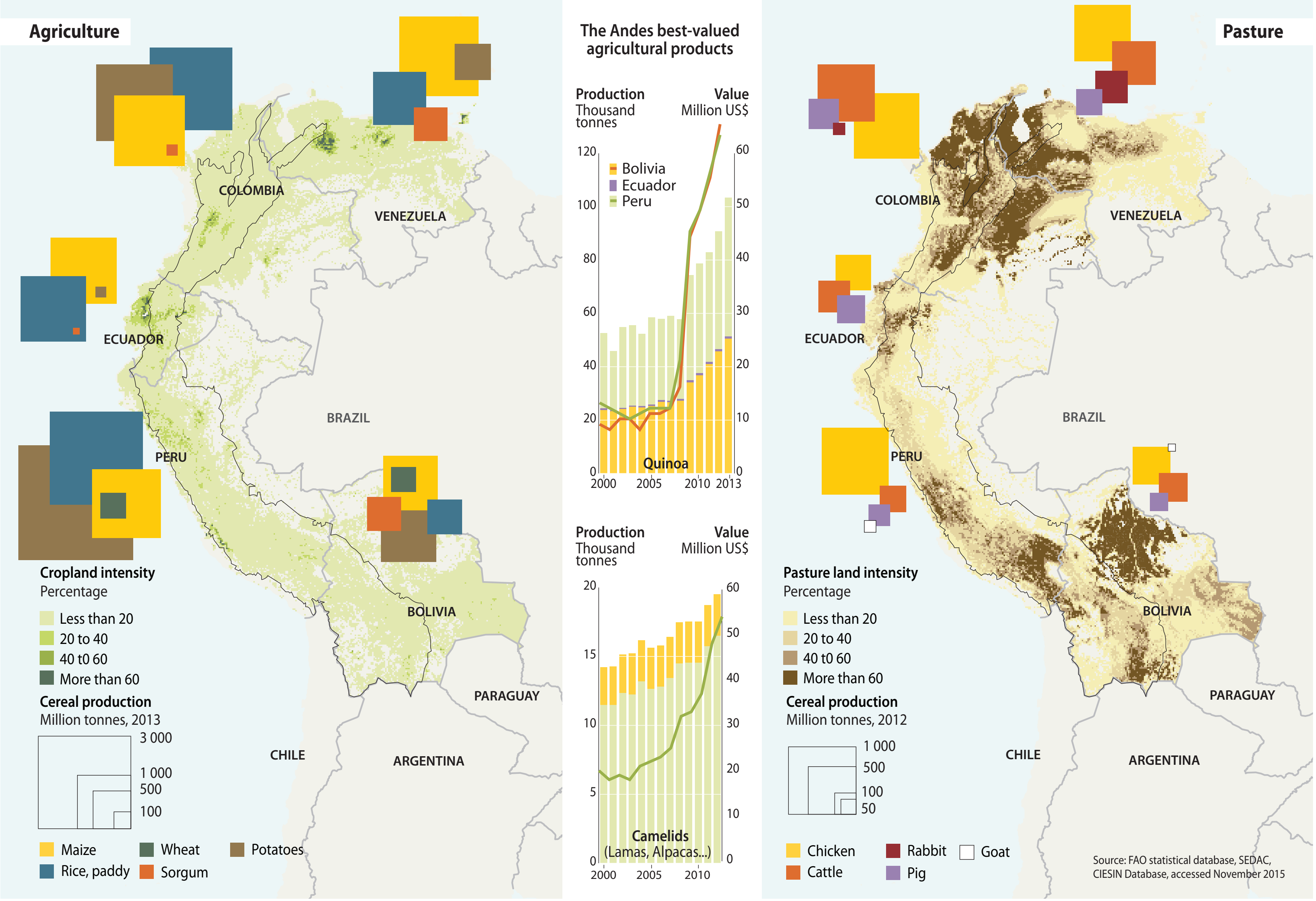
Agriculture, being one of the most significant economic activities in the Andes Mountains, is particularly important to those living there but also to the wider economy. However, it is one of the human activities most affected by climate change. The agricultural industry increases in significance from north to south in Andean countries, from 4 per cent of GDP in Venezuela to 13 per cent in Bolivia (World Bank, 2013). This is also generally the case for the degree of employment in agriculture, from 8 per cent in Venezuela to 32 per cent in Bolivia. Precipitation and water flow changes will have significant effects on irrigation across the region. In the Bolivian mountains and Altiplano, the increased concentration of the rainy season has already affected farmers (Boillat and Berkes, 2013). Farmers have shifted their crops to fast-growing vegetables relying more on artificial irrigation. This puts pressure on water flow, which is eventually shared with communities in the lowlands. Many rural farming communities are significantly affected by national and international migration. Young men disproportionally migrate in search of employment and opportunities elsewhere. This leaves responsibilities for agriculture in the mountains in the hands of women, children and the elderly. The fact that women generally have less access to adaptation options is therefore particularly problematic for many mountain communities.

Agriculture will be both positively and negatively affected by climate change. A general trend is that as the mountains become warmer, crops suited to warmer environments will be able to grow in higher elevations. Reduced frost in the high mountains is beneficial since badly timed frost-nights can destroy harvests (Condori et al., 2014). Temperate farming, such as for maize and rice, could also benefit from increased warming through upward expansion of farmable land. A study of corn farmers in Peru found that in the last two decades, crops had been extended by 200-300 m in altitude (Skarbø and Lambrou, 2015). The crops adapted to the higher altitudes, however, are likely to suffer due to natural limitations to upward relocation.

Potato and oca are examples of crops particularly threatened by climate change. For tubers to keep

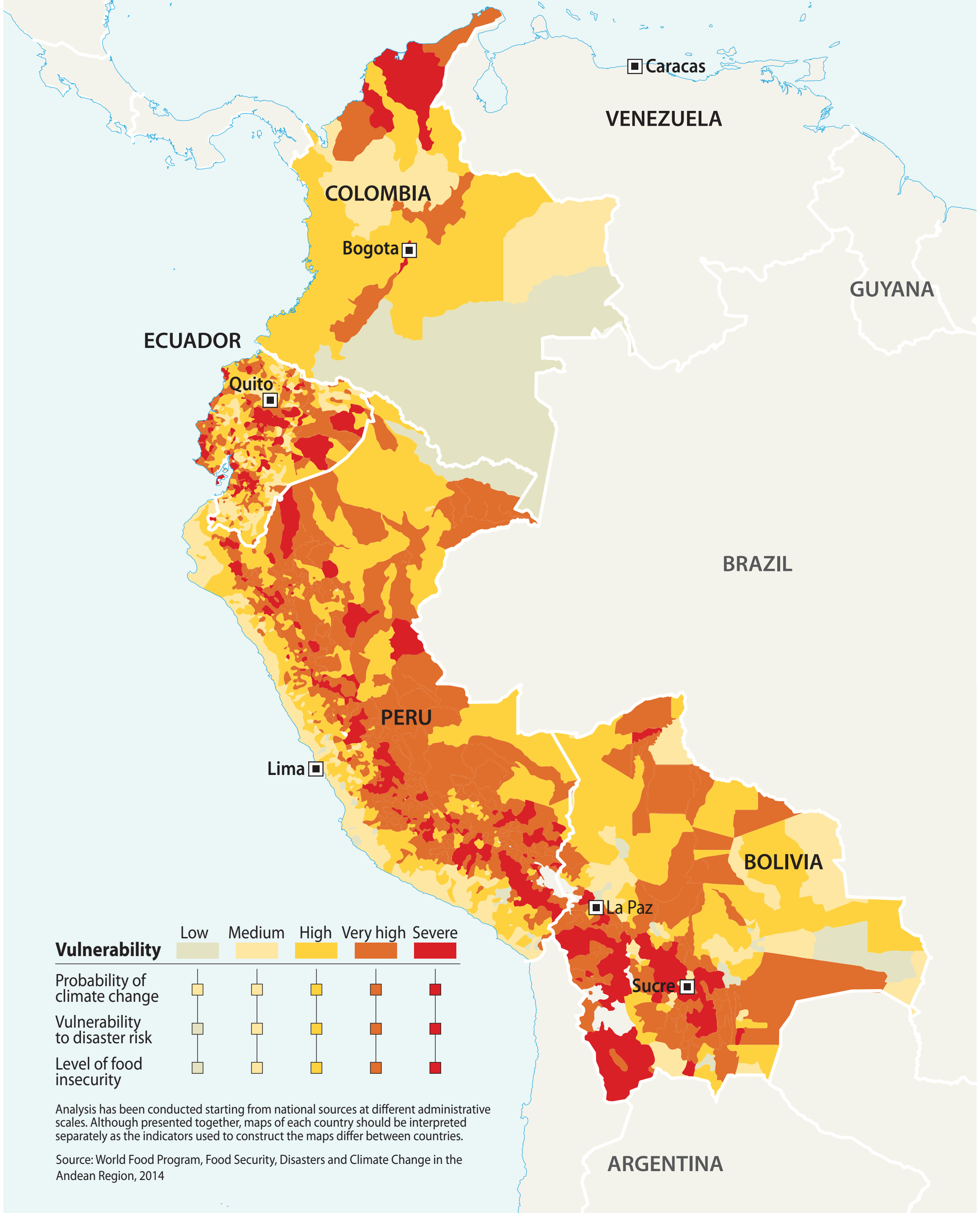
Cocora Valley, Colombia

Agriculture and pasture production in the Tropical Andes region



Source: FAO statistical database, SEDAC, CIESIN Database, accessed November 2015

Food security, disasters and climate change vulnerability in the Tropical Andes region



their nutritional properties, they require cold temperatures (Ortiz, 2015). Many farmers in the high Andes are pushed upward to maintain favourable temperatures for their crops. One study shows that potato farmers in the region have moved their crops upward by about 150 m in the last 30 years (Shaw and Kristjanson, 2013). Reduced frost in the high Altiplano also threatens the production of Chuño, freeze-dried potatoes, which for centuries have been a source of food security (Valdivia et al., 2013). Chuño is still an important food component for many in the region. Investment is needed to preserve the genetic resources of the Andean potatoes as well as to find substitutes capable of coping with the changing climate.

Pastoralism is an important part of the agriculture of the grasslands of the high Andes. Here alpacas, sheep and lamas graze all the way up to the snowline. Moving upward in elevation, agriculture generally shifts to mixed farming and pastoralism gives way to mainly pastoral communities. Pastoralists are sometimes more resilient to change due to the mobility of their herds. However, when disaster strikes their wealth is also more concentrated. Climate change is also threatening high mountain grasslands important to pastoral communities (López-i-Gelats et al., 2015). The southern Tropical Andes are also home to two wild species of camelids, vicuñas and guanacos. Both provide significant income for local farmers through their fine wool, which is the most expensive in the world. The animals are caught, sheared and then released back to the wild. However, sustainable ecosystem management is required to prevent pastoralism of domesticated animals from pushing these wild animals out of their grazing areas or infecting them with diseases.

Being able to interpret seasonal changes in the natural environment has been important to cope with the harsh mountain environment, for example to time sowing and harvesting. Traditional agricultural knowledge is in many places losing its utility as local climates and ecosystems are changing (Berkes et al., 2000). Past practices to reduce risk, such as crop rotation and the cultivation of multiple kinds of tubers in each lot, have in recent years been increasingly abandoned, partly to meet market expectations (Ruiz et al., 2013). This also has a negative effect on communities' ability to cope with unexpected change; forces beyond their control are threatening the resilience that some rural communities have developed over centuries.

Forests, lakes, rivers and other ecosystems currently provide important food sources for many living in the Tropical Andes. Fishing is an important source of protein for many communities, including people living on and around Lake Titicaca, where fishing is a significant industry. Foraging in the tropical forests and valleys of the Andes is another important food source. The rich biodiversity also has the potential to provide agricultural crops in the future. Many of the current food staples around the world were originally found in the Andes Mountains and there could potentially be species suited for growing in changing and challenging environments.

Fisherman on Lake Titicaca, Bolivia

Otavalo market, Ecuador

Tubers

Health

Problems with water supply, hydropower, agriculture and biodiversity all have drastic effects on human health. Agricultural problems will drive poverty and food insecurity primarily among people living in the mountains but also in South America as a whole. Reduced biodiversity and damaged mountain ecosystems will also threaten the nutritional ecosystem services they provide. This includes wild harvesting of edible and medicinal plants and firewood as well as fresh water. Damage to fish stocks and unique Andean ecosystems could also threaten tourism. One broad implication is contribution to poverty and its wide-reaching associated ills. When people's economic situation is worsened, other negative effects of climate change are aggravated.

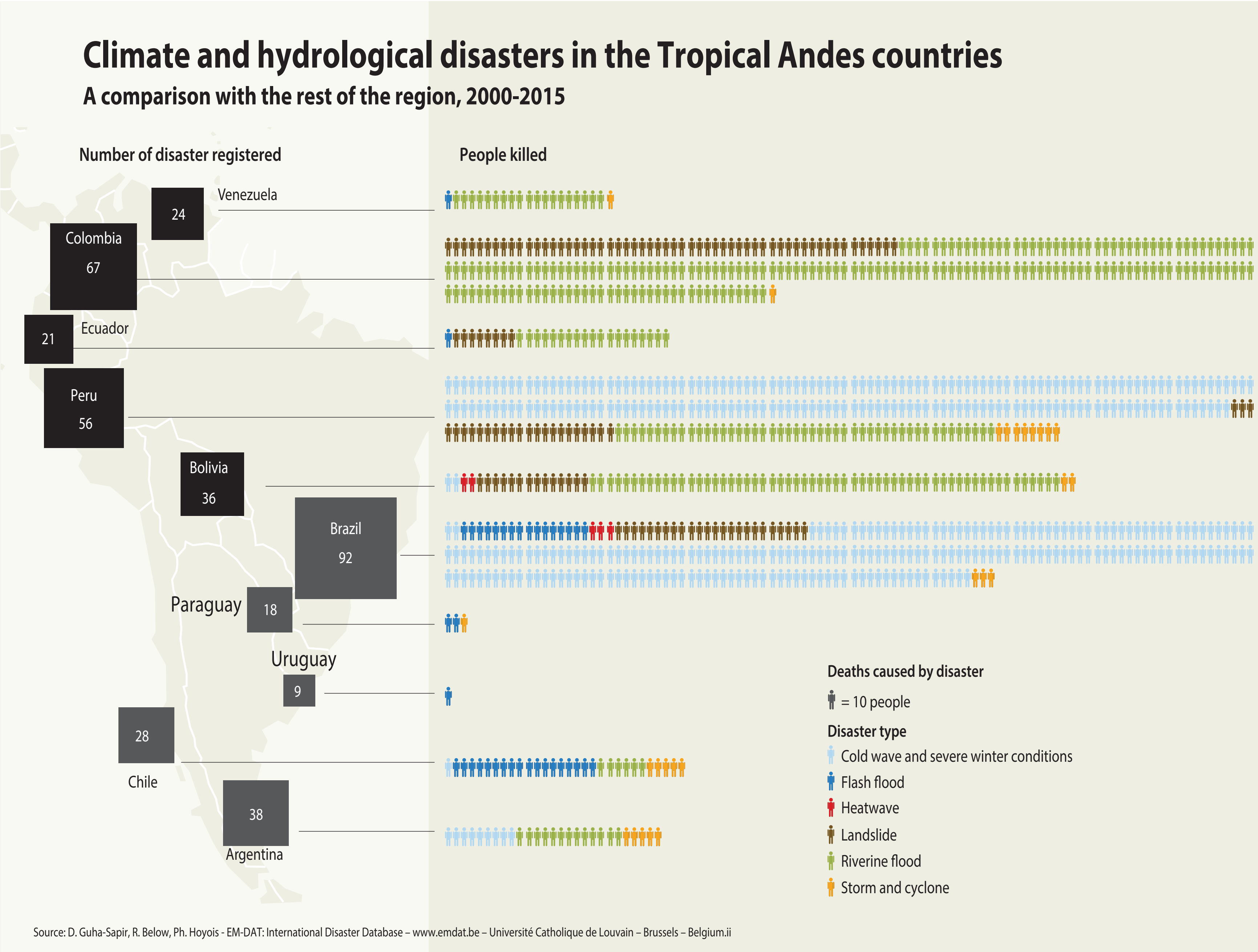
Changes in water availability, particularly in poor urban areas, could cause a significant increase in infectious diseases and generally limit the lives of millions of the most vulnerable. Access to improved sources of water for sanitation in Bolivia was about 61 per cent of the population in urban areas in 2015 (WHO and UNICEF, 2015) , but only 28 per cent in rural areas. In Peru, the numbers are 82 and 53 per cent respectively. Decreased water flow in the dry season will also have significant effects on sewage systems and sanitation. Diarrhoea remains a major killer of children in the world as well as in South America. El Niño events and temperature increases have also been associated with increased frequency of diarrhoea in Peru (Checkley et al., 2000). The relationship between climate change and diarrhoea, however, remains unclear.

Warming of the climate also influences the spread of insects and associated diseases (Thomson, 2014). Vector-borne diseases have moved upward in elevation as the climate has become warmer. Malaria, dengue fever and other diseases will therefore become more prominent in the mountains. El Niño events and climate change have been demonstrated to significantly increase the altitude at which vector-borne diseases are experienced in Colombia (Poveda et al., 2000). Increased frequency of extreme El Niño events is estimated to contribute to an increase of vector-borne disease (Thomson, 2014). These phenomena in combination could have a significant effect, especially in highly populated areas in the mountains, such as Bogotá and Medellín in Colombia. A recent study from the Antioquia region in Medellín demonstrates that malaria will become more prevalent in the highlands because of increased temperatures (Siraj et al., 2014).

The Andes are characterized by significant risk for extreme events. Some are climate driven, such as wildfires, mudslides and avalanches, while others are not, such as volcanic eruptions and earthquakes. However, climate change will increase vulnerability even to non-climate-driven disasters. For example, the steep slopes of the Andes combined with warming and increasingly concentrated precipitation in some places will increase the risks of landslides. These topographic features exacerbate the problems already expected from increasingly concentrated rainfall and increased frequency of extreme El Niño events. This directly threatens infrastructure, ecosystems and human lives. Socioeconomic issues determine to a significant degree the outcome of such disasters for different social groups. In cities in the Andes, slums are often found along the steepest hillsides and have poor building quality (O'Hare and Rivas, 2005). These areas, home to millions of people, are the most vulnerable to landslides. Due to lack of legal ownership for the residents, as well as lack of infrastructure, these communities have restricted capacity to adapt.

Glacial Lake Outburst Floods in the Tropical Andes

Melting glaciers also contribute to increased risk of Glacial Lake Outburst Floods (GLOFs). As glaciers melt, lakes of meltwater build up and can sometimes burst out, causing severe damage. These lakes are often particularly fragile because the dam is made of loose moraine gravel and rock. Climate change is increasing the risk of GLOFs in the Cordillera Blanca, both because of increased melting and through an increased number of extreme events. In 1970, an earthquake caused the bank of a glacial lake on the Huascarán Mountain to collapse, causing a flood that killed 20,000 people (Hegglin and Huggel, 2008). In 1941 a similar disaster occurred in the same area after a huge part of a glacier fell into Lake Pallqaqucha, causing a GLOF which killed over 50,000 inhabitants of the city of Huaraz. The Peruvian government has made significant progress in monitoring these lakes and creating risk reducing infrastructure, such as overflow tunnels. These demonstrated their worth in 2002 when a rock avalanche caused a 70 m high wave in Laguna Safuna. Due to the overflow tunnels, no human lives were lost, despite significant damage and the death of a number of grazing animals (Chevallier et al., 2010).



Climate and hydrological disasters in the Tropical Andes countries
A comparison with the rest of the region, 2000-2015
Number of disaster registered
People killed
Venezuela
24
Colombia
67
Ecuador
21
Peru
56
Bolivia
36
Brazil
92
Paraguay
18
Uruguay
9
28
Chile
38
Argentina
Deaths caused by disaster
= 10 people
Disaster type
Cold wave and severe winter conditions
Flash flood
Heatwave
Landslide
Riverine flood
Storm and cyclone
Source: D. Guha-Sapir, R. Below, Ph. Hoyois - EM-DAT: International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium.ii

Energy

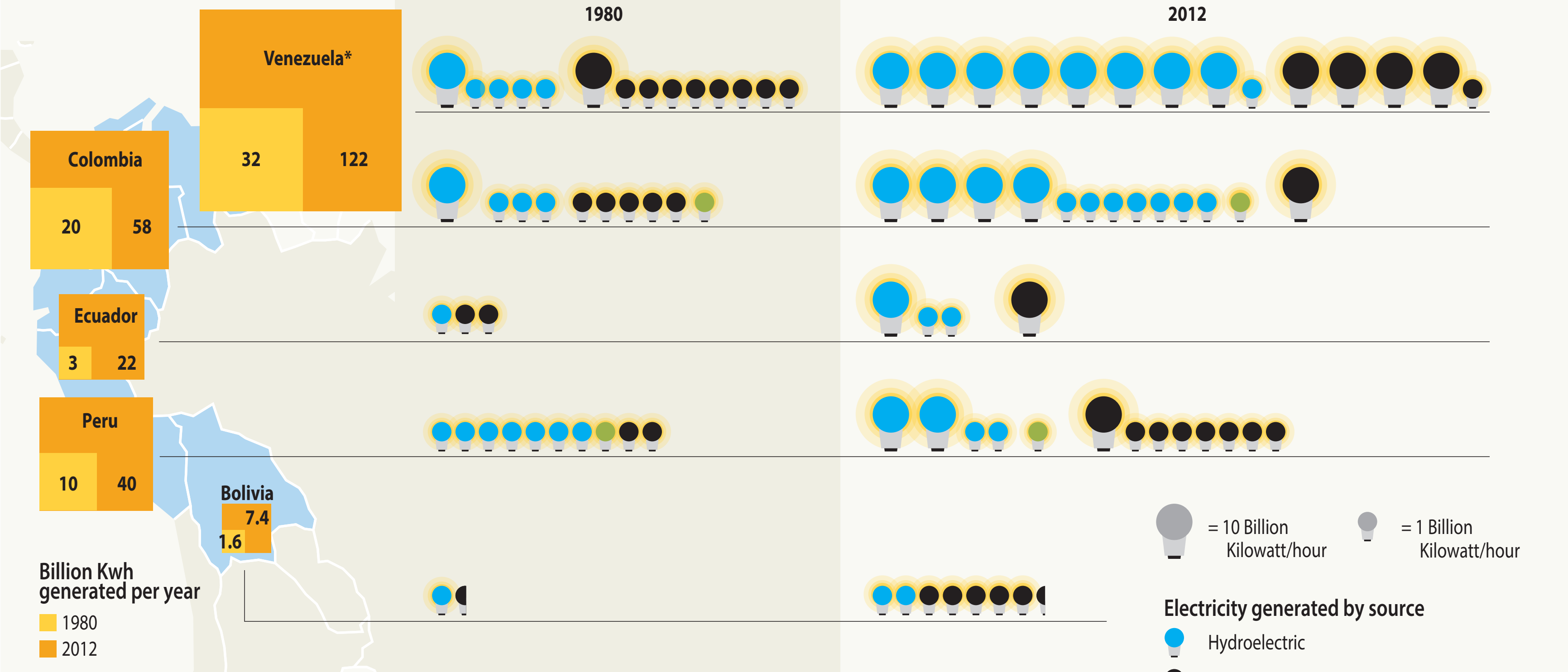
As we have seen, climate change will have a significant impact on water flow, thus affecting hydropower generation, which generates the majority of power in the region. In South America as a whole, hydropower generates about 65 per cent of electricity (WWDR, 2014). The majority of hydropower facilities are located in the mountains. In the region, Peru is the country most reliant on glacial water also for its hydropower generation. Southern Peru and Bolivia also rely significantly on hydropower and are, in addition to melting glaciers, expected to experience a decrease in precipitation. North-western Peru, Ecuador and Colombia are expected to see an increase in precipitation, which could increase their hydropower generation capacity. For eastern Colombia and Venezuela, on the contrary, reduced precipitation could cause reduced capacity. Drastically changing glaciers, páramos and other ecosystems must also be accounted for in the development of hydropower policies in the futures. This is also true for the increasing proportional demand from other sectors of the economy including the rapidly rising population.

Solar panel on rural house, Peru

Mountains also present alternatives for other renewable energy sources. A rapidly rising population and per capita energy use mean that the region will require substantial additional energy production in the future. Adapting to climate change also involves adapting to climate change mitigation, which is increasingly relevant for Andean states. The topography of the Andes can create areas of intense winds suitable for turbines, yet this resource is largely untapped. Another important energy source is firewood, which is an ecosystem service provided by sustainable mountain forest management. Solar power is another resource with significant potential in the Andes due to high radiation at high altitudes (Kawajiri et al., 2011). This source of power has the potential to provide electricity for larger urban areas. It can also be particularly suitable for remote rural communities in the high mountains. Increasing or diversifying electricity production could also increase the adaptive capacity of rural communities.

Hydropower lights up the Tropical Andes

Electricity production trends and sources



*Most of Venezuela's hydroelectric power is generated in the Amazon region and not in the mountains

Source: U.S. Energy Information Administration, accessed Novembre 2015

Industry

Changing hydrology in particular will influence many industry sectors, although industry also relies on the forests and biodiversity in the Andes for pharmaceutical products, food and raw materials. Mining is a key economic activity in the Tropical Andes, which relies heavily on water resources for production. Mining competes for water resources along with agriculture, other industries and human settlements. In areas where water becomes scarce, effective management systems become increasingly necessary. Competition for water resources has previously led to protests and vocal conflicts in some places. For example, around the Yanacocha mine in the north of Peru, the second largest gold mine in the world, farming communities came into conflict with the mining company regarding control over water flow (Bebbington and Williams, 2008).

Tourism is also an important industry in the mountains, with many tourists drawn by the Andean mountains' unique ecosystems and landscapes. Ecotourism and adventure tourism are particularly dependent on sustainable management and protection of key ecosystems. Cloud forests, páramos, glaciers and river systems will all be affected by climate change, which in turn will affect the tourism industry. Studies in the region also indicate that tourism generally has a negative direct impact on biodiversity (Barros et al., 2014). Tourism is therefore another stressor on ecosystems, but through effective management, tourism can often help finance the protection of ecosystems and the services they provide.

Yanacocha gold mine, Cajamarca region, Peru

Key risks related to climate change

Summary of key hazards, vulnerabilities and risks			
Climate Hazards	**Key Vulnerability**		**Key Risk**
Warming			
• Rising mean land temperatures	• Heavy reliance of winter tourism economy on steady snow cover • High geographic exposure of agricultural and farming land, homes, property and assets, including physical exposure of rural and urban populations to potentially flooded areas • Ageing energy infrastructure located in downstream flood-prone areas • Poor land management and spatial planning practices • Limited capacity of local and national public institutions to respond immediately to natural disasters, as well as to adapt to increased floods	*ECONOMIC* *ENVIRONMENTAL* *SOCIAL*	• Lower yield and/or crop failure can lead to economic losses/destruction of livelihoods/ exacerbation of poverty and reduced development. • Increased risk of food insecurity leading to malnutrition of those communities that are depending on these crops (with the highest risk to the poorest), and subsequent risk of harm or loss of life due to malnutrition. • Potential loss of biodiversity (including endemic species) and degrading of the capacity of ecosystems to provide important ecosystem services (including hydrological). Loss or decrease of wild food options.
• Increasing frequency and extension of vector-borne diseases (malardia, dengue, Zika) into higher elevations.	• Underdeveloped capacity to respond to outbreaks of vector-borne diseases (communities without prior experience are more susceptible). • People already facing other stressors (such as poverty and malnutrition) are particularly susceptibility, especially where population density is high (big cities).	*SOCIAL* *INSTITUTIONAL*	• Increased mortality and morbidity, illness and increased burden on health-care systems. • (Pan) epidemics.

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Summary of key hazards, vulnerabilities and risks *(continued)*

Climate Hazards	Key Vulnerability		Key Risk
Shift of seasons			
• Change of precipitation patterns • Concentration of rainy season	• Mostly in the Altiplano and southern Peru. Too much precipitation. • Communities lacking water management infrastructure to store excess water for later use. *NB Rainfall (precipitation) does not fall uniformly across the Tropical Andes. It varies from north to south and east to west. Precipitation also varies from one season to another. While the overall annual precipitation has remained the same, it is the seasons of rainfall that are changing the most. During the rainy season, precipitation is becoming concentrated in fewer rainy days with a higher intensity.*	*INSTITUTIONAL*	• Economic loss and exacerbation of poverty due to lack of irrigation, resulting in lower yield and crop failure, which in turn can lead to malnutrition and its related health risks. • Increased infectious diseases due to lack of water for sanitation.
Floods			
• Increase in annual precipitation • Changes in run-off pattern • Increase in frequency of floods	• Areas already experiencing problems with flooding (mainly Ecuador and Colombia). The north-western Tropical Andes in and around Ecuador are predicted to see the highest increase in precipitation. • High geographic exposure of agricultural and farming land, homes, property and assets, including physical exposure of rural and urban populations to potentially flooded areas. Urban populations are especially densely populated, rural populations are often even less protected and the poorest are the most vulnerable. • Areas with inadequate flood protection and drainage infrastructure. • Ageing energy infrastructure located in downstream flood-prone areas. • Poor land management and spatial planning practices. • Exposed mining facilities containing polluting substances. • Insufficient governmental dedication to disaster risk management.	*SOCIAL* *ECONOMIC* *INSTITUTIONAL* *ENVIRONMENTAL*	• Death, injury and loss of other valuables. • Risk of reversal of progress in reducing poverty and malnutrition. • Displacement of population, causing unrest elsewhere. • Increased landslide risk (exacerbated by deforestation and inadequate land management). • Damage to infrastructure, including hydropower systems, economic loss. • Loss of ecosystem services, such as carbon sequestration and soil protection. • Spread of pollutants from mining areas with inadequate flooding protection, leading to health and environmental risks.

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Summary of key hazards, vulnerabilities and risks *(continued)*

Climate Hazards	Key Vulnerability		Key Risk
Floods *(continued)*			
• Increase in frequency of landslides	• People living on steep hillsides. Communities with frail infrastructure and degraded ecosystems are particularly vulnerable. *NB Rainfall-induced landslides are very common, with above-average rainfall having been linked to landslide activity (see Kirschbaum et al., 2012). However, both natural factors and human factors, including human (mis)management of land and forest areas, are also contributing factors; the interaction of climate hazards in combination with land-use practices can make landslides and erosion much more severe.*	*ENVIRONMENTAL* *SOCIAL*	• Death, injury and loss of other valuables. Security. • Destruction of infrastructure and communication systems.
• Increase of erosion and soil degradation	• Agricultural communities are most vulnerable. • Lack of good land management (both the land itself (pasture and agriculture) and the management of livestock). • Infrastructure and general environment in steep erosion-prone areas.	*ENVIRONMENTAL* *SOCIAL*	• Economic loss, food insecurity. • Damage of communication and transport infrastructure.
Droughts			
• Decrease in annual precipitation and consequent decreasing river flow (accompanied by an ever-increasing demand for water and energy)	• Exposed areas (mainly Altiplano and Venezuela) that already have low water availability. • Agricultural crops need more water to grow but there is a lack of irrigation infrastructure. • Cities and communities dependent on riverine water supply for drinking, hygiene and irrigation. • Urban and rural communities dependent on hydropower production. • Poorer and more vulnerable populations (e.g. elderly) in rural and urban settings are more susceptible to food insecurity, decreased sanitation. • Biodiversity and ecosystems that need fresh water resources and forest ecosystems will be under stress.	*ECONOMIC* *ENVIRONMENTAL* *SOCIAL* *INSTITUTIONAL*	• Economic loss and exacerbation of poverty due to lack of irrigation and subsequent crop failure/ lower yield. • Risk of increased malnutrition due to acute crop failure, risk of loss of life. • Loss of biodiversity and ecosystem services. • Water shortages, risks to crops and health. • Infectious disease. • Exacerbated water conflicts and social and political unrest. The most vulnerable living in border areas might become increasingly vulnerable in terms of water "ownership". • Economic loss. • Decreased capacity for hydropower production.

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Summary of key hazards, vulnerabilities and risks *(continued)*

Climate Hazards	Key Vulnerability		Key Risk
Droughts *(continued)*			
	NB It is somewhat difficult to know exactly what is caused by climate change and what is caused by climate variability. The drought in the Colombian highlands and the Peruvian southern Andes, and the flooding in the southern Andes are not because of climate change but because of ENSO. However the effects of ENSO (and El Niño) seem to be exacerbated by the effects of climate change: generally this translates into dry areas getting even dryer and wet areas, wetter (at least during some periods of the year).		
Glacier melt			
• Accelerated and advanced glacial melting of glaciers/ disappearance of glaciers	• Decreased dry-season discharge/diminished water availability, leading to increased water-resources-related vulnerability: – Cities and communities heavily reliant on glacial meltwater in dry periods/seasons are most vulnerable – Water supply less reliable for ecosystems that adapted to conditions created by glaciers – especially wetlands. • Communities with cultural and/or religious ties to glaciers and snow-capped mountains. • Specific local areas dependent on ice and snow-related tourism.) • Mainly: glacier retreat can exacerbate current water-resources-related vulnerability.	*ECONOMIC* *ENVIRONMENTAL* *SOCIAL*	• Exacerbated droughts and dry spells causing water shortages and water insecurity, with associated negative impacts on agriculture productivity, human health and energy production, leading to economic loss and harm to health. • Irreplaceable loss of water supply. • Meltwater might contain harmful metals which can pose a health risk to those using it (also indirectly through agriculture). • Loss of biodiversity and ecosystem services.
• Increase of glacial lake outburst floods (hazard specific to Peru only)	• People (and infrastructure) living below rapidly melting glaciers without adequate monitoring and early warning systems. • Inadequate governmental attention to risk reduction.	*ECONOMIC* *SOCIAL* *INSTITUTIONAL*	• Death, injury and loss of livelihoods and other valuables. • Damage and destruction of infrastructure and communication systems.

TROPICAL ANDES MOUNTAINS

Policy assessment

La Paz, Bolivia

Analysis of relevant adaptation policies and frameworks of the major vulnerable sectors

People have adapted to the past climate in the Tropical Andes over millenniums, from the domestication of crops and livestock such as potatoes and alpacas and the acclimatization of the Andean population to high altitudes, to institutional arrangements developed for facing mountain environments and extreme weather events. In the current climate change discourse, however, the necessity of adaptation has only recently gained pre-eminence, and become as widely accepted and supported as that of mitigation to greenhouse gas emissions (Agrawala and Fankhauser, 2008). For Latin America and the Caribbean (LAC), the economic cost of a 2.5°C rise in temperature (most probably around 2050) for the region at between 1.5% and 5% of the region's present GDP depending on which study is used, although these are conservative estimates which have a high degree of uncertainty (ECLAC, 2015).

How national policies and instruments were assessed in this report

National adaptation policies and instruments of each country were assessed using the following indicators:

- Funding
- Adaptation targets
- Multisectoral articulation
- Implementation tools
- Focus on mountain ecosystems and adaptation in particular
- Adaptation programmes

Each indicator was given a numerical score, ranging from (1) Existent and sufficient, (2) Existent but insufficient/planned but not implemented, (3) General mention, (4) Non-existent.

The second analysis focuses on adaptation measures addressing key risks in the following thematic area for each country:

- Water resources
- Land
- Agriculture
- Hydropower
- Public health
- Forests
- Disaster risk management

These sectors are similar to the key sectors evaluated for key vulnerabilities and risks in Chapter 2. Each is assessed below according to the presence or absence of the following: (i) Adaptation goals, (ii) Adaptation targets, (iii) Implementation tools, (iv) Mountain adaptation policies, (v) Regional considerations, (vi) Adaptation actions.

The goal of this chapter is to qualitatively assess the adaptation policies or policy instruments of Bolivia, Colombia, Ecuador and Peru.[2] We consider policy instruments as strategies, plans and programmes at the national level. The scope of this assessment excludes policies at the local level of government since the aim of the report is to provide recommendations for national and Andean regional policies. The analysis is based on four sources of data: publically available official policy documents, a survey answered by government officials, input provided at a regional stakeholder consultation workshop carried out in September 2015 in Lima, and expert opinion.

This chapter is organized into three sections: the first analyses policy instruments for adaptation to climate change at the global and (sub-)regional levels (organizations formed by the tropical Andean countries). The second section focuses on the national level, where both national policy and instruments targeting key sectors affected by climate change are assessed according to a set of indicators (see textbox below). The third section describes the institutional framework of climate change adaptation policies within each country.

Adaptation policies tailored specifically to mountain ecosystems are extremely rare in the Andean region. This might be due to policymakers not perceiving mountains as isolated units for policy intervention and not treating them as a "special" type of ecosystem. Moreover, policies address public problems and needs rather than specific ecosystems or territories, except perhaps in the case of Amazonian forests (e.g. Peruvian Forest Law). However, a similar trajectory to the Amazonian forests may be initiated just for glaciers and mountain environments: for instance, Ecuador is integrating weather stations' monitoring of páramos and glaciers into the national network of weather stations.[3]

The main findings of this chapter are:

- Adaptation is gaining importance within countries' priorities. All countries have national policy instruments in one form or another (e.g. national strategy or a plan for climate change adaptation; or joint mechanisms for adaptation and mitigation in the forest sector in the case of Bolivia), although the means for implementing adaptation programmes and measures are still being developed. All countries have submitted their Intended Nationally Determined Contributions (INDCs) to the UNFCCC. In generally, funding remains insufficient and adaptation targets and implementation tools are general and vague.
- The rising recognition of adaptation in policymaking is hindered by weak or non-binding international agreements and the lack of attention given to environmental issues in supra-national organizations.
- Mainstreaming adaptation policies across sectors and from national to local levels is an ongoing but slow process.
- Institutions from an increasing number of sectors are articulating policies around adaptation to climate change.
- Mountains are rarely treated as a specified target of adaptation policies.
- Ecosystem services provided by mountain ecosystems, such as wetlands, grasslands and tropical mountain forests, are both essential to people and threatened by climate change, and measures such as ecosystem-based adaptation measures which are designed and implemented in a participatory process to address specific issues in mountain communities could be further pursued.
- Although many sectoral policies do not explicitly focus on adaptation to climate change in mountains, they often address broader issues that influence mountain adaptation. These policies may be opportunities to include adaptation measures when explicit mountain adaptation policies are lacking.
- Gender and ethnic inequalities are insufficiently addressed by adaptation policy. Recognizing the contributions of women and indigenous people to adaptation to climate change may encourage policymakers to address discrimination.

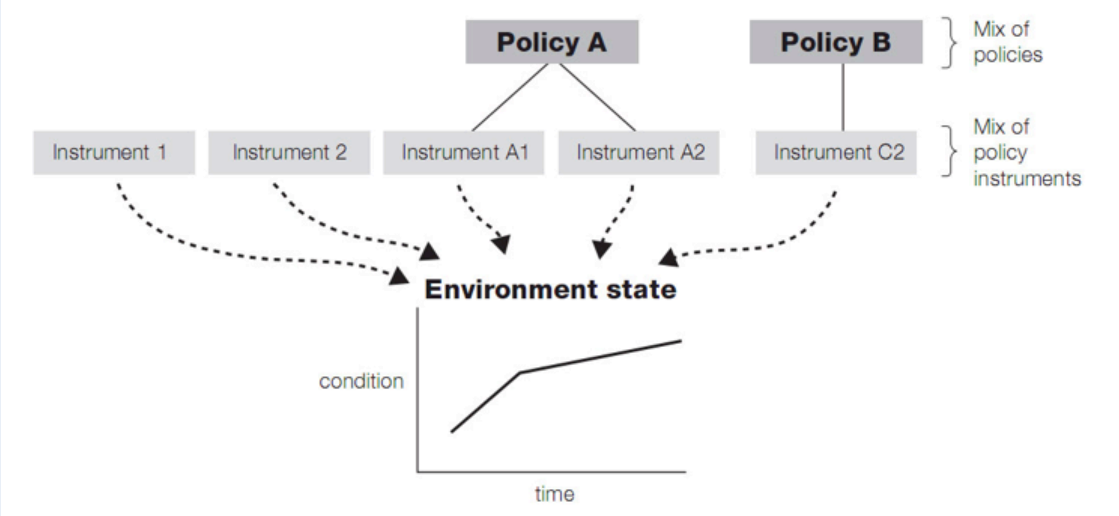
Farmers, Paramo El Zumbador mountains, Venezuela

Limitations to analysis

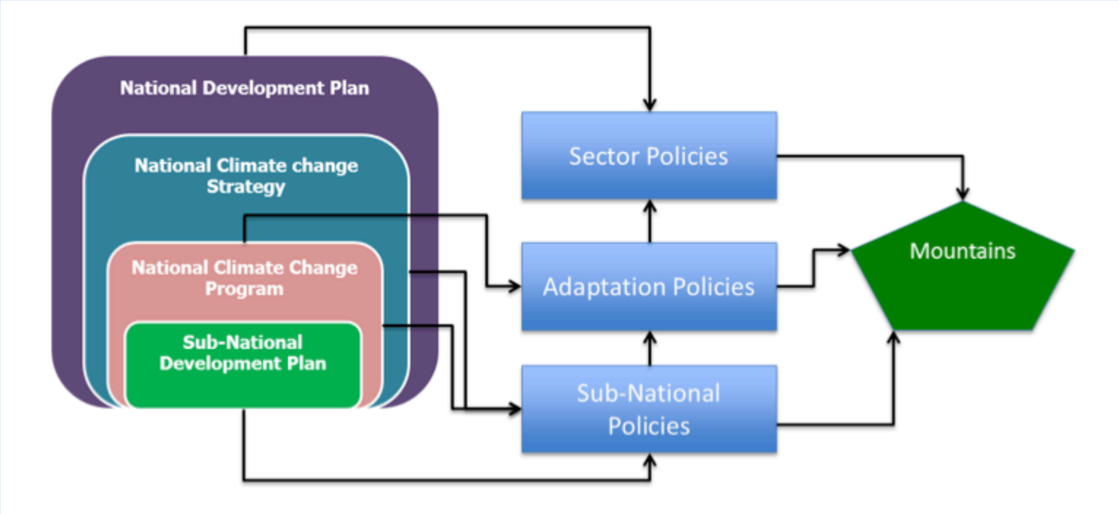
The analyses presented in this outlook have some limitations and caveats. Firstly, because many policies have been formulated they may not yet have been implemented or yet have results or impacts; therefore, it is difficult to assess policy performance. Also, most adaptation policies fail to include monitoring mechanisms, which makes it difficult to assess their effectiveness. Monitoring effectiveness is further complicated when multiple policy instruments are used to address the same issue, or when instruments yield unintended effects. In other words, social and economic policies not intended to reduce climate change risks also affect the degree of adaptation (e.g. programmes for poverty alleviation that decrease population vulnerability). Furthermore, there are policies with unexpected or unintended impacts on adaptation. For instance, trade agreements that promote water-intensive crops can increase pressure on water resources and provisioning ecosystems.

Instruments 1, 2, A1, A2 and C2 correspond to different policies and sectors (A, B) that, whether coordinated or not, affect the environment. Adaptation policies rarely indicate which instruments address which vulnerabilities, nor whether they focus on mountains or other ecosystems. Therefore, progress on adaptation and on other issues results from different policies and targets different sectors. This mix of policies makes attribution and measuring effectiveness challenging.

There are at least two ways to frame the lack of focus on adaptation in mountains. The first



Policies and instruments targeting the environment. Source: IEA Community Learning Platform – Graphic[4]



Countries' architecture for policy instruments

is as exclusion, whereby mountains are not recognized as a unique territory. The second is as an opportunity for redefining and redirecting unspecific policies from multiple sectors towards the adaptation of vulnerable mountain ecosystems.

Mountains are important for public issues that belong to many sectors; therefore, mountains do not fall within any single sector, nor are they exclusively addressed by any single policy analysed. The figure shows how national climate change strategies fall under (and have to be consistent with) national development plans, and are above the subnational development plans. Each of these instruments generates policies that interact with each other (e.g. adaptation policies influence sector policies) and apply in the mountains.


Man harvesting potatoes, Bolivia

Policy approaches

Adaptation covers a wide range of activities, from reducing risk and vulnerability, to taking advantage of opportunities, to building capacities at multiple government levels and across sectors, and coping with climate change impacts (Tompkins et al., 2010). Additionally, the complexity of adaptation requires governments to respond in multiple policy sectors (e.g. agriculture, ecosystems, and urban areas) (Eakin and Lemos, 2006). Central government authorities design adaptation policies that ought to be locally implemented. This requires coordination and feedback among multiple levels of governance. However, weak vertical integration among governance levels and highly heterogeneous capacities among actors at a given level (e.g. municipalities) make success of adaptation strategies implemented exclusively by subnational (local) governments highly inconsistent. A balance needs to be attained between centralized and decentralized approaches in a long-term transition process towards more effective work by local governments.

One reason for underdeveloped adaptation policies is the lack of strong institutions, stable budgets and political will as well as appropriate mechanisms to align international agreements to national agendas. The increasing number of policy instruments designed at the global level is not adequately reflected in the countries' adaptation policies.

Global policy instruments

Treaties and international agreements are the main framework of global policy, with some also establishing funding commitments for adaptation. The UNFCCC is the most prominent international treaty addressing climate change. The UNFCCC has advocated adaptation and has founded the Adaptation Committee.[5] In addition, the Convention has facilitated the creation of the Adaptation Fund, which since 2010 has committed US$ 331 million in 54 countries for climate adaptation and resilience activities,[6] as well as other financial and technical assistance mechanisms for adaptation and resilience-building (e.g. Green Climate Fund, Climate Technology Centre and Network). Existing global estimates of the costs of adaptation in developing countries range between US$ 70 billion and US$ 100 billion per year globally by 2050, although this is likely to be a significant underestimate especially after 2030 (UNEP, 2014).

The UNFCCC, as well as relevant financial mechanisms, assists countries to mainstream climate change considerations into national agendas and priorities, and provides a framework for regional joint initiatives and national policy responses to climate change. Even though global mechanisms may lack binding or regulatory capacity, they provide effective leadership and guidance for innovative policies for confronting climate change in national policymaking.

During the 20th meeting of the Conference of the Parties to the UNFCCC (COP20) in Lima in 2014, countries agreed on the importance of implementing National Adaptation Programmes of Action (NAPAs) and identifying vulnerable populations in a participatory and transparent manner. The importance of focusing on people in vulnerable situations to prevent damage by climate change was reiterated in the 2015 Paris

Landscape in Cordillera Blanca, Peru

Agreement (UNFCCC, 2015). The international acknowledgement of the importance of focusing on vulnerable groups and incorporating traditional knowledge brings the opportunity for including women and indigenous peoples' perspectives in the policy instruments. However, funding, specific mechanisms and institutions for such inclusion need to be strengthened and/or created.

Regional and sub-regional level policy instruments

Policy instruments at the regional and sub-regional[7] level are primarily created in the framework of the regional organizations in which the Andean countries participate: the Union of South American Nations (UNASUR), the Andean Community (CAN), the Pacific Alliance and the Community of Latin American and Caribbean States (CELAC). These organizations aim to provide representation in international negotiations on trade agreements and on enhancing sovereignty for the region.

UNASUR is formed of 12 South American countries: Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and Venezuela. Its stated objective is to build a space for cultural, economic, social and political integration. It also aims to eliminate socioeconomic inequality and expand social inclusion to increase civil participation.[8] Key guiding documents of the organization mention the relevance of: addressing causes and effects of climate change; protecting biodiversity, water resources and ecosystems and; cooperating for disaster prevention. However, these aims have not led to actions on climate change adaptation. Moreover, UNASUR does not have an environmental commission or any other agency responsible for environmental issues or for implementing measures to address climate change risks.

The Andean Community (CAN)[9] was formed to promote industrial, agricultural, social, and trade cooperation between member countries (Bolivia, Colombia, Ecuador and Peru). The environment has been a top priority for CAN for many years. During this time it has supported the development of the Environmental Andean Agenda to guide multi-country actions on climate change, biodiversity and water resources; and actions to face climate change effects in the Andes and its basins. Activities undertaken as part of this agenda include but are not limited to:

- The Climate Change Adaptation Programme in the Andean Region, which compiled information on climate change impacts on the ecosystems in the Andean region.
- Project for Adaptation to the Impacts of Receding Glaciers in the Tropical Andes (PRAA), which implemented a pilot programme on adaptation measures in glacial basins of Bolivia, Ecuador and Peru.
- Climate Change and Environment in the Social and Economic Cohesion Sector (ANDESCLIMA), which is oriented towards mountain EbA to climate change in the Andean Region.
- The establishment of research stations and research projects for monitoring climate change impacts on biodiversity (e.g. GLORIA-Andes[10]).

CASE STUDY

Monitoring climate change impacts on mountain biodiversity in the Andean Highlands (GLORIA-Andes)

The impact of climate change is a major long-term threat to biodiversity in mountain regions around the world. Nevertheless, information on how climate change threatens biodiversity in the Andean highlands is lacking. This includes a lack of long-term observations suitable to establish a baseline for comparison with the predicted climate change impacts. To address this need, the GLORIA Research Program (Global Observation Research Initiative In Alpine Environments) was established as a global effort for long-term observation and comparative study of climate change impacts on highland biodiversity.

Through coordinated efforts of CONDESAN, the General Secretariat of the Andean Community (SGCAN) and several South American research centres, the High Andes Biodiversity Monitoring Network was created in 2010, in the framework of the GLORIA Global Initiative. The objective of this network is to provide technical assistance to operators of South American sites, to ensure their sustainability in the long term, and to produce regional outlooks aimed at supporting the design of adaptation measures and policies under an ecosystem-based approach.

At present, the network has promoted the establishment of 12 GLORIA sites in five countries, which cover more than 5000 km from the Eastern Andes of Colombia, through Ecuador, Peru and Bolivia, to the Argentinean highlands at the limit of the Tropical Andes Ecoregion. Along this huge area, more than 800 vascular species are monitored, making it the biggest biodiversity and climate change research network in the Andes.

Grasslands and the Sincholagua Volcano, Ecuador

The Pacific Alliance is an effort for regional integration among Chile, Colombia, Mexico and Peru.[11] Its stated aims are the free movement of goods, services, resources and people; to drive growth, development and competitiveness for improving the well-being and overcoming inequality of its members; and to foster political action on economic and commercial integration projected with the Asia-Pacific region. The Alliance has not been as active as CAN on climate issues, although it supported the actions planned at COP20 for addressing climate change.

CELAC seeks deeper integration within the region and to facilitate discussion on regional issues. On the topic of climate change, CELAC hosted a meeting in 2014 for the elaboration of the Sixth Special Declaration on Climate Change and Disaster Risk Management. The Declaration stressed the need for the international community, particularly developed countries, to comply with the Kyoto Protocol and the principle of common but differentiated responsibility.[12] It also called for developed countries to respect and strengthen their commitments to financing climate change adaptation and technology transfer.

UNASUR and, in particular, CAN have been active in supporting climate change actions in regional projects. In recent years, however, they have become less active on environmental issues and have given more attention to trade and economic integration.

National policy frameworks for adaptation

Bolivia. The design and implementation of adaptation policies are still in their early stages (Hoffmann, 2015), though the Bolivian government is working on consolidating and improving adaptation measures. Part of the initial effort was the inclusion of risk management and climate change adaptation as development planning criteria in Bolivia's 2009 Constitution. The Development Plan for Living Well,[13] however, only mentioned possible effects of climate change and did not outline strategic actions. The authority on climate change was the National Program on Climate Changes of the Ministry of Environment and Water until 2012, when the Framework Law of Mother Earth and Integral Development for Living Well No. 300 was approved. This framework created the Plurinational Authority of Mother Earth as the new institution for leading the country's work on climate change, which started operating in 2014.[14] Law 300 also created three mechanisms with which to address climate change:

1. Art. 55: The Mitigation Mechanism for Living Well, focused on emission reductions from non-forestry sectors;
2. Art. 56: the Adaptation Mechanism for Living Well; and
3. Art. 54: The Joint Mitigation and Adaptation Mechanism for the Holistic and Sustainable Management of the Forests of Mother Earth (MCMA) - Bolivia's alternative to REDD+.[15]

The new institutional arrangement entered into force in 2014, thereby generating a two-year institutional vacuum and few policies on climate change adaptation. The National Mechanism for Adaptation to Climate Change and the National Plan on Climate Change ended in 2011 and 2012 respectively. Furthermore, the ongoing National Strategy of Information and Communication for Climate Change aims to build capacity for addressing climate change, while the National Strategy on Forests and Climate Change aims to stop forest degradation caused by a changing climate.

Colombia. Climate change is a key threat to Colombia's ecosystems and socioeconomic development.[16] This has led the country to prioritize four strategies within the National Development Plan 2010-2014 (Prosperity for all) to take an integrated approach towards addressing climate change. One of these strategies includes the elaboration and implementation of the National Plan for Adaptation to Climate Change (PNACC).[17]

The purpose of PNACC is to reduce the risks of climate change. PNACC aims to do this by incorporating climate change considerations into the planning of five sectors: agriculture, energy, transport, housing and health. The goal is to prioritize adaptation actions within the development plans of each sector in order to reduce vulnerability to climate change.

The PNACC addresses climate variability and change through four objectives:

1. To widen knowledge generation about potential risks and actual challenges.
2. To take advantage of the opportunities brought by climate change and variability.
3. To incorporate climate risk management in sectoral and territorial development planning and
4. To identify, prioritize, implement, evaluate and monitor adaptation measures for reducing vulnerability and exposure of socioeconomic systems to climatic events.[18]

The inclusion of climate risk management in territorial planning objective (iii) links development with climate change at the local level. In so doing, it brings climate change from the environmental into the socioeconomic realm, thereby helping address the non-climatic aspects of vulnerability such as poverty, inequality or illiteracy. Moreover, the PNACC guides the formulation of priority programmes and projects, as well as strengthening actions. Local participation and democratic dialogue between stakeholders are important for implementing sustainable adaptation actions locally.

Ecuador. The high relevance of climate change is acknowledged in the Article 414 of the Constitution, with an emphasis on mitigation:

"The State shall adopt adequate and cross-cutting measures for the mitigation of climate change, by limiting greenhouse gas emissions, deforestation, and air pollution; it shall take measures for the conservation of the forests and vegetation; and it shall protect the population at risk" (Ecuador: 2008 Constitution in English, Translated by Georgetown University).[19]

In 2009, Executive Order 1815 recognized the National Commitment to Climate Change and expanded it to include adaptation.[20] The Ministry of Environment was appointed to raise awareness of climate change and develop a national strategy. This commitment was made operational through the Plan Nacional del Buen Vivir (2013-2017), with policy 7.10 to implement mitigation and adaptation measures for reducing economic and environmental vulnerability.

Additionally, Executive Decree 495° (8 October 2010) created the Inter-institutional Committee on Climate Change (CICC)[21] whose main task is to promote the implementation of Ecuador's National Strategy on Climate Change (ENCC) (Ludeña and Wilk, 2013). The ENCC focuses on adaptation and mitigation, with adaptation prioritized in the following sectors: Agriculture, livestock and food sovereignty; Fishing and aquaculture; Health; Water resources; Natural ecosystems; Vulnerable human groups; Tourism; Infrastructure; and Human settlements. While actors in each of these sectors may implement significant adaptation policies in mountains, there are no specific policies for mountains. ENCC policies will be carried out through the National Adaptation Plan, which will implement national programmes to strengthen the country's capacity to face climate change.

Though national programmes for Ecuadorian mountains are still scarce, it is worth mentioning two national programmes that promote payments for ecosystem services, one for the restoration of Andean grasslands – páramos (the SocioPáramo Program) and one for the restoration of forests (the SocioBosque Program). One reason for implementing these programmes was the interconnectedness between the environment and agriculture (e.g. degraded landscape, páramos and forest).

Peru. The importance of climate change in general, and adaptation in particular, are gaining in formal recognition in the policy framework of Peru. For the long term, the Bicentennial Plan[22] (National Strategic Plan up to 2021) considers adaptation as one of its five priorities. Adaptation is also indirectly included in the following policies of the Acuerdo Nacional (National Agreement): Fostering food security and nutrition; Sustainable development and environmental management; Rural and agrarian development; Disaster risk management; Water resources; and Territorial ordering and management.[23] Climate change adaptation is mentioned in the National Environmental Policy and the National Law of the Environment[24] as being important for the population's security. Also, the Multi-year Macroeconomic Framework, an instrument that defines the destination of public expenses, considers climate change to be a priority for public investment and risk control.

The most important instrument for climate change adaptation in Peru is the National Climate Change Strategy (ENCC),[25] published on 23 September 2015. Its objectives include raising awareness about climate change and increasing the adaptive capacity of people, businesses and the government. It also aims to increase private investment and quality of public expenditure on climate change adaptation, to reduce human and economic losses due to climate-related disasters, and to increase research and technology to guide adaptation and risk management for climate change. Elements in the ENCC plans particularly relevant for mountain communities are: capacity-building at the subnational level; gathering, generating and disseminating information about climate change effects; evaluation of climate change effects on basins and ecosystems; strengthening local and traditional knowledge and generation of technology for adaptation to climate change; and providing technical assistance for preventing dissemination of pests and diseases threatening food security (Ministerio del Ambiente, 2015). Despite the multisectoral approach needed to achieve results, the inclusion of the strategy within sectoral policies has been quite partial and uneven. However, the Action Plan for Adaptation and Mitigation for Climate Change, from 2012, includes climate change adaptation measures to reduce economic, social and environmental vulnerability.[26]

Currently, MINAM is designing the National Programme on Climate Change to implement the National Strategy on Climate Change. There are also initiatives on climate change adaptation from other ministries, which focus on assessing specific effects by sectors. For instance, "Disaster risk and climate change vulnerability" is a priority, justified using evidence of climate change impacts on Peru's landscape, and articulated in the

Nazca Province, Peru

section Environment, biological diversity and risk management of a planning document for 2021. The country has defined five priority sectors: water; agriculture; fishery; forestry; and health, based upon scientific evidence and consultations with relevant actors in each sector, subnational authorities and civil society.[27]

Funding for climate change management at the national level comes chiefly from the government itself, although international donations cover a small part. In 2011, the total budget for 88 programmes was about US$ 809 million, of which 49 per cent was funded directly by the government, 34 per cent as loans from international agencies (which will also by paid by the government), and 17 per cent through official development cooperation (Pereira et al., 2014). The last decade has seen several adaptation projects in different sectors supported through international cooperation (e.g. PACC, IPACC, Glaciares 513, IMACC, TACC, EbA Montaña, PRAA, PROCLIM, AMICAF and Humboldt).

These projects have aimed to strengthen institutions, implement pilot projects for adaptation and develop financial mechanisms and scientific research (Ibid).

Adaptation measures to address key vulnerabilities and risks

The key risks and vulnerabilities from climate change were presented in Chapter 2.[28] Although it would be expected that countries use this information for designing policies for climate change adaptation, the use of scientific evidence to support and guide policymaking is generally weak because of the underdeveloped science-policy interface. This is particularly problematic at the local level of government where adaptation measures addressing the climate challenges for each community must finally be specified. Policymaking responds to pressures from non-scientific realms (e.g. lobbyists) and the insufficient participation of experts in decision-making processes (Sutcliffe and Court, 2005).

Water resources policy analysis

In **Bolivia**, water availability is an issue for many communities. It has therefore been prioritized under the Framework Law of Mother Earth and Integral Development for Living Well No. 300[29] and included in the Plurinational Policy and Plan of Climate Change for Living Well. Article 27° (Water) of this law sets priorities for the integrated management of water resources, including 13 lines of action, although only two are specific to climate change adaptation (Asamblea Legislativa Plurinacional de Bolivia, 2012). Being a framework law, it still requires lowel level and more specific legislation in order to be implemented. The 2025 Bicentennial Patriotic Agenda also has specific objectives and strategies programmes that focus on water, but neither mentions climate change or mountains specifically.

Colombia's National Policy for Integrated Water Resource Management 2010–2022 (Ministerio de Medio Ambiente, 2010)[30] recognizes the impacts of climate change on water management (e.g. through flood risk and water availability). The policy's main objective is to have an integrated management of risks related to water supply. It proposes:

- the generation and dissemination of information on the potential climate change risks to water resource availability (strategy 4.1);
- the incorporation of water supply and availability risk management into the planning instruments (strategy 4.2); and
- mitigation and adaptation measures to reduce the risks resulting from climate variability and climate change (strategy 4.3) (Ministerio de Ambiente, VyDT, 2010).

The development of adaptation measures is important for water regulation for ecosystems and important economic sectors. Consequently, Colombia has developed the Project for Adaptation to the Impacts of Receding Glaciers in the Tropical Andes (PRAA). This initiative aims partly to generate data to reduce vulnerability and improve risk analysis of changing water availability. Moreover, the Colombian Government has analysed hydrological cycles and glacier retreat in the high mountains.

Summary of the assessment of national policy instruments per country

	Colombia	Ecuador	Peru	Bolivia
Funding	2	3	3	3
Adaptation targets	3	2	2	4
Multisectoral articulation	1	1	2	3
Implementation tools	3	2	2	3
Mountain adaptation	3	3	4	2
Adaptation programmes	3	2	3	2

1: Existent and sufficient, 2: Existent but insufficient/planned but not implemented; 3: General mention; 4: Non-existent.

The Government has also implemented projects for watershed management in páramos, and created water reservoirs and rainwater harvesting systems (Gutierrez and Espinoza, 2010).

Ecuador manages its water resources through the Organic Law of Hydric Resources, Uses and Utilization of Water (2014). The document acknowledges the relevance of páramos as an ecosystem serving to store water and the dependence of the Andean population on their services. The importance of this ecosystem underscores the significance of implementing policies for its sustainable management and conservation.[31]

The Ecuadorian National Climate Change Strategy (ENCC) addresses adaptation in the water sector by planning the following activities: development of the Plan of Water Resources; identification and use of aquifers to head off potential droughts; capacity-building on water scarcity; implementing two projects for water management; building water reservoirs for different uses in case of extreme weather events; and establishing a coordination platform for management and conservation of water resources.

The national water authority is the Ecuadorian National Water Secretariat (SENAGUA), which participates in information exchanges about climate change with ministries involved in the water sector.[32] It has also been involved in the preparation of the National Plan for the Integrated and Integral Management of Water Resources,[33] which will include climate change adaptation indicators or measures. This type of involvement by SENAGUA creates institutional links that may yield robust management, adaptive responses and, more broadly, resilient governance of water resources.

Peru's policy on water resources in the National Agreement (Acuerdo Nacional[34]) provides the framework for water policy instruments.[35] In this policy, the government commits to stewardship of water as part of the nation's heritage, and to access to potable water as a human right. The policy emphasizes the importance of integrated management of water resources as an approach for sustainable, equitable and rational water use. This approach considers basins as the management unit, and climate change as a perturbation.

The relevant law governing water resources is the National Policy and Strategy of Hydric Resources.[36] A strategic component of this policy is Climate change adaptation and extreme events, which aims to reduce vulnerability by enforcing integrated management of water resources. Moreover, this component combines knowledge generation, policy articulation, and adaptation measures. It promotes research, capacity-building, climate change adaptation and risk management within the water sector.

Adaptation policies should be articulated with other instruments (e.g. laws, decrees, planning processes) for risk management in the water sector. In order to institutionalize this articulation, it has to be included in the framework formed by the National System for Environmental Management and the National System of Risk Management. Adaptation measures and mechanisms need to address the supply, demand and use of water resources in a way that considers both current and future impacts of climate change and disaster risk management (Ministerio de Agricultura y Riego, 2015). The National Policy and Strategy is also in accordance with the Peruvian National Environmental Policy and the recently published National Strategy for Climate Change 2015 (Ministerio Del Ambiente, 2015).

Although the Ministry of Agriculture and Irrigation, through the National Water Authority, is the main competent authority for water-related issues, there are other government bodies that also have authority over areas that affect water resources. The Ministry of Environment, water providers and the National Superintendence of Water and Sanitation Services, for example, are responsible for protecting water sources. There are other initiatives, including the Public Investment Projects, that involve multiple sectors such as: environment, housing, agriculture, economy and finance. Due to the different and partially overlapping objectives and priorities of these various governmental agencies and authorities in water-related issues, it is difficult to make concrete action and to attribute concrete responsibilities.

Water policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Adaptation goals	1	1	1	1
Adaptation targets	1	1	1	1
Implementation tools	1	1	1	1
Mountain adaptation	0	0	0	0
Regional considerations	0	0	0	0
Adaptation actions	0	1	1	0

0: Absence; 1: Presence.

CASE STUDY

Adaptation to Climate Change through Effective Water Governance in Ecuador (PACC)

The PACC Project in Ecuador (implemented between July 2008 and May 2015) was a pioneering initiative by improving water resource governance as a means for climate change adaptation. Many communities in the country suffer from the risk of water shortages, and/or are highly vulnerable to the effects of floods and landslides associated with heavy rainfall. The PACC was financed mainly by the Global Environmental Fund (GEF), the implementing agency was the United Nations Development Programme (UNDP) and the Ministry of Environment of Ecuador was the executing agency, through the National Office of Climate Change Adaptation (DNACC) of the Under Secretariat for Climate Change (SCC).

The PACC aimed to increase the ability to respond to the risks of climate change in water resources management at the national and local levels. It was designed as a project generator, implementing pilot projects to generate knowledge for different types of interventions applying the integrated water resources management (IWRM) approach. IWRM is a framework for sustainable watershed management, and is an essential element of adapting to climate change. Pilot projects included constructing water management infrastructure and plans in highland communities.

The intervention had the following priorities:

- Promote sustainable use of water for irrigation and drinking using a watershed approach and support GADs in project management with the participation of other local stakeholders;
- Develop planning tools that integrate climatic and historical findings with hydrological models to inform management plans;
- Support basin management organizations that can manage the use of water within the basin, while working on own GADs programs that increase energy and food security in accordance with the Buen Vivir principle.

Cajas National Park, Azuay, Ecuador

The PACC implemented 20 pilot projects in the highland provinces of Azuay, Canar and Loja, in the Ecuadorian coastal provinces of Manabi and Los Rios, and in the Amazon province of Morona Santiago.

The main project results were:

- The risk of climate change in the water sector was integrated into key plans and programs.
- Strategies and measures to facilitate adaptation to climate change impacts on water resources were implemented locally.
- Institutions had capabilities strengthened, and research findings were disseminated.

CASE STUDY

The Impact of Glacier Retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies

The UNESCO International Hydrology Programme (IHP) project "The Impact of Glacier Retreat in the Andes: International Multidisciplinary Network for Adaptation Strategies" aims to identify the vulnerability of glaciers to climate change, as well as to facilitate adaptation policies targeting glacial melting. To identify these policies, a set of regional activities were organized since 2012, strengthening the science-policy dialogue in the Andean Region.

Four background papers were developed to identify the current gaps and opportunities related to climate change effects on water resources and adaptation potential. The papers were later transformed into policy briefs to inform decision makers. The first policy brief dealt with 'Mapping of vulnerability of water resources to global changes in the Andean Region' and focused on the physical environment. The second brief was entitled 'Policy needs for adaptation strategies in water resources management', and addressed current policies in different countries to identify gaps to meet future conditions . The third paper dealt with 'Education and curriculum needs' on water resources, and snow and glacier issues, showing current gaps. The last paper documented 'Climate Change Adaptation local practices in the Andean Region'.

Complementary to this effort, a regional assessment of the vulnerability of Andean natural resources (water and environmental resources) to glacier melt was finalized. This has led to the identification of areas with higher vulnerability to glacier retreat, and areas for follow-up activities to develop adaptation strategies. A website was created to present these outcomes (http://unesco.envisim.com/) and a final document is being created for public diffusion, in collaboration with GRID-Arendal. A scientific paper has also been submitted for peer review titled "Tracing the white water: Tropical glacier melt contribution to human water use" (Buytaert et al., forthcoming).

Based on the capacity building realized as part of the project, and in collaboration with the project partners and the Andean Climate Change Interamerican Observatory Network project (ACCION) in particular, a manual for analysing glacier mass balance is under development and will be released in 2015.

Peru recently established the National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM).[37] This institute is responsible for generating and consolidating scientific knowledge on climate change to improve conservation and resource use in glaciers and mountain areas. It is expected that it will coordinate with initiatives led by the General Directorate of Climate Change, Desertification and Water Resources on mountains and climate change. Another potential partner is the Working Group on Mountain Ecosystems, which was recently created within the National Commission of Biological Diversity.

Land policy analyses

In **Bolivia**, Law 300 states that the Plurinational Authority of Mother Earth is responsible for implementing a Joint Mitigation and Adaptation Mechanism for the integrated and sustainable management of the forest and Mother Earth. This mechanism aims to conserve, protect and restore biodiversity and ecological functions by facilitating optimal land use. These uses would be part of sustainable production systems, and include agricultural and forestry practices for reducing deforestation and forest degradation as part of mitigation and adaptation strategies (Asamblea Legislativa Plurinacional de Bolivia, 2012). Land, however, is only referred to in the mechanism as it relates to production or other important resources (e.g. forests). This perspective overlooks the importance of soils for responding to climate change, and indicates a potential gap for action. However, this may be solved by the programme Sustainable Management and Use of the Land. This programme is part of the Patriotic Agenda's strategy, Agrarian and productive development. Additionally, there is a specific objective to support communitarian economic entrepreneurs who favour food sovereignty and security (Ministerio de Autonomías, 2013).

Colombia has a National Policy for the Integrated Environmental Management of Land (GIAS), which is governed by the Ministry of Environment and Sustainable Development (MADS). This policy prioritizes sustainable agriculture and forest management, which may be considered an adaptation measure. It may also contribute to mitigation through carbon sequestration. The main goal of this policy is disaster risk reduction (Ministerio de Salud y Proteccion Social, 2012). The policy includes a sustainability principle, with one of its key elements being climate change resilience.

CASE STUDY

Regional Initiative on Hydrological Monitoring of Andean Ecosystems (iMHEA)

A key service provided by Andean ecosystems is the supply and regulation of water for domestic use, agriculture and hydropower generation. However, basic information about hydrological processes in the Andean ecosystems is still needed to understand the effectiveness of different climate change adaptation measures that target land use in Andean watersheds. However, it has been difficult to establish and maintain research-grade observation networks because of remoteness and the lack of recognition of these ecosystems as water providers. The iMHEA was created by Andean experts and institutions to address these obstacles.

Cotopaxi National Park, Ecuador

The iMHEA aims to increase knowledge about the hydrology of Andean ecosystems to support decision-making for the sustainable management of Andean water resources. The researchers who are members of the iMHEA agreed on the following goals for the network:

- Generation and management of information, according to common standards, about the hydrology of Andean ecosystems;
- Promotion of interaction among research, public, private, and community entities interested in Andean hydrology;
- Strengthening the technical capacities of local entities about water resources;
- Diffusion of the results of research on Andean hydrology.

Currently the network monitors 17 small catchments in 8 communities throughout the Tropical Andes, which will soon make it possible to draw conclusions at the regional level and to identify spatial variability in sub-regions. The programme also benefits these communities through capacity building and detailed hydrological information for water management. This monitoring program fills a gap in the data from the national hydro meteorological networks, initiatives on monitoring of glaciers under climate-change conditions, and hydrological modelling studies, which have been insufficient for hydrological management decisions in the Andes.

It also mentions risks and vulnerabilities of land to climate change. Therefore, adaptation policies for preventing degradation or improving soils quality need to be included in future plans and activities. The Colombian National Pilot Programme for Climate Change Adaptation (INAP), for example, proposes planning models for land use that incorporate climate change. Furthermore, one of the specific prioritized actions is the delimitation and protection of 36 páramo areas (approximately 3 million hectares) by 2030.[38]

The fifth objective of the **Ecuadorian** ENCC includes adaptation strategies for protecting land experiencing climate change, including the protection of natural protected areas, sustainable land management, and remediation of over 1,000 hectares of land (Ministerio del Ambiente, 2012). The land sector is managed by the Ministry of Urban Development and Housing through the Public Policy for the Use and Management of Land,[39] which does not include climate change adaptation goals but focuses on urban planning. This provides an opportunity to design adaptation policies for urban expansion in the mountains, in particular related to the importance of protecting soil and building on suitable soils and slopes.

Peru's National Environmental Policy includes activities to prevent desertification and to mitigate or remediate soil degradation and loss (Ministerio del Ambiente, 2009). The ENCC includes a key goal for the public and private sectors to conserve carbon reserves and reduce greenhouse gas (GHG) emissions (Ministerio del Ambiente, 2015). Moreover, the ENCC links the vulnerability of land with that of water: land vulnerability increases water vulnerability, and vice versa.

Agriculture policy analysis

Article 24° (Agriculture, Fishing and Farming) of **Bolivia**'s Law 300 specifies that the sustainable development of agriculture and farming is important for achieving good living standards, and an expansion in agricultural area if foreseen over the coming ten years. Additionally, the resilience of the agricultural sector is important for maintaining the country's food sovereignty. However, the article dedicated to agriculture does not mention climate change (Asamblea Legislativa Plurinacional de Bolivia, 2012). Although this omission may be due to an understanding of climate change as a cross-cutting issue, generating knowledge on the impacts of climate change on agriculture and mountain ecosystems would allow policies to target specific issues in different communities, diminish vulnerability, and increase adaptive capacities. One such example that could be replicated is from the recent pilot project on Ecosystem-based Adaptation (EbA) in Nor Yauyos-Cochas Landscape Reserve, Peru, which has been jointly implemented by UNEP, UNDP and IUCN (see case study).

Colombian agriculture policy, Action Plan 2014,[40] includes actions towards reducing the risk of climate change for specific crops and territories. Colombia is also implementing the strategy Climate and Colombian Agricultural Sector: Adapting for Sustainable Production. This strategy seeks to improve the competitiveness of the agricultural sector through the implementation of policy instruments, strengthening investment for research, technological development, and innovation.[41] Under the strategy, data has been gathered and is being used to generate models for interactions between climate change and agriculture. It is providing agro-climatic forecasts for the main agricultural areas of Colombia. Additionally, it has identified climate-limiting factors for rice, beans and maize production, which may result in production gaps for farmers in 11 of the 32 departments (departamentos) in Colombia. This information raises important questions that can help the development of policies for climate change adaptation (e.g. which crops and/or activities could replace rice, beans and maize cultivation? Is there research on drought-resistant or heat-tolerant varieties?). The knowledge-policy interface may be an area that requires work in multiple sectors.

According to the **Ecuadorian** ENCC, the country has implemented measures to guarantee food sovereignty under changing climate conditions and to react to the risks of climate variation for its crops (Ministerio del Ambiente, 2012). However, the Ministry of Agriculture, Farming, Aquaculture and Fishing – the governing

Land policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Adaptation goals	1	1	1	1
Adaptation targets	1	0	1	1
Implementation tools	1	0	0	1
Mountain adaptation	0	0	0	0
Regional considerations	0	0	0	0
Adaptation actions	0	0	0	0

0: Absence; 1: Presence.

CASE STUDY

Ecosystem-based Adaptation (EbA) in the Nor Yauyos Cochas Landscape reserve, in the Peruvian Andes

In the high mountains of Peru, an Ecosystem based Adaptation (EbA) pilot project was implemented. This is an innovative approach which protects ecosystems as a means to adapt to climate change. The project was implemented in the Nor Yauyos Cochas Landscape Reserve (NYCLR), located in the Lima and Junin departments (see image). Its main objective was to strengthen the country's capacity to identify and implement climate change Ecosystem-Based Adaptation (EbA) measures, by developing the tools necessary for both implementation and monitoring.

The Peruvian EbA pilot project supported local communities in developing sustainable livestock practices, including grassland management to prevent overgrazing by domesticated animals. This benefits natural grasslands, comprising bofedales (wetlands) and pajonal (puna grasslands), which are the NYCLR's most extensive ecosystems. These ecosystems are the most pressured by livestock grazing, and are potentially the most seriously threatened by the adverse effects of climate change, according to the vulnerability assessment conducted as part of the project. The most important ecosystem services for the local community is providing pastures and water for livestock production - the major economic activity in the area. Other ecosystems services include fresh water provision and biodiversity preservation also for lowland communities.

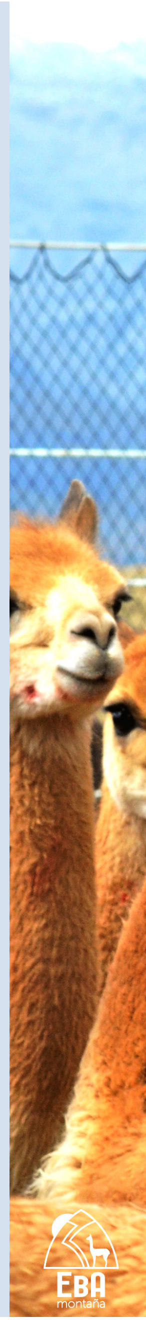
As a result of measures taken by the communities, facilitated by the EbA programme, the mountain ecosystems now also provide economic benefits from the vicuña (vicugna vicugna), a wild camelid threatened by livestock overgrazing and spreading diseases. The vicuña is gathered in season in a communal effort to collect their wool before they are released back into the wild. It's wool is one of the finest natural fibres in the world and is among the most expensive. Sustainable management of this resource therefore provides important revenue to the community, further enhancing its adaptive capacity and well-being.

EbA measures implemented in the reserve:

- Vicuña management for animal fiber (in Tanta and Tomas);
- Community-based sustainable native grasslands management, including livestock management (in Tanta, Canchayllo and Miraflores); and
- Community-based sustainable water management, including (ancestral) hydric infrastructure, and wetland and grasslands restoration (in Canchayllo and Miraflores).

The project has also made progress towards its aim to upscale EbA and to mainstream the concept in public policy. Through an initiative to foster the preparation of guidelines for public investments in biodiversity and ecosystem services, the project positioned EbA in the guidelines for public investment projects related to biodiversity and ecosystem services. These were recently released jointly by the Ministry of Environment and the Ministry of Economy and Finance.

The pilot project in NYCLR was part of the Ecosystem-based Adaptation Programme (EbA), which was a global initiative implemented by UNEP, UNDP and the International Union for the Conservation of Nature (IUCN), funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The World Conservation Monitoring Centre (UNEP-WCMC) also participated in this effort. These organizations cooperated with national governments to use the EbA approach. Mountain ecosystems and populations were particularly sensitive to the impacts of climate change, and hence are targeted by the EbA Programme. In addition to the project in Peru, experiences of EbA in mountains were being developed in the Himalayas in Nepal, and in the East African mountains on Mount Elgon in Uganda. In Peru, the programme was commissioned by the Ministry of Environment of Peru (MINAM) with the support of the National Service of Natural Protected Areas (SERNANP). The activities under IUCN's responsibility were implemented in partnership with The Mountain Institute (TMI) in the communities of Canchayllo and Miraflores.



Vicuña management, Peru (Mountain EbA Project)

Agriculture policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Adaptation goals	1	1	1	0
Adaptation targets	1	0	0	0
Implementation tools	1	0	0	0
Mountain adaptation	0	0	0	0
Regional considerations	0	0	0	0
Adaptation actions	1	0	0	0

0: Absence; 1: Presence.

body of food production – does not have initiatives for climate change adaptation. Currently there is no consistent approach in implementing actions for food security through the ENCC, nor does the national authority in agriculture have any adaptation actions that reflect the multisectoral nature of climate change. Extensive efforts should be dedicated to creating institutional arrangements that would tackle the impacts of climate change on food production.

In **Peru**, the Ministry of Agriculture and Irrigation (MINAGRI) has implemented the Plan for Risk Management and Adaptation to Climate Change in the Agricultural Sector (PLANGRACC- A) to assess the impact of four extreme events (frost, hail storm, flood, and drought) on 11 crops, four species of livestock, and four species of grass. In addition, a project on the construction, maintenance and recovery of terraces combined with the conservation of natural resources is expected to optimize farming and generate environmental services for adaptation to climate change and reduction of desertification. However, Peru faces the challenge of linking the results of sectoral policies. Another challenge is to coordinate national and subnational levels to provide consistency, constructive feedback, shared lessons, and economies of scale in interventions.

Public health policy analyses

Bolivia has not yet implemented climate change adaptation policies in the public health sector, even though there is evidence of climate change having a wide-ranging impact on human health in the country.[42] According to UNDP,[43] data gathering and information systematization on climate change impacts on human health are still in their early stages.

Colombia's Ministry of Health and Social Protection (MSPS) has been leading several actions to assess the sector's vulnerability to climate change.[44] Since 2011, MSPS has conducted several workshops to raise awareness on climate change and environmental health. It has also funded campaigns to monitor and prevent vector-borne diseases (e.g. dengue fever), which are increasing due to climate change.[45] In addition, adaptation initiatives are part of the 10-year Plan of Public Health 2012–2021, specifically the Integral Risk Management in Emergencies and Disasters component. The goals include greater disaster risk management to reduce current and future impacts of climate change.

The Ministry is preparing the sectoral plan for climate change adaptation following the directives of the National Climate Change Adaptation Plan (Ministerio de Salud y Protección Social, 2012). Moreover, the MSPS is formulating the environmental health component of this plan, which is expected to be fully implemented by 2015 throughout all of the Regional Directorates of Health.

The **Ecuadorian** Ministry of Public Health, through its Environment and Health Directorate, protects human health from the impacts of climate change with measures such as identifying the relationships between climate change and the occurrence of malaria, dengue, leishmaniasis and respiratory diseases. Between 2010 and 2012, the Control and Monitoring of Malaria

Health policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Adaptation goals	1	1	0	A
Adaptation targets	1	1	0	NA
Implementation tools	1	1	0	NA
Mountain adaptation	0	0	0	NA
Regional considerations	0	0	0	NA
Adaptation actions	1	0	0	NA

0: Absence; 1: Presence, NA: Not Available. Authors' elaboration.

Disease Programme has contributed to a 70 per cent reduction in malaria diagnosis.

The Environment and Health Directorate supports capacity-building plans for environmental and occupational health, and climate change. Additionally, Ecuador has free health care, which is a particularly important provision, especially for the most vulnerable groups.

The **Peruvian** Health Ministry (MINSA) does not have actions specifically directed towards climate change. It does, however, have actions for disaster risk management which include climate-related events. These actions include the provision of health care in the event of disasters. One example of the increasing recognition of climate effects on health is the participation of the Ministry in the Multisectoral Plan for the El Niño phenomenon.

Disaster risk management policy analyses

Bolivia's Law 300 is a framework law which addresses disaster risk management. Article 17° specifies relevant sectors to be protected or to have risks managed, with climate-related disasters being referred to directly in subarticles (Asamblea Legislativa Plurinacional de Bolivia, 2012). It is possible that areas impacted by disasters related to climate change will be targeted by funding recently allocated by the World Bank in 2016 to implement risk management and climate change adaptation programmes (World Bank, 2015b).

Risk management is included in Bolivia's Patriotic Agenda's section Strong Production and Employment. The third strategy of the section is Environmental Quality Management and Integral Risk Management, which includes three programmes: Disaster Prevention in vulnerable sectors; Hydrometheorological information for Risk Management, and National Sectoral System for Risk Management and Early Warning (Ministerio de Autonomías, 2013).

Colombia understands risk management and climate change adaptation as complementary strategies, although the responsibility for these rests with different institutions and thus requires coordination (Departamento Nacional de Planeación, Ministerio de Ambiente y Desarrollo Sostenible, 2013). The National Unit for Disaster Risk Management (UNGRD) is the agency in charge of disaster risk reduction, while SISCLIMA (National Climate Change System) is the agency responsible for climate change adaptation. The existence of multiple organizations with partially overlapping mandates has not led to joint actions at the regional or local level, and better coordination is required between these institutions and subnational level authorities. Nevertheless, risk management has been included in some projects in the agricultural, land, hydric and energy sectors.

Ecuador has mapped the susceptibility and risk of mass movement processes using mapping analysis and climate change scenarios. It has also identified and started implementing at least three multipurpose infrastructure projects to address extreme water events caused by climate change. These infrastructure projects include creating protection for riverbeds, building retaining walls to reduce flood risk, and digging drainage channels. In addition, Ecuador's National Plan for Risk and Emergency Prevention incorporates measures to adapt to climate change. Furthermore, three studies of flood control projects have been conducted in the most sensitive areas of the coastal region.

Peru's National System for Disaster Risk Management (SINAGERD) is in charge of pre-and-post disaster actions and is supported at the highest political level.[46] SINAGERD coordinates the participation and responsibilities of different ministries, including the Ministry of the Environment and the National Service of Meteorology and Hydrology (SENAMHI, 2014). SINAGERD is responsible for both climate-driven and non-climate-driven disasters (such as frost due to El Niño) (see Table).

SINAGERD has only recently been created and so is not tested in responding to extreme climatic events. However, it is performing an important role in implementing evidence-based responses to risk scenarios.

Case study: legal framework for disaster risk management in Peru

<table>
<tr><th></th><th colspan="2">Strategic Instruments for Risk Management Action</th></tr>
<tr><td rowspan="3">Law N° 29664 to create SINAGERD</td><td colspan="2">Multisectoral Plan for Frost and Extreme Cold Spells 2015</td></tr>
<tr><td rowspan="2">Supreme Decree N° 160-2015-PCM[47]</td><td>Multisectoral Actions Plan in the event of the El Niño Phenomenon</td></tr>
<tr><td>Multisectoral Actions Plan for the rainy season 2015–2016[48]</td></tr>
</table>

Risk management policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Funding	1	1	1	1
Adaptation targets	1	1	0	1
Multisectoral articulation	1	1	1	0
Implementation tools	0	0	0	0
Mountain adaptation	0	0	0	0
Adaptation programmes	1	1	1	0

0: Absence; 1: Presence.

Andean forest policies analyses

Bolivia's Joint Mechanism of Mitigation and Adaptation of Integral and Sustainable Management of the Forest and Mother Earth includes forests as one of its goals (Pacheco Balanza, 2014). The document does not, however, present specific strategies for Andean forests. There is an opportunity to work with the government, international organizations, civil society and local populations to formulate programmes for Andean forests in Bolivia.

Both **Ecuador** and **Peru** focus their strategies for their Andean forest (and forests in general) on climate change mitigation (e.g. reduced emissions from reduced deforestation through the REDD+ initiative) rather than on adaptation.

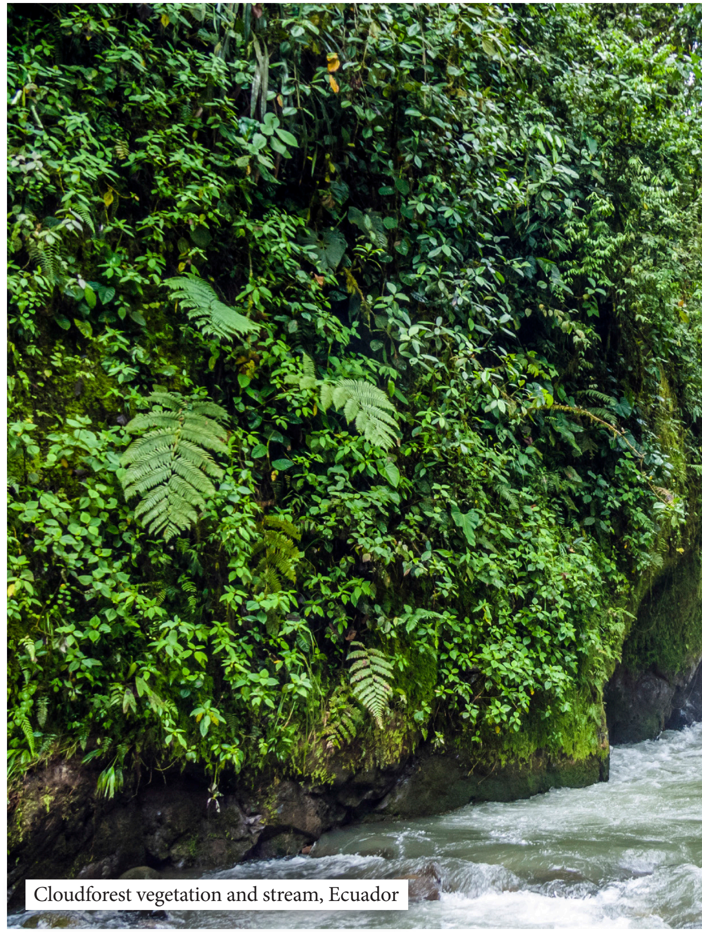
Colombian Andean forests are within the legal framework that protects flora (laws 299, 464 and 599). International agreements for timber use, including penalties for illegal use of non-timber forest products, also apply. In 2010, resolution 383 listed the threatened wild species, including tress, across the country (Garavito et al., 2012).

Andean forests are part of the Páramo Programme for the restoration and sustainable management of the Colombian high mountain ecosystems. One of the programme's objectives was to expand research on climate change in mountain ecosystems in order to understand the ecosystem goods and services provided; the structure and function of forest ecosystems; ecological restoration; and vulnerability to climate change. In addition to research, the programme also included goals and activities for conservation, mitigation, and adaptation of páramos to climate change (Ministerio de Medio Ambiente, 2002).

Andean forest policy matrix

Sector	Colombia	Ecuador	Peru	Bolivia
Funding	1	0	0	0
Adaptation targets	1	0	0	0
Multisectoral articulation	1	0	0	0
Implementation tools	0	0	0	0
Mountain adaptation	0	0	0	0
Adaptation programmes	1	0	0	0

0: Absence; 1: Presence.


Cloudforest vegetation and stream, Ecuador

Hummingbird, Cocora Valley, Colombia

CASE STUDY

The Andean Forest Monitoring Network: a communication platform for science and policy in the Andean countries (Red de Bosques Andinos)

Tropical mountain forests are fragile but contain high biological diversity. In total these forests host 45,000 vascular plants and 3,400 species of vertebrates in just 1% of the Earth's land mass. However, high mountain tropical forests are seriously threatened by climate change and land use changes. Despite these threats, knowledge about the effects of global change on biodiversity in tropical mountain forests is still poorly understood. It is therefore a priority to establish and apply long term monitoring of these ecosystems.

A workshop held in October 2012 in Lima, Peru, brought together more than 40 scientists and policy makers working on Andean forests. Among the results of the workshop, it led to the formation of the Andean Forest Monitoring Network. The goals of the network include stimulating scientific research on Andean forest ecosystems by promoting collaboration among scientists, and serving as a platform to facilitate applied research and communication between scientists and policy makers. Current members of the network include scientists from Argentina, Colombia, Ecuador, Germany, Peru, USA, and representatives of Ministries of Environment and the national Climate Change adaptation programs of Colombia, Bolivia, Ecuador, and Peru. The creation of the network, and the development of its first two papers, was possible thanks to the financial support of the Swiss Agency of International Cooperation (SDC) through the International Centre on Environmental Monitoring (CIMA), the German Corporation for International Cooperation (GIZ), and the endorsement of the Andean Community General Secretariat (SG-CAN).

The network has produced two important documents for the region. The first is an extended protocol to monitor biodiversity and carbon dynamics in Andean forests (Osinaga et al., 2014). This protocol was developed by the Institute of Regional Ecology, National University of Tucuman, Argentina, and has been revised by experts working in the Andes. It describes methods to monitor ecological changes over midrange and long periods of time. It focuses on changes in the diversity and growth rates of trees, shrubs and lianas; the cover of herbaceous species; and the carbon content in forests. This protocol is a useful tool for those interested in conducting long-term ecological research. Moreover, its use produces standardized data needed to understand ecological processes.

The second document presents a meta-analysis of the dynamics of trees and carbon in the region, the first conducted in the region. Network members contributed data from more than 60 monitoring sites located from Colombia to Argentina. Some sites have been monitored since the 1990's. The initial results indicate that warmer, wetter, and more seasonally differentiated forests had higher turnover rates of individual trees, and biomass. Most of these patterns hold for both, tropical and subtropical forest sites.


Uyuni Salt flat, Bolivia

Institutional and stakeholder analysis

The following paragraphs identify Andean countries' formal and informal institutions that are relevant for climate change adaptation. The formal institutions are explicitly integrated in relevant policy processes through the national instrument for climate change adaptation. The informal institutions are those participating in the process but without holding a formal policy responsibility. Moreover, involved institutions are characterized as either public, international or civil society organizations.

Bolivia

Law 300 and the Patriotic Agenda constitute the framework for adaptation measures in Bolivia. The Plurinational Mother Earth Authority (APMT) and the Ministry of Environment and Water are the authorities responsible for climate change adaptation. However, actions to address climate change are of a multisectoral scale and implemented by the respective sectoral institutions. As of today, there is no national strategy or policy on climate change or climate change adaptation. Civil society participation in elaborating climate change adaptation policy approaches appears to have declined in recent years. In 2009, the Platform for Social Organizations for Climate Change was formally created, to include an alliance of 180 social movements, national and international NGOs and other civic organizations. The objective of this Platform was to represent the needs of the groups most vulnerable to climate change. However, this Platform shows no evidence of recent activity.

Colombia

Colombia has an intersectoral policy approach to climate change adaptation involving a variety of institutions. The responsibility rests on the competent respective sector agencies and the regional and local authorities rather than on the National Development Plan (NDP), which lays out SISCLIMA, the instrument for coordinating public offices for adaptation action. One implication of this decentralized approach is that SISCLIMA funds and proposes programmes on agriculture adaptation, whereas the competent ministry (in this case the Ministry of Agriculture and Rural Development – MADR) is responsible for its implementation. Nonetheless, SISCLIMA involves not only public bodies but also civil society institutions such as universities, indigenous communities' representative institutions, research centres, as well as companies.

The Organisation for Economic Cooperation and Development (OECD) considers SISCLIMA a strong policy framework for climate resilience actions, with its ambitious design and wide institutional network and linkages. It is equipped with a coordination mechanism and each involved office and unit has a specific role. For instance, the Intersectoral Commission on Climate Change (COMICC) manages SISCLIMA. It is also in charge of proposing strategic action to the Financial Committee. COMICC is assisted on sectoral issues by consultative boards, two of which are permanent: scientific- technical and technical-political. The Financial Committee funds the other committees' activities, using advice received from the COMICC. Other committees, such as sectoral, territorial, international affairs, information and climate change cross-cutting research, also have working groups for designing cooperation, research and evidence collection.

Colombia's Climate Change Regional Nodes (NRCC) support the design of territorial plans, which envisage the participation of relevant stakeholders (Departamento Nacional de Planeamiento, 2010). The greatest challenge facing the successful implementation of Colombia's adaptation policy is the lack of capacity to control and monitor the effectiveness of measures carried out to address climate change. In addition, having several institutions responsible for sectoral actions does not guarantee that capacities are at the same level.

Ecuador

Ecuador has also adopted an intersectoral approach to climate change adaptation. This approach allows for the participation of different public, private and civil society actors through coordination networks established between the responsible ministries and autonomous decentralized governments (GADs). These GADs are multi-level: region, province, canton and parochial. The CICC is responsible for intersectoral coordination. Moreover, this network includes ministries and GADs for the design and implementation of policies.

Case study: Objectives of the CICC

The CICC has the following objectives in the context of climate change:

1. Leading and coordinating the execution of policies relevant to climate change, the ENCC and the agreements of the UNFCCC
2. Promoting research and technical input for policy development
3. Coordinating the preparation and validation of mitigation and adaptation parameters for public budgeting projects
4. Enabling the participation, counselling and the assembling of specific work groups
5. Supporting capacity-building, technical counselling, specialization and diffusion of innovations
6. Gaining additional financial and technical support through international cooperation
7. Defining official positions and delegations for international negotiations and
8. Coordinating, facilitating the preparation of, and approving the national reports and technical instruments for international presentations.

The CICC's constitution authorizes it to establish sectoral councils able to call on institutions to undertake sectoral and intersectoral actions. The actions are coordinated by a ministry and have a technical secretary, full members, associated members and guest members. Civil participation is not formally included in the ENCC. However, the ENCC emphasizes the relevance of considering the opinion of civil society when implementing adaptation actions at the local level.

Peru

MINAM is the institution responsible for climate change adaptation and creates the National Strategy for Climate Change (Ministerio del Ambiente, 2015). MINAM has a General Directorate of Climate Change, Desertification and Water Resources (DGCCDRH) that directly supervises climate change policy. Though MINAM is a governing body, it has to coordinate its actions on sectoral issues with other ministries. For instance, to address climate change impacts on fishing, MINAM has to coordinate with the Ministry of Production. Further, MINAM's budget has to be approved by the Ministry of Economy and Finance, though climate change research and projects are also funded by other sources such as through international cooperation. The funds, however, support specific projects (responding to a specific interest of the concerned funding agency or country) for a specific period of time.

Peru's governing agency leads a National Commission for Climate Change (CNCC). Within this Commission, civil society and the government exchange proposals and evidence to assess the effects of climate change. CNCC has technical groups formed by intersectoral entities addressing several topics, including climate change adaptation. Additionally, Peru's subnational governments have to include climate change considerations in their development plans. In September 2014, 14 regional governments agreed to draw up Regional Strategies for Climate Change (RSCC), 23 had created Regional Technical Groups for Climate Change, and one formed a Regional Council for Climate Change and elaborated an Implementation Plan for its RSCC (Ministerio del Ambiente, 2015).

Peru hosted the UNFCCC COP20 in December 2014, which put climate change and mountains on the national agenda and empowered civil institutions working on it. Currently, there is activism for climate change awareness in the population; particularly among young people. Some indigenous organizations participated in the COP and have undertaken various actions to build capacity and adopt climate change adaptation measures. Furthermore, there are high expectations for the adaptation goals proposed in the INDC, which include increasing water availability; reducing the negative impacts of climate change on agriculture and fisheries; increasing forest resilience through sustainable land management and taking a landscape perspective; and reducing vulnerability and increasing resilience to climate change effects on health.[49] The National Adaptation Plan – the national instrument for implementing these goals – is expected to be elaborated soon; however, funding has not been secured to complete the activities needed.

Gender issues

Mitigating the negative effects of gender inequalities is not adequately addressed in the climate change adaptation policies of the Andean countries. Though gender norms and sex-specific issues may be explicitly mentioned in some policies, Andean countries have not systematically included gender considerations in adaptation policies; thus, overlooking rampant inequalities. Ecuador includes mention of gender inequality in policies prioritizing sectors and actions through the ENCC, including prioritizing groups according to age, gender, and poverty levels, although the procedures to achieve this criterion in practice are not explained. Meanwhile, states such as Peru and Colombia have ministries (e.g. Peru's Ministry of Development and Social Inclusion) responsible for including people who are vulnerable due to gender norms. Nonetheless, awareness of the importance of gender relations for adaptive capacity is more developed within civil society, where NGOs promote the incorporation of a gender perspective throughout the government.

Salt evaporation ponds, Maras, Peru

Indigenous people

Indigenous people have interacted with climatic variability and change in the Tropical Andes Mountains over millenniums. In the process, people have developed essential knowledge about the local climate and environment (Melo Cevallos 2014; Llosa Larrabure, et al., 2009). This knowledge is increasingly acknowledged and included in policy instruments and practices for adapting to climate change (Torres et al., 2014). Peru's ENCC states that actions should be implemented with an intercultural perspective that is appropriate to their indigenous populations' collective rights. Colombia's Joint Programme for Ecosystem Integration and Adaptation to Climate Change in the Colombian Massif aims to generate adaptive capacity in rural and indigenous communities by truly acknowledging these populations as citizens with rights and knowledge, respecting their way of life, and exchanging experience (Ministerio del Ambiente y Desarrollo Sostenible, 2015). It is also relevant to emphasize the changes brought about by COP20 which, by increasing the number of stakeholders involved in the process, included increasing the representation from indigenous organizations in the discussion and final agreements. The importance of strengthening the knowledge of indigenous people on climate change to facilitate adaptive capacity, in addition to removing other barriers, such as discrimination and poverty, was further stressed in the 2015 Paris Agreement (UNFCCC, 2015).[50]

Locals in a market in Pisac, Peru

TROPICAL ANDES MOUNTAINS

Gap analysis

Bus travelling on road through landslide terrain in Peruvian Andes

Comparative analysis of available policies

Following the review of the impacts of climate change on natural and human systems (Chapter 2) and analysis of existing policies (Chapter 3), this chapter identifies existing adaptation policy gaps, but also opportunities, relating to country and sectoral policies on water; ecosystem functions and biodiversity; food; health, and energy. A selection of regional cases illustrating adaptation measures and policies are also presented.

The analysis of national and sector policies shows that one potential gap is that policies are not designed for easy integration with other instruments, which is further complicated when policies are from another sector. Because adaptation has just started to receive more attention in policy circles over the last few years, there is little experience on how to vertically integrate adaptation instruments and measures from national to local levels, and whether to do this across and/or by sector (Hoffmann, 2015). This early stage of adaptation policy development explains, in part, why they are still absent in some sectors, and why existing instruments have not included performance indicators. Generally speaking, the policies analysed have been found to be based on sectors' needs, whereby key climate risks identified under Chapter 2 have not guided policy design.

Analysis reveals that there is little specific mention of mountains in the sectors'[51] policies and few specific policies for mountains. However, certain instruments do have a mountain specific scope. For example, in Ecuador the páramo are defined as fragile ecosystems in Ecuador and included as such in different policies. In addition to the perceived

Farmers, Venezuela

remoteness of mountains, this neglect could be due to several factors. These could include the perception that mountains do not have unique problems or that the problems are already being addressed by non-mountain-specific approaches (Ariza et al., 2013). The difficulty in defining mountain ecosystems (including their boundaries) hinders using them as units for policy design, even when there is political interest in such ecosystems. Policies may also be more focused on urban and/or lowland areas and there might be greater interest in protecting an ecosystem's functions and services rather than the ecosystem itself (i.e. mountains). Another possible explanation is that mountains become objects for policymakers only when impacts visibly affect urban centres, lowlands or productive activities important for the Gross National Product [including "damaging extractive industries"]).

Though mountains in the region are not specifically acknowledged as policy "objects/subjects of interest", more analyses are needed of the multiple impacts of climate change on mountain ecosystems and sectors. For instance, changing water availability within mountains may have significant impacts on health, energy, and several productive sectors, which in turn will feed back on adaptive capacity and exposure of mountain social-ecological systems. Further, these impacts will hinder economic development from the national to the local levels, and cause livelihood and economic losses at the local levels.

Although extreme weather events and their direct impacts (e.g. through floods and landslides) on populations do grant them attention from policymakers, this is mainly in the form of emergency ad-hoc measures and disaster risk management/reduction, while adaptation policies to prevent such losses or increase resilience remain sectoral-based.

Finally, there is a clear disconnect between the scientific community and the transfer and uptake of scientific knowledge in policymaking. This gap is an opportunity for collaborative work among scientists, public and international agencies, civil society, and mountain populations (who are among the most vulnerable to social, political and climatic changes).


Mérida city, Venezuela

Water

Current and projected changes in precipitation, floods, droughts, and glacier melt all bring with them a number of key climate-related risks (identified in Chapter 1), including conflict and political and social unrest over water supply, decreased quality and quantity of water supply, and reduced capacity of mountains to provide water for drinking, sanitation, industries, mining, agriculture and energy.

All Andean countries have developed policies to tackle floods and droughts. These policies are developed by different sectors depending on the impacts. For multi-sector responses, reactive logic over prevention generally prevails. For instance, the transport and housing sectors normally respond when floods destroy infrastructure (e.g. bridges, roads and towns), while measures from the energy sector address the effects of flooding on power plants. The agricultural sector responds when floods damage crops and livestock. Similarly, when floods affect drinking water or people's health, then it is the health sector that responds. Additionally, floods are also considered disasters and are attended to by each country's risk management agency. The occurence of a strong ENSO in 2015/16 has triggered responses ranging from cleaning the basins to flood management programmes, from finishing the school year early to prevention campaigns. Peru also dropped the idea of hosting the Dakar Rally, alleging possible impacts of El Niño in early 2016.

The water management policies of the tropical Andean countries are chiefly guided by the Integrated Water Resources Management approach (IWRM) (Garcia, 2008; Mulligan et al., 2010; Boelens, 2008) although this is not the only approach used.[52] IWRM promotes the coordinated management of water, land and related resources, to maximize economic and social welfare equitably and without compromising the sustainability of vital ecosystems (UNEP, 2009). However, in order to manage water-related risks in a changing climate, IWRM needs to be extended with respect to the risks of climate change (Mulligan et al., 2010; Döll et al., 2015). This extended approach incorporates knowledge generation about potential risks and opportunities, implementing adaptation measures and building water management infrastructure. The countries have implemented institutional arrangements for addressing water-related risks, though their effectiveness has not yet been tested.

Puya clava-herculis bromelia, Ecuador

Opportunities

Increasing water flow and/or precipitation in some areas of the Tropical Andes may be beneficial if the appropriate policies are in place. Policies should promote research to understand impacts of a wetter climate, and inform the creation of enabling conditions to take advantage of such new conditions.

Unstable water supply and soaring demand are leading to water conflicts. This represents an opportunity for forward-looking planning, which promotes a development model drawing on adaptive institutions for addressing conflicts and on land uses that are less demanding on water resources.

Policy gaps

- Insufficient institutional coordination capacities among sectors threatened by water-related risks.
- Limited budget for early warning systems and rehabilitation measures.
- Policies and measures are biased towards urban areas.
- Lack of mountain-specific focus.

Loss of ecosystem functions and biodiversity

Globally and also within the Tropical Andes countries, biodiversity policies are more aligned with the goals and strategies of the Convention on Biological Diversity (CBD) than of the UNFCCC. For example, biodiversity policies are mainly aimed at conserving species and landscapes threatened by human activities e.g. land use. However, biodiversity policies are increasingly acknowledging the threats of climate change to species, ecosystems and ecosystem functions.

Opportunities

Climate change is modifying the ranges of species' habitats and ecological niches, whereby species are moving to new locations or disappearing when suitable conditions no longer exist. In this context, protected areas may not be covering what used to be habitats and landscapes of endangered species. It is also possible that such species have moved beyond the area's boundaries. This represents an opportunity for linking conservation and climate change while revising the location and function of protected areas. Protected areas – and more specifically, mountain protected areas – have been identified and are increasingly recognized, as instruments for climate change adaptation policies (Dudley et al. 2010; Hoffmann et al. 2011). Considering the long-term impact of climate change, it may be worth exploring how protected areas ought to be selected and designed, bearing in mind that species' ranges and habitats will continue to shift due to climate change.

Furthermore, there is increasing global recognition of the links between biodiversity and climate change and the opportunities provided through ecosystem-based approaches to adaptation to climate change (EbA), which links the conservation, restoration and sustainable use of biodiversity and ecosystem services with climate change adaptation.

Policy gaps

- Adaptation policies have generally not yet included actions to prevent climate change impacts on ecosystems and biodiversity (although Peru, for example, has included EbA within its INDCs).
- Systematic and functional linkage of CBD and UNFCCC programmes and strategies.
- Insufficient protection of the full range of ecosystem services contributing to human well-being. This is more acute in the case of services provided by mountains, probably based upon the little recognition of both the services themselves and the role played by their inhabitants in their maintenance.
- Insufficient recognition of protected areas on sub-national levels as important instruments for climate change adaptation.

Flamingos, Uyuni Salt flat, Bolivia

Health

Health policies in the region that explicitly address climate change effects are generally guided by the perspective of disaster risk reduction. Extreme events are prevalent in the mountains and thus are important for mountain communities, but climate change will also affect health more broadly, such as by affecting economic development and nutrition. In the tropical Andean countries there are also increasing efforts to understand the effects of climate change on vector-borne (e.g. malaria, Zika, dengue) and respiratory diseases (e.g. asthma and respiratory tract infections). As the fourth IPCC report (Field et al., 2012) notes, climate change will generally exacerbate already-prevalent diseases and will threaten people who are already vulnerable to health problems. Latin American countries have in general made significant progress in expanding health-care coverage (Atun et al., 2015). However, remote and poor communities are still disproportionally lacking health care. This increases the risk from climatic changes in addition to other health risks affecting vulnerability to these changes.

Woman weaving, Cajamarca, Peru

Policy gaps

- Lack of mountain-specific health policies for addressing climate change impacts and general lack of access to health care in poor and remote communities.
- Insufficient cross-sectoral coordination and vertical integration (from the national to the local level) on targeting vulnerable groups with health care and development measures that take account of climate change.
- Insufficient research generated about the indirect effects of climate change on health. For instance, climate change impacts on water availability may result in higher rates of infectious diseases due to strained sanitation systems. The effects of climate change on agriculture and nutrition may also impact on health.

Opportunities

People's health may reflect impacts of both extreme events and climate change. Thus, there is an opportunity for multisectoral work on adaptation to improve peoples' health.

Food (agriculture)

Farming in the high Tropical Andes is dominated by small-scale family farms in communities with few other economic opportunities and limited adaptive capacity (Wymann et al., 2013). Adaptation measures in these areas must also address wider social factors, such as poverty, education, and urbanization. Some farmers could see diminishing crop yields, which would negatively affect their nutrition and general economic situation. This is due to the numerous effects of climate change, including changes in hydrology, temperature, precipitation, ecosystem degradation and changing pests. However, certain crops are positively affected by climate change, which could improve the situation of other farmers. Combining technical capacity with traditional knowledge on climate change is necessary to ensure that highland communities can adapt to these changes and improve their economic situation.

Tropical Andean countries emphasize different adaptation approaches to changes in agriculture. However, in a general, the specific problems facing highland farmers are not afforded attention. Colombia combines the reduction of risk for crop failure with strengthening competitiveness for export: it is implementing adaptation policies while investing in research and innovation. Ecuador focuses on securing its food sovereignty. An important component of sustainable food sovereignty is the capacity for quick response when crops are threatened by extreme climatic events. Ecuador's government institutions working on agriculture stress the importance of food sovereignty and extreme events. Policies on the latter reflect a focus on short-term climatic variation, but lack a long-term perspective on climate change. Similarly, Peru emphasizes preventing impacts of extreme events and crop failure. Bolivian policies stress the relationship between resilience and food sovereignty. The country has developed and is implementing an insurance scheme against climate hazards for agricultural productions (National Institute for Agricultural Assurance).

Policy gaps

- Lack of policies targeting climate change impacts on mountain agriculture. For instance, upward migration of crops and ecosystems, and its effects on croplands, overlying pastures and high Andean biodiversity.
- Lack of overarching programmes and a long-term perspective on cross-sectoral coordination for agricultural adaptation to climate change.
- Lack of efforts to improve the science-policy interface in order to facilitate the formulation of evidence-based policies.
- Inadequate coordination between national and subnational levels: the interventions have missed opportunities for constructive feedback, experience sharing, and economies of scale.
- Inadequate policy coverage addressing the consequences for food production of outmigration from rural mountain communities, as well as potentially positive impacts on mountain agricultural systems.
- Lack of efforts to strengthen knowledge about climate change in mountain communities and to integrate climate science with traditional and local knowledge.

Opportunities

Ongoing concerns on climate change impacts represent an opportunity for studies to generate knowledge on impacts on agriculture and mountain ecosystems. Moreover, this knowledge would uncover the need for policies targeting specific vulnerabilities, diminishing exposures and increasing adaptive capacities. Mountains territories have important resources for national economies (e.g. minerals, water). Intersectoral dialogue may bring the opportunity to include other resources (e.g. agroecosystems, land, knowledge) in these studies. Moreover, links with other sectors would allow a more comprehensive understanding of mountain ecosystem dynamics under climate change and socioeconomic pressures.

Woman collecting dried potatoes, Peru

Energy (hydropower)

The Andean countries are highly dependent on hydropower: hydroelectric energy represents an average of about 64% of total energy supply across the Andean countries (CEPAL, 2011), of which 52% is generated within the mountain region overall, but with large variation between countries (CONDESAN, 2012). The mountain regions harbour the majority of the hydropower dams of the seven countries. However, there are very few studies on the future impacts of climate change on hydropower generation.

Each country adopts a different approach to addressing adaptation in the energy sector. Policies in other sectors, such as water resource management, also affect energy production. Colombia is planning to diminish its energy vulnerability through a comprehensive approach, which combines improving efficiency, diversifying sources and conserving watersheds and ecosystems. Ecuador's energy policy indirectly relates to hydropower because of its focus on diminishing the country's dependency on fossil fuels: hydropower will thereby gradually increase its share as an energy source. Bolivia is planning large hydro schemes in the Andean foothills (El Bala) and the Amazon lowlands (Cachuela Esperanza, Riberao). Peru's perspective is the optimal use of energy resources, and improving infrastructure. Thus, the country advocates the efficient use of energy to mitigate GHG emissions and promotes climate change adaptation measures. Further, Peru is starting to diversify its energy mix to diminish its dependency on natural gas, promoting renewable energy sources including forms other than hydropower such as wind farms, solar and biomass power plants.[53] Many economical activities with significant potential (such as hydropower) and that depend on ecosystem goods and services will be negatively affected by climate change.


Tominé Reservoir, Cundinamarca, Colombia

A number of studies (e.g. Fearnside, 2002; Fearnside, 2005) have shown that large scale hydro in the Amazon lowlands result in higher GHG emissions than conventional power plants, due to the combined effects of forest land destruction and additional methane production during normal operation. Out of some 151 dams proposed for the Amazon system, over half are expected to disrupt or sever the river connectivity between the Andean highlands and headwaters and the Amazon lowlands (Finer and Jenkins 2012).

Opportunities

Energy demand currently outstrips supply in the region. The Andes have huge potential for generating hydropower to meet the energy supply. Despite the climate impacts, hydropower will remain an important source of energy production in the Andes. However, managing it properly will require forward-looking adaptation measures including conservation and management of (transboundary) watersheds and ecosystems, as well as the climate-proofing of relevant infrastructure. The focus on hydropower in Andean watersheds highlights the importance of protecting the remaining Andean forest ecosystems, which supply almost 50% of the water budget of existing dams (Sáenz and Mulligan, 2013). Policies are needed to support the diversification of the overall energy mix, promote investment (public and private) in this sector and also regulate its socioeconomic and environmental impacts on mountain systems.

Policy gaps

- Adaptation policies in the energy sector require updated vulnerability studies of hydropower provision per basin, whereby adaptation measures are prioritized for the most vulnerable basins. Studies on the impact of climate change on future water availability are needed, and have to be incorporated already in the planning and design phases of projects.
- Lack of awareness of impacts of increasing hydropower generation on mountain ecosystems. For instance, there will be increased pressure and impact on mountains from energy-demanding regions and sectors, which will potentially increase ecosystem degradation and further exclude the local population.
- While focusing on climate change impacts on hydropower plants, there is insufficient data and information about the impact of these plants on mountain social-ecological systems (e.g. people, landscape, water bodies, fishing).
- There is insufficient political support for comprehensive diversification of energy sources.

Are the responses forward-looking?

The Andean countries ideally ought to address both climatic variability – such as seasonal and year-to-year variability, and both slow and fast onset events of climate change. With regards to climate change, fast onsets of climate change encompassing extreme events and most disasters events find themselves more on the government radar than slow onset events, because of their short-term nature. Slow onset events, such as longer droughts or the loss of soil moisture, do not impact in a short time frame and are therefore more difficult to grasp. Moreover, these impacts may occur over a longer time frame than the political cycles; thus, actions to address climate change may not render political benefits in the short term or contribute to re-election.

Health policies exemplify the dynamics of the temporal perspective and the need for a long-term perspective. For example, Colombian health care policies are forward-looking because they are focused on the impacts of disasters on health (short term), while assessing the interactions between changing climate and vector-borne diseases (midterm) and expanding the coverage of the health system to include diseases related to climate change (long term) (McMichael et al., 2006).

In general, the lack of performance indicators in policies makes it impossible to assess their efficiency and effectiveness. Nonetheless, some adaptation policies in the analysed Andean countries have set adaptation goals and targets, showing some rather slow progress.

The national and sectoral policies that have been analysed in this report do not specifically include adaptation measures on mountains. Moreover, existing policies do not fully integrate flexible approaches such as resilience and adaptive systems, which would increase the countries' capacity for responding to climate change. However, climate variability and socioeconomic impacts are acknowledged through responses to extreme weather events. The governments' disaster risk management offices usually lead these responses, though they are implemented with the sectors mainly through special programmes due to the emergent nature of the event.

Policies vary between countries and also between sectors (within a country), though some patterns are worth mentioning. IWRM is a fairly common approach in the countries of our study and can be seen as forward-looking because it aims to integrate different water uses by considering the water flows needed by the ecosystem (for a critical perspective on IWRM see Boelens, 2008). Although IWRM may not specifically address mountains, these ecosystems are considered crucial for the functioning of and service provision in the

Ciudad Perdida, the Lost City of Colombia catchment area and, therefore, for all watersheds. The IWRM perspective has aspects for improving the adaptive capacity and diminishing exposure to climate change. This includes, for instance, the understanding that watershed sections (upper, mid and lower) are interconnected through flows and feedbacks of water, chemicals, sediments and organisms. Additionally, the emphasis on multi-level management offers institutional flexibility for responding to extreme climate events, adapting to long-term climate change, and including elements of adaptive governance of water.

In addition to the temporal scale, we must consider the institutional scale in assessing whether policies are forward-looking. In so doing, we can evaluate whether policies include paths and evidence for achieving results in climate change adaptation. In the Andean countries analysed, most national policies for adaptation to climate change are in the initial phases, distributing responsibilities (and hopefully funding) among sectors. Also, even if the scientific evidence was incorporated into policy design, policies are not addressing mountains as a policy target yet, which limits its capacity to be forward-looking. Moreover, it seems that countries have chosen the multisectoral policies path (which is commonly favoured in environmental management, although an integrated approach would be preferable) towards climate change adaptation, which requires institutional coordination, resources, leadership and vision for effective performance. It is too soon to know how the chosen path will respond to abrupt changes, which require effective rapid responses, and long-term changes, which require dynamic and flexible policies adjustable to uncertainty and changing conditions.

The mismatch between sectors' actions and climate change effects on ecosystems is a policy gap. In other words, because ecosystems do not correspond to specific sectors and vice versa, climate change impacts on ecosystems remain largely unattended. Though risks tend to be addressed by sectoral actions, some risks may be shared by more than one sector: for example, water risks are shared by health, agriculture, energy and environment, among other sectors. As for mountains, many sectors could be involved, depending on the particular risk. In this scenario, forward-looking policies should strengthen institutional arrangements at all levels, involving public, private and other social actors from the regional and local levels in policy implementation.

The effects of many of the identified risks are amplified by prevalent non-climatic problems (e.g. poverty, marginalization). Thus, a forward-looking institutional approach would link adaptation policies and non-climatic policies through plans for subnational units, which are known in some countries as territorial management plans. Additionally, when these plans are scaled up to the national level (e.g. Colombian National Adaptation Plan) they offer broad scope for adaptation policies to be included in specific territories. Moreover, territorial plans may address problems, which may later positively impact on the adaptive capacity of ecosystems. Moreover, an effective climate change adaptation policy would have to understand the coupled sector-ecosystems interactions, vulnerabilities and feedback. This understanding is a step towards managing risk reduction and adapting to climate change.

Climate change will increase the frequency and intensity of extreme weather events, with future scenarios indicating increasing severity of climate change impacts in the Andean countries. Furthermore, the ever-expanding integration and interdependency within the region may increase the trans-boundary impacts of climate change. Therefore, instruments of regional integration should consider strategies for collaboratively addressing large-scale events (e.g. El Niño), including observation, monitoring, data and lesson sharing, and investment schemes for improved adaptation and resilience to climate change at the regional level. Regional institutions that play an active role in understanding climate impacts - such as the International Research Centre for El Niño (CIIFEN) - and academia should play an active role in collaboratively addressing and understanding these large-scale events.

Increasing urbanization of Andean cities and expanding economic activities will continue to drive demand for energy and other resources and services. Therefore, in the long-term, mountains may gain further strategic importance in supplying hydropower and other services to cities and lowlands. Additionally, in a scenario of increased vulnerability of countries' energy supplies to climatic variability and change, establishing a regional energy network across the Andes could help provide a redundant energy supply.

TROPICAL ANDES MOUNTAINS

Conclusions

Bogota, Colombia

Conclusions

The policies of the Andean countries analysed in this report fall short in terms of their inclusion of both mountains and adaptation to climate change. Though mountains hold strategic resources (e.g. water, food, minerals), the development models promoted in these countries have favoured urban areas, flat regions, and lowlands. It has also been noted that the few mining regulations may hinder policies towards conservation or sustainable mountain development. Moreover, mountains are home to indigenous populations that have historically been marginalized and excluded from access to and control of their resources.

Ongoing policies are overlooking the synergic effects and feedback between climatic and non-climatic processes on mountains. For instance, some risks emerging from these effects but not yet addressed are food insecurity, biodiversity loss, population displacement, diminishing provision of ecosystem services, and changing water availability. In addition, the impact of these risks and their effects on the adaptive capacity and resilience of local communities are not considered, which in turn may increase their vulnerability.

The risk of glacier lakes outburst floods (GLOF) has not been addressed in this Outlook because these are present mainly in Peru and Bolivia (to a lesser degree). However, the recently created National Institute of Research on Glaciers and Mountain Ecosystems in Peru illustrates an institutional arrangement that can address risk of GLOFs but also tackle the understanding of mountains impacts and adaptation to climate change.

Bottlenecks affecting adaptation-related policies are often caused by limited institutional capacity. This translates as rare coordination between sectors whose activity areas overlap, and little integration between national and local activities. This little integration may be worse if the authorities belong to rival political parties. The small budget for adaptation and mountains leads to bottlenecks and is indicative of the little priority given to these areas in the political agenda. At the local level, there is salient insufficient technical capacity to understand climate-crop relations and climate change impacts on agriculture. Furthermore, the network of meteorological stations has little coverage and low density, particularly in the mountains. This hinders the generation of knowledge on local weather to inform policies. However, the Initiative for Hydrologic Monitoring in the Andean Ecosystems aims to improve data coverage and sharing to inform policymaking. This initiative still needs to be linked to national meteorological services to achieve major impact.

Finally, the policy analysis also shows the uneven development of policies among sectors. While sectors such as water seem to have some policy instruments, the health and energy sectors in mountains are less prepared for adapting to climate change. Though this chapter does not aim to explain such unequal attention, it is worth mentioning in order to promote the sectoral exchange of information and lesson sharing, as well as to stimulate research to analyse such differences.

Methodological limitations

National and sectoral policies initially reviewed were those accessible by Internet. Later, government officials provided inputs in a workshop held in Lima. They also responded to a survey, and sent additional documents. This Outlook has benefited from these and other officials' comments on sectoral and adaptation policies in the Andean region.

Gathering the relevant information for a proper, comprehensive and exhaustive assessment has had some shortcomings in relation to data, information and institutions:

- Lack of data (or access to it) and information about benchmarks, performance indicators, implementation stage, outcomes and bottlenecks of existing policies.
- Limited institutional capacity to provide updated information about policies' status.
- Inadequate monitoring and evaluation system.
- Lack of adequate intersectoral collaboration.
- National and sectoral policies implemented on the same territory are sometimes difficult to differentiate. Thus, overlapping policies have different priorities, time schedules, resources employed, and discourses used. This reveals the challenge presented by a joint national climate change adaptation goal.
- The little recognition given to mountains and adaptation within the countries' agenda.

Miraflores, Nor Yuayos-Cachos, Peru

Acronyms*

ACCION	Andean Climate Change Interamerican Observatory Network Project
AMICAF	Assessments of Climate Change Impacts and Mapping of Vulnerability to Food Insecurity under Climate Change to Strengthen Household Food Security with Livelihoods' Adaptation Approaches
ANDESCLIMA	Climate Change and Environment in the Social and Economic Cohesion Sector
APMT	Plurinational Mother Earth Authority – Bolivia
CAN	Andean Community
CBD	Convention on Biological Diversity
CELAC	Community of Latin American and Caribbean States
CICC	Inter-institutional Committee on Climate Change – Ecuador
CIIFEN	International Research Centre for El Niño
CIMA	International Centre on Environmental Monitoring
CNCC	National Commission on Climate Change – Peru
COMICC	Intersecretarial Commission on Climate Change
CONDESAN	Consortium for Sustainable Development of the Andean Ecoregion
COP20	20th session of the Conference of the Parties to the UNFCCC
DGCCDRH	Directorate General for Climate Change, Desertification and Water Resources – Peru, MINAM
EbA	Ecosystem-based Adaptation
ECLAC (CEPAL)	Economic Commission for Latin America and the Caribbean
ENCC	National Strategy for Climate Change – Ecuador
ENSO	El Niño-Southern Oscillation
GAD	Autonomous Decentralized Governments
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GIAS	National Policy for the Integrated Environmental Management of Land – Colombia
GIZ	German Corporation for International Cooperation
GLOF	Glacial Lake Outburst Flood
GLORIA	Global Observation Research Initiative in Alpine Environments
IEA	Integrated Environmental Assessment
IMACC	Implementation of Climate Change Adaptation Methods – Peru
iMHEA	Initiative on Hydrological Monitoring of Andean Ecosystems
INAIGEM	National Institute for Research on Glaciers and Mountain Ecosystems – Peru
INAP	National Pilot Programme for Climate Change Adaptation – Colombia
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
LAC	Latin America and Caribbean
Law 300	Framework Law of Mother Earth and Holistic Development for Living Well
MADR	Ministry of Agriculture and Rural Development – Colombia
MADS	Ministry of Environment and Sustainable Development – Colombia
m.a.s.l.	metres above sea level
MCMA	Joint Mitigation and Adaptation Mechanism for the Integral and Sustainable Management of Forests and Mother Earth
MINAGRI	Ministry of Agriculture and Irrigation – Peru
MINAM	Ministry of Environment – Peru
MINSA	Ministry of Health – Peru
MSPS	Ministry of Health and Social Protection – Colombia
NAPA	National Adaptation Programme of Action
NDP	National Development Plan – Colombia
NGO	Non-Governmental Organization
NRCC	Regional Nodes on Climate Change
NYCLR	Nor Yauyos-Cochas Landscape Reserve
OECD	Organisation for Economic Co-operation and Development
PACC	Climate Change Adaptation Programme – Peru
PCM	Presidency of the Council of Ministers
PDO	Pacific Decadal Oscillation
PDOT	Plan for Territorial Development and Organization
PLANGRACC-A	Climate change adaptation and disaster risk management plan for the agriculture sector – Peru
PNACC	National Plan for Climate Change Adaptation – Colombia
PRAA	Project for Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes – Ecuador
PROCLIM	Forum for Climate and Global Change
RCP	Representative Concentration Pathways
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RSCC	Regional Strategy for Climate Change – Peru
SENAGUA	National Water Secretariat – Ecuador
SENAMHI	National Service of Meteorology and Hydrology – Peru
SERNANP	National Service of Natural Protected Areas – Peru
SGCAN	General Secretariat of the Andean Community
SINAGERD	National Policy on Disaster Risk Management – Peru
SISCLIMA	National Climate Change System – Colombia
TACC	Territorial Approach to Climate Change
TMI	The Mountain Institute
UNASUR	Union of South American Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGRD	National Disaster Risk Management Unit – Colombia

*Translated to English where necessary

Notes

1. UNEP's (2002) definition of mountainous environment includes any of the following: Altitude of at least 2,500 m; Altitude of at least 1,500 m, with a slope greater than 2 degrees; Altitude of at least 1,000 m, with a slope greater than 5 degrees; Altitude of at least 300 m, with a 300 m elevation range within 7 km.
2. Venezuelan mountain adaptation policies are not considered in this chapter because of limited availability of specific information central to the objectives of the assessment. This in no way indicates that adaptation policies are not important in these areas to protect essential services provided by Venezuelan mountain environments and its inhabitants.
3. http://www.ambiente.gob.ec/mae-e-inamhi-firmaron-carta-de-compromiso-para-traspaso-de-dominio-de-estaciones-y-equipos-de-red-de-monitoreo-automatico-de-paramos-y-glaciares/
4. http://www.unep.org/ieacp/graphic.aspx?f=grb/fig5-26.jpg Last reviewed 18 August 2015
5. The function of the Adaptation Committee is to promote the implementation of enhanced action on adaptation in a coherent manner under the Convention. http://unfccc.int/adaptation/groups_committees/adaptation_committee/items/6053.php
6. https://www.adaptation-fund.org/about/
7. "Sub-regional" level is defined as a limited number of countries within Latin America and the Caribbean;
8. http://www.unasursg.org/es/quienes-somos Last accessed 17 August 2015.
9. http://www.comunidadandina.org/Seccion.aspx?id=189&tipo=QU&title=somos-comunidad-andina Last accessed 17 August 2015.
10. Please refer to the case study.
11. http://alianzapacifico.net/en/que-es-la-alianza/#what-is-the-pacific-alliance Last accessed 17 August 2015.
12. http://celac.cubaminrex.cu/sites/default/files/ficheros/doc_3_17_cambio_climatico_ingles.pdf
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14. Published in the Official Record No. 300 by the Plurinational Legislative Assembly on 15 October 2012
15. http://theredddesk.org/countries/laws/law-300-framework-law-mother-earth-and-holistic-development-living-well
16. https://www.minambiente.gov.co/index.php/component/content/article?id=476:plantilla-cambio-climatico-32#documentos
17. http://www.slideshare.net/OECDdev/session-vi2-diana-hernandez-gaonacolombiadepartment-of-planning Last accessed 8 September 2015
18. www.sigpad.gov.co/sigpad/archivos/ABC_Cambio_Climatico.pdf Last accessed 8 August 2015
19. http://pdba.georgetown.edu/Constitutions/Ecuador/english08.html Last accessed 8 April 2015.
20. Published in the Official Record No. 636 of 17 July 2009.
21. The CICC includes the Ministry of Environment, the Ministry of Foreign Affairs, Commerce and Integration, the National Planning and Development Secretariat, the Coordinating Ministries of Heritage, Social Development, Strategic Sectors and Production, Employment and Competitiveness, and the National Secretariat for Water and Risk Management
22. www.minedu.gob.pe/DeInteres/.../plan_bicentenario_peru_hacia_2021.pdf Last accessed 10 October 2015
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24. www.minam.gob.pe/wp-content/.../Política-Nacional-del-Ambiente.pdf Last accessed 10 October 2015
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26. Translated by the authors from: Plan de Acción de Adaptación y Mitigación frente al Cambio Climático, 27, MINAM. http://cambioclimatico.minam.gob.pe/plan-de-accion-de-adaptacion-y-mitigacion-frente-al-cambio-climatico/ Last accessed 8 June 2015.
27. http://www4.unfccc.int/submissions/INDC/Published per cent20Documents/Peru/1/INDC per cent20Per per centC3 per centBA per cent20english.pdf
28. The key risks and accompanying vulnerabilities were identified through a stakeholder consultation process, literature review and feedback from questionnaires. See Chapter 2 for more detail.
29. http://www.cambioclimaticoyagua.del.org.bo/sites/default/files/ley_de_la_madre_tierra_20121015-11-53-28.pdf Last accessed 27 September 2015.
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34. At its signing in 2002, the National Agreement contained 29 state policies.
35. http://acuerdonacional.pe/politicas-de-estado-del-acuerdo-nacional/politicas-de-estado per centE2 per cent80 per cent8B/politicas-de-estado-castellano/iv-estado-eficiente-transparente-y-descentralizado/33-politica-de-estado-sobre-los-recursos-hidricos/
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50. https://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf
51. These sectors relate to: water; biodiversity and ecosystem function, food, health and energy.
52. For example, novel concepts such as "life zones" and "life systems" have been applied in Bolivia.
53. See also INDC from the Republic of Peru http://www4.unfccc.int/submissions/INDC/Published per cent20Documents/Peru/1/INDC per cent20Per per centC3 per centBA per cent20english.pdf

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