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### Preface:



Glaciers in the tropical Andes have suffered from retreat rates that are among the highest globally, with around 50% of glacier area lost over the past 4-5 decades. Projections for the 21st century indicate that the tropical Andes will become largely deglaciated. More precisely, the glaciers at lower elevation are committed to extinction irrespective of future warming, while strong and rapid action on greenhouse gas reduction can still save about half of the glacier areas at higher elevation. The glacier loss in the tropical Andes has implications for a wide range of ecosystems and people living in the Andes and also in the lower and coastal areas. For instance, wetlands in the high Andes, fed by glacier melt water, have essential ecological functions and provide ecosystem services to rural and urban populations. However, if there is no glacier and hence no melt water anymore to provide water during the dry season, such ecosystems start to degrade and can transform from CO2 sinks into CO2 sources, and hence in turn initiate a feedback process that is all but worsening the situation. Agriculture, both small and large scale, is one of the economic sectors most affected by climate change and glacier retreat. Studies have shown that for the Santa river valley in Peru with about 650,000 inhabitants loss of melt water from glaciers could result in annual economic losses of about USD 200 to 300 million by mid-century. Glacier loss also disrupts long-lived traditions and cultural practices of local people and their sense of attachment to place. Such intangible losses are often as irreversible as the loss of glaciers.

This perspective underlines the importance of adaptation, as a fundamental measure to reduce the adverse effects of climate change and glacier loss, and this report provides important insights into the stage and ways of adaptation in the countries of the tropical Andes. In fact, the tropical Andes have pioneered adaptation actions, especially in relation to adaptation to glacier retreat, with both national and regional projects having generated invaluable experiences on the ground, and at the collaborative interface of research, policy and practice. However, these projects and initiatives have so far often been at the level of local pilot studies. In this way, important experiences on and beyond the case could be drawn but a larger scaling up has not yet taken place.

The new report of the Intergovernmental Panel on Climate Change (IPCC), published in 2022, emphasized that current adaptation efforts are insufficient to cope with the adverse effects of climate change, and that it is urgent to scale up adaptation at a higher speed and depth of implementation, especially in view of a closing window of opportunity over about the next 10 years. The urgency not only for mitigation of climate change but also for adaptation to climate change is actually one of the key messages of the new IPCC report. This UN report also comprehensively assessed that anthropogenic climate change has had widespread impacts on glaciers, ecosystems, economic sectors and societies in the Andes and showed how these impacts from rapidly shrinking glaciers cascade through natural and human systems.

National governments, international organizations such as the OAS, development banks, international cooperation and climate funds, research and civil society need to join forces for the great endeavor of transformative change that is critically required to sustainably manage climate change and glacier loss. The glaciers are icons of the tropical Andes, and while every effort at the global level needs to be secured to save as much as possible of the glaciers by reducing emissions, the tropical Andes should continue and strengthen pioneering efforts in adaptation and transformation to secure a climate resilient and sustainable future for its people.

Christian Huggel, Dr. Professor Department of Geography University of Zurich.

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Finally, we would like to thank each of the panelists from the governments of Peru, Colombia, Chile, Bolivia and Ecuador, who participated in the two high-level regional dialogues on deglaciation in the tropical Andes and South America, organised by the Water Program of the Department of Sustainable Development of the Executive Secretariat for Sustainable Development of the Organization of American States, between 2020 and 2021. In this framework, the technical and thematic participation of the Swiss Agency for Development and Cooperation (SDC) for the Andean countries has been of great relevance to learn about the challenges and responses of the countries in the face of deglaciation.

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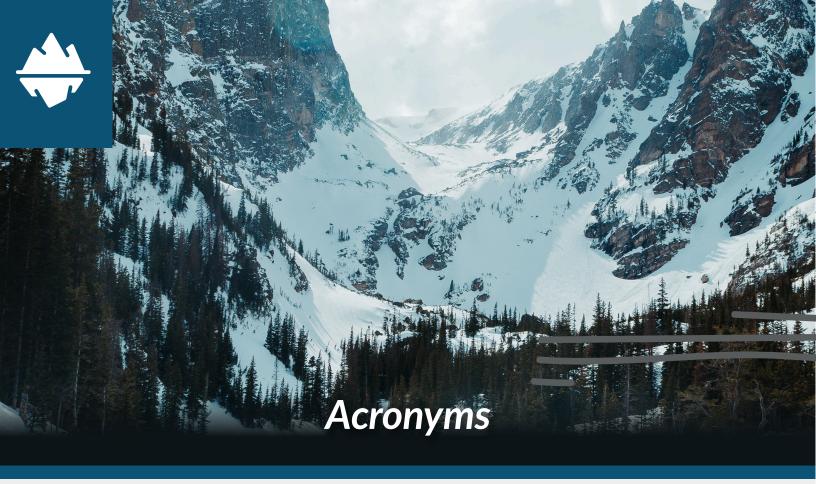






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Acronym	Meaning
AECID	The Spanish Agency for International Development Cooperation
ANA	National Water Authority
APMT	Plurinational Authority of Mother Earth
CAN	The Andean Community
CANCC	The High Level Commission on Climate Change
CBD	Convention on Biological Diversity
CCA	Climate change adaptation
CICC	Intersectoral Climate Change Commission
CNCC	The National Commission on Climate Change
CONDESAN	Consortium for Sustainable Development of the Andean Ecoregion
DRM	Disaster Risk Management
DSD	Department of Sustainable Development
ENCCE	Ecuador's National Climate Change Strategy 2012-2015
ENFC	The National Strategy for Climate Financing

Acronym	Meaning
GTM-NDC	Multisectoral Temporary Working Group responsible for producing technical information to guide the implementation of Nationally Determined Contributions
GS/OAS	General Secretariat of the Organization of American States
IAvH	The Alexander von Humboldt Research Institute of Biological Resources
IDB	Inter-American Development Bank
IDEAM	The Institute of Hydrology, Meteorology and Environmental Research
INAIGEM	The National Institute for research in Glacier and Mountain Ecosystems
INAMHI	The National Institute for Meteorology and Hydrology
IPCC	Intergovernmental Panel of Experts on Climate Change
IRD	Institut de Recherche pour le Développement - National Research Institute for Sustainable Development
IWRM	Integrated Water Resource Management
MAATE	Ministry of Environment, Water and Ecological Transition
МСР	Participatory community monitoring
MINAM	Peru's Ministry of the Environment
MINAMBIENTE	Colombia's Ministry of Environment and Sustainable Development
MMAyA	Bolivia's Ministry of Environment and Water
OAS	Organization of American States
PNACC	National Plan for Climate Change Adaptation
PRAA	Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes Project
SAT	Early Warning System
SEDI	Executive Secretariat for Integral Development
SGCA	The Andean Community General Secretariat
SIMOG	National Glacier Information and Monitoring System
SIARH	The Environmental and Water Resources Information System
SISCLIMA	The National Climate Change System
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change



#### Introduction

South American tropical glaciers are part of the environmental, economic, social and cultural wealth of America in general, and of the Andean countries in particular.

They are not only ecosystems that provide hydrological services for energy, agricultural activities and for water and sanitation. They also play a key role in regulating the high mountain climate and biodiversity ecosystems of the Andean region. Their scenic beauty is a source of tourism promotion. Moreover, because of their historical legacy and relevance, they belong to the cultural and spiritual system of the surrounding towns.

Despite their relevance and immeasurable value, tropical glaciers are fragile

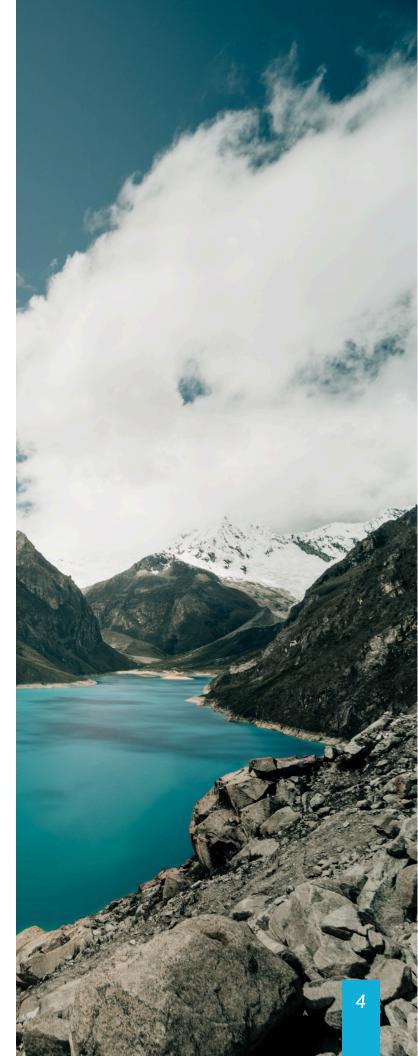
ecosystems. During the second half of the 20th century, they have suffered an accelerated process of extension loss. Therefore, data reported by countries affected by deglaciation suggest that glacier mass loss worsened between the decades of the 1970s and 1980s. Between 1962 and 2016, Peru lost 53.56% of its glacier mass; while Bolivia, on the other hand, suffered the retraction of around 50% of its glaciers over the past 50 years. Ecuador is going through a similar situation, having lost 50% of its glaciers between 1976 and 2006; while Colombia only has 6 glaciers left. Also, it is highly possible that by 2100, 80% of glaciers in the tropical region of the Andes will disappear under a scenario of high greenhouse gas emissions (IPCC, 2019).

The implications of glacial retreat are numerous. On the one hand, it leads to

scenarios of water insecurity since glaciers are sources of freshwater. Thus, their decrease impacts water availability for human consumption, power generation and economic activities development, such as family or community agriculture and livestock. On the other hand, glaciers loss affects high mountain ecosystems, such as páramo, wetlands and high Andean forests, among others. This jeopardizes mountains' biodiversity and alters existing natural and social dynamics. The above means that glacial retreat also affects the cultural practices and spirituality of indigenous peoples and communities living in periglacial areas.

However, tropical glaciers are not only sources of wealth, but also of hazards. Avalanches and lahars have caused significant economic damages and deaths. In Peru alone, nearly 25,000 human casualties were reported between 1941 and 2014 as a result of glacier disasters (Carey, 2014). In addition to that, over 23,000 people died in Colombia when around 10km2of ice broke off due to the eruption of Nevado del Ruiz in 1985 (Schoolmeester *et al.*, 2018). However, the number of casualties could be greater if one considers the challenges each country faces in recording the damage caused by emergencies and disasters.

Considering that glaciers – as part of mountain ecosystems – play a key role for the sustainable development of the countries in the region, the objective of this document is to an assessment of how countries prepare for deglaciation by compiling systematised information on the loss of tropical glaciers. It also aims to encourage discussion on what measures to promote within the framework of national agendas for climate change adaptation, taking into account four central findings of this publication:



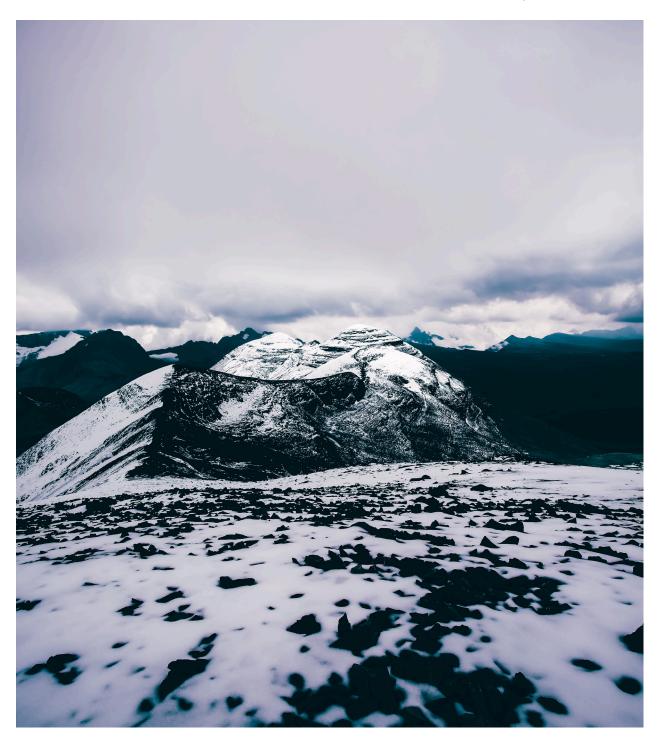
- i. A Future with Fewer Glaciers: Research on glaciers and mountain ecosystems in the tropical Andes conducted by governmental technical institutions, as well as by research institutions from different universities among other civil society actors , report scenarios where some of them will be extinguished or significantly reduced.
- From research to action: Countries with tropical glaciers in their territories tend to focus on knowledge management processes (monitoring and research on glaciers), considering the possibility of a future with fewer glaciers or with any glaciers at all. Despite the relevance of knowledge production applied to development and public policies, the identification, design and implementation of adaptation measures against glacial retreat does not yet have the same level of thought and progress. In addition, it is necessary to quantify the impacts of glacier loss as a research strategy for decision-making and adaptation measures funding.
- Adaptation to glacial retreat: Tropical glaciers are strategic ecosystems for national and subnational development processes, as well as for mountain communities' well-being, due to the diverse ecosystem services they provide. However, countries must adapt their water, energy, alimentary security, and disaster risk management models against a future with fewer or without glaciers, in some cases.
- Integrated adaptation with co-benefits: Glacier retreat impacts several governmental and productive sectors, as well as multiple dimensions of citizens' lives in the Andes mountains. Hence, the most effective adaptation measures are those that address issues in an integrated form, and that promote co-benefits to agendas for biological biodiversity conservation, preventing desertification and risk management.

Given the implications of glacier loss, this research paper systematizes information on the glaciers' situation and deglaciation in four countries with tropical glaciers. It does not intend to produce conclusions that can be extrapolated to other countries affected by deglaciation in the Americas, but rather to propose lines of analysis and considerations to be applied in climate adaptation policies and in NDCs, so as to contribute to the strengthening of glacier issues within the regional agenda. This study is a case study analysis in a methodological sense.

While each country represent a specific reality and faces different challenges within its territory against deglaciation, there are enough common elements to build a long-term

regional dialogue. Through it, countries could exchange experiences, build stronger foundations for action and encourage development banks, global funding, cooperation agencies and the private sector to support their efforts in adapting to a scenario with less snow, ice and fresh water.

For explanatory purposes, the first section of this document presents an overview of glacial retreat in the tropical Andes. The second section focuses on Peru, while the third, fourth and fifth focus on Bolivia, Ecuador and Colombia, respectively. Finally, conclusions and recommendations are provided.





### 1.1. General overview of Deglaciation

Over the past 50 or 60 years, the scientific community and the countries with glaciers have observed an accelerated process of glacier mass loss, as a result of the increase in global average temperatures (IPCC, 2019). Indeed, although glaciers loss has multiple edges, there is currently a consensus that their retraction is considered as one of the symptoms and challenges of climate change (Schoolmeester *et al.*, 2018; IPCC, 2019).

On the one hand, it is possible to say that deglaciation is a symptom or evidence of climate change and, according to the levels of certainty of the Intergovernmental Panel on Climate Change (IPCC), human influence is the main driver of glaciers retreat across the globe since the decade of the 1990s (IPCC, 2019).

Also, countries such as Peru, Colombia, Bolivia and Ecuador have determined – through different environmental and climate policy instruments – that the increase in average temperatures led to the extinction of some of their glaciers and the reduction of glacier mass in different mountain ranges.

The impacts of climate change on mountain ecosystems, such as glaciers, are well known to American countries. South American tropical glaciers are a good example of this situation<sup>1</sup>, being particularly fragile ecosystems due to the weather conditions of the tropics (Schoolmeester *et al.*, 2018).

Various assessments suggest that the Andes mountain range holds between 95% and 99% of the world's tropical glaciers (CAN, UNEP, AECID, 2007; Ceballos, 2012; Schoolmeester *et al.*, 2018). They provide mountain communities – and even cities such as La Paz in Bolivia, Quito in Ecuador and Huaraz in Peru – essential ecosystem services for family farming, hydroelectric power generation, water supply for human consumption, among other benefits provided by glaciers in sustainable development.



On the other hand, climate change poses several challenges related to glaciers loss because – despite the important role they play in environmental, economic, social and even cultural terms – by 2100, 80% of the glaciers in the tropical Andes region could disappear, under a scenario of high greenhouse gases emissions (IPCC, 2019). In addition, NDCs of countries such as Peru, Bolivia and Ecuador report the disappearance of at least 50% of their glacier mass in periods ranging from the second decade of the 20th

century and the first 20 years of the 21st century.

In the tropical Andes, deglaciation results in at least three interconnected risk, damage and loss scenarios. The first shows a context in which glaciers loss leads to the decrease of freshwater sources. Consequently, this situation leads communities and countries to the possibility of facing cases of water, food and energy insecurity, considering that water from glacial melting is used for water and

<sup>&</sup>lt;sup>1</sup> Tropical glaciers are located between latitudes 30° North and 30° South. It is estimated that approximately 71% of these are found in Peru, while approximately 22% lie in Bolivia, 4% in Ecuador, 3% in Colombia and Venezuela (CAN, UNEP and AECID, 2007; Ceballos, 2012). Venezuela is currently the most affected country. Between 1952 and 2019 it saw 9 of its 10 glaciers disappear, becoming the first South American country to face a future without glaciers and ice.

sanitation systems, and agricultural and power generation. In this regard, it is important to note that in the tropical Andes there is a lack of calculations that account for the economic impact of glacier loss in sectors such as hydropower, agriculture and human consumption (Drenkhan et al., 2019).

The second scenario is framed by the increased risk of disasters related to hazards such as glacial outburst floods and glacial lake outburst

floods. Approximately 48,000 human casualties are estimated between Peru and Colombia, as a result of glacier-related disasters. In fact, it is estimated that due to glacial outburst floods and glacial lake outbursts alone, almost 25,000 people died in Peru between 1941 and 2014 (Carey, 2014); while, in Colombia, around 1985, the eruption of Nevado del Ruiz caused the detachment of a 10 km² block of ice that killed more than 23,000 Colombians (Schoolmeester et al., 2018).

Finally, deglaciation foresees a scenario of risks, losses and damages on a cultural and spiritual level. Indigenous communities and peoples who live and interact in mountain ecosystems have an oral culture and rituals that revolve around glaciers (IDEAM, 2012; Boyano, 2017; Walter, 2016). Culture and religion are also affected by climate change and deglaciation.

The deglaciation scenarios in the tropical Andes vary from region to region or between mountain ranges, within the same country. Therefore, the problems and responses of each State are different, although there are common elements that facilitate technical dialogue and cooperation in pursuit of a climate and development agenda to help countries and their communities adapt to a future with little glacier mass or without any glaciers at all.



# 1.2. Institutionality and policies against deglaciation

Each of the South American countries with tropical glaciers in their territories has an institutional framework that addresses knowledge management on glacial ecosystems, as well as encouraging decision-making against deglaciation. Although they differ from each other, the institutions are part of a series of actions promoted in partnership with cooperation agencies, banks and development funds, civil society organizations and the academia.

In general terms, the initiatives promoted by countries with tropical glaciers affected by climate change revolve around public policy instruments development; behavior monitoring and glacier analysis against rising temperatures; and the implementation of development projects. In this regard, the Nationally Determined Contributions (NDC) and national communications to the United Nations Framework Convention on Climate Change (UNFCCC) are relevant because they synthesize information and account for national actions against glacier retreat, within the technical and policy considerations established through climate change adaptation agendas.

In addition, experts from the region aim for developing public policies for the sustainable management of high mountain ecosystems, such as glaciers. This is the case in Peru, where the State has been promoting the development of a National Policy on Glaciers and Mountain Ecosystems. As well in Colombia, there is a technical proposal to establish the Strategy for Integrated Monitoring of High Mountain Ecosystems.

Although in Bolivia and Ecuador, there are no regulatory development processes focused on glaciers and mountains -as in the case of Peru and Colombia-, they have policy instruments (Figures 4, 5, 7 and 8) that incorporate information and considerations for action against deglaciation. In addition, each of the four countries analyzed has institutions and technical units, from which glacier monitoring initiatives, technical and political discussions and adaptation initiatives are promoted.

It is important to specify that, in each country, discussions about glaciers, as strategic and fragile ecosystems, are intrinsic to the debates and actions driven by climate change adaptation; to the extent that countries seek to adapt to a future without glaciers or with fewer glaciers, that is a future with fewer freshwater sources and degraded high Andean ecosystems, which are relevant to the hydrological supply.



### 2.1. General overview of Deglaciation

Peru is home to approximately 71% of the world's tropical glaciers (Kaser, 1999; Francou et al. 2013; INAIGEM, 2017; INAIGEM, 2018). Distributed across 18 mountain cordilleras<sup>2</sup> and 10 departments<sup>3</sup> (INAIGEM, 2018), they provide several ecosystem services fundamental for sustainable development, poverty eradication and human rights

Glaciers provide Peru with water for domestic agriculture and livestock development, agro-industrial and hydroelectric energy projects, and drinking water for cities such as Huancayo, Huaraz and Lima, among others.

In fact, more than 8,000 lakes created from glaciers provide water supply services for human consumption and power generation. And because of their scenic beauty, both glaciers and lagoons contribute to the tourism sector (INAIGEM, 2018).

<sup>&</sup>lt;sup>2</sup> Glacier Cordilleras: Blanca, Huallanca, Huayhuas, Raura, Huaguruncho, La Viuda, Central, Huaytapallana, Chonta, Ampato, Vilcabamba, Urubamba, Huanzo, Chila, La Raya, Vilcanota, Carabaya and Apolobamba.

 $<sup>^3</sup>$  Departments with glaciers: Ancash, Pasco, Lima, Junín, Huancavelica, Ayacucho, Cusco, Apurímac, Arequipa and Puno..

## Glaciers' contribution to water and sanitation, and power generation

- Located in the central Andes of Peru, Huaraz is the capital of the department of Ancash, and represents the country's fifth largest economy, contributing 3.9% of the national Gross Value Added (GVA), according to the Central Reserve Bank of Peru. In a year with regular or usual rainfall, glacial meltwater represents approximately 67% of Huaraz's water supply. On the other hand, during a drought year, glaciers can provide up to 91% of fresh water (Schoolmeester et al., 2018).
- The Vilcabamba Mountain Range, in the department of Cusco, has a retreat rate of 3.91 km²/year. According to the National Institute for Research in Glaciers and Mountain Ecosystems (INAIGEM), the glaciers of that mountain range will disappear by 2042 if the current trend of increasing temperatures continues. If the glaciers disappear, the water resources stored in Vilcacamba which allow 107 MW of energy to be generated through the Machu Picchu hydroelectric power plant will be affected. The loss of scenic beauty would also affect the tourism sector (INAIGEM, 2018).

In addition to their relevance as sources of water, glaciers also play a role in regulating climate and ecosystem health. Therefore, they contribute to the biodiversity conservation, tourism and the continuity of cultural and spiritual practices of the citizens of the Andes (INAIGEM, 2018; Boyano, 2017; Walter, 2016).

Despite its relevance, between 1962 and 2016, Peru lost 1,284 km<sup>2</sup> of its glacial surface, equivalent to 53.56% of the total area. Currently, it preserves 46.44% of its glaciers but it is expected that by 2048, 12 of them could disappear, while the rest would gradually extinguish by 2111 (INAIGEM, 2018).

The Peruvian State has determined, through its National Strategy against Climate Change and the update of its NDCs, that glaciers loss is not only evidence of the impacts from the average temperature increase on mountain ecosystems. It is, first and foremost, one of the side effects of climate change.

## Glaciers loss in the National Strategy against Climate Change and the NDCs of the Peruvian State

- "The State's interest in addressing climate change is based on the concern about its adverse effects at the national level. These are observed in glacial retreat and access to water resources related to it, in the unusual variability of temperatures on land and at sea, in the change in rainfall historical patterns and in the coastal outcrop, as well as in the increase in the intensity and frequency of extreme weather events." (MINAM, 2015, p. 9)
- "Alterations in climate and the increase in the frequency and intensity of hazards related to climate change affect our country through the increase in average temperature, the loss of glacial surface, the incidence of prolonged droughts, the increased frequency of heavy rains that cause landslides and floods, among others. These dangers have an impact on various population groups; on ecosystems and their ecosystem services; on the national productive structure; and on the economic and social infrastructure, which causes the deterioration of the population well-being. Many of these effects can already be observed and will continue in the medium and long term." (MINAM, 2020, pp. 13-14).

Deglaciation leads to a series of damages and losses that affect the Peruvian State and its citizens. On the one hand, from a water security perspective<sup>4</sup>, it presents scenarios caused by avalanches, the emergence of new lakes<sup>5</sup>, overflow of glacial lakes and decrease in volume of water used for economic activities.

## Losses and damages associated with risks related to glaciers and deglaciation in Peru

• In Peru, almost 25,000 people died between 1941 and 2014, as a result of glacial disasters (Carey, 2014). Within this story of tragedies, glacier lake 513, located in the city of Huaraz, is one of the most dangerous. Some of its last outbursts date back to April 2010, when it destroyed "dozens of homes, roads, bridges, farmland and irrigation canals. Thousands of residents also lost access to safe drinking water when flooding damaged the water treatment plant" (Ibid.: 20).

<sup>&</sup>lt;sup>4</sup> For the purposes of this paper, water security is defined as "the ability of a population to safeguard access to adequate quantities of water of acceptable quality to sustain both human and ecosystem health, based on watersheds, as well as to ensure the protection of life and property from water-related hazards, floods, landslides, soil subsidence and droughts" (UNESCO, 2012, p. 5).

<sup>&</sup>lt;sup>5</sup> It is expected that 201 new lakes may appear in Peru as a result of deglaciation. Some of these could be dangerous (Guardamino et al., 2019).

- In 2016, the National Institute of Civil Defense (Instituto Nacional de Defensa Civil, INDECI) warned about the possible overflow of the Chuspicocha lake, located in the Huaytapallana mountain, and its potential impacts on the city of Huancayo, in the Department of Junín. The INDECI technical report determined a high risk of overflow as a result of a flood, and damage to one of the walls or dams of the lake. Furthermore, it estimated that at least 1,934 people could be affected by the flood and the possibility that there could be a total of 7,504 people affected is not dismissed. The alert recalled that, in December 1990, an avalanche of ice and rock from Huaytapallana fell on Chuspicocha, causing it to burst its banks. At least four people died, access to drinking water was affected and high-altitude Andean farmers were also affected (INDECI, 2016).
- By the end of 2050, glaciers in the Cordillera Blanca could lose between 30% and 50% of their glacier mass. As a result, water supply in the Santa River basin would decrease by 57-78 million m³ in dry seasons and by 103-155 million m³ in rainy seasons. These changes in water availability are expected to result in economic losses in various sectors. In this regard, it is estimated that, by 2050, the reduction of water supply in the Santa River basin would result in the loss of around USD 300 million/year for the main water use sectors at wholesale prices (Drenkhan et al., 2019).

On the other hand, glaciers loss in Peru leads to impacts on the mountain ecosystems biodiversity such as wetlands, high Andean forests, grasslands, among others (INAIGEM, 2017). Likewise, it also affects the cultural heritage of the Andes where glaciers are sources of knowledge, on which local culture about the ecosystem's function is based, as well as oral literature and ritual practices full of spirituality.

In this scenario, the Peruvian State promoted the development of a governmental framework focused on managing the impacts of deglaciation, taking into account integrated water resource management (IWRM), disaster risk management (DRM) and climate change adaptation (CCA). However, it is through its public policy instruments on climate change and mountain ecosystem management that glaciers and deglaciation have been established as topics of concern in public management.

# 2.2. Climate Public Policy: The Peruvian State Against Deglaciation

The death of around 1,800 people and the destruction of the city of Huaraz – following the alluvium of the Palcacocha glacier lake in December 1941<sup>6</sup> – is a milestone in the history of glacier and lagoon monitoring in Peru.



As a result of this disaster, the Peruvian State began a process of research, technological innovation and public management aimed at glacial risk reduction (Carey, 2014). For this reason, around 1942, a Lagoon Control Office of the Cordillera Blanca was created within the Directorate of Water and Irrigation of the Ministry of Development and Public Works; and in 1951, "President Mr. Manuel Odría created the Control Commission of Cordillera Blanca Lakes to conduct research on glacial lakes as well as projects of disaster prevention" (INAIGEM, 2016, p. 16)<sup>7</sup>.

The Commission succeeded in compiling an inventory of glacial lakes in the Cordillera Blanca. Since then, the research of glaciers and their lakes - as well as their drainage has undergone several changes. In fact, the responsibility for promoting this process shifted from the Control Commission of Cordillera Blanca Lakes (1950-1969) to the Glaciology and Hydrological Resources Unit of the National Water Authority (2008-2014)8. However, Law No. 30286 created the National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM), as a specialized technical body attached to MINAM. As such, since 2014 it has assumed the role of developing,

<sup>&</sup>lt;sup>6</sup> Located in the department of Áncash, in the Cordillera Blanca of the Central Andes of Peru.

<sup>&</sup>lt;sup>7</sup> The Commission was created in response to an avalanche generated by an ice avalanche from Alpamayo in October 1950, which caused the destruction of the Chimbote-Huallanca railway and the Cañón del Pato hydroelectric power plant, whose construction was nearing completion (INAIGEM 2016).

<sup>&</sup>lt;sup>8</sup> Between 1968 and 2008, there were several organisational changes in glacier risk management. According to the institutional reports of INAIGEM and the National Water Authority, during this period, the most important were the Corporación Peruana del Santa (1966-1973), Electroperú (1973-1977), Instituto de Geología y Minería - INGEOMIN (1977-1978), Instituto de Geología, Minería y Metalurgia - INGEMMET (1979-1981), Electroperú (1981-1986), Hidrandina (1986-1990), Electroperú (1991-1999), INRENA (1999-2008).

proposing approval and managing the execution and monitoring of the National Policy on Glaciers and Mountain Ecosystems. It was also responsible for conducting research and technological development that contributes to the Andes' sustainable development; preparing the national inventory of glaciers, glacial lakes and wetlands: and formulating preventive measures against climate change impacts on glaciers and mountain ecosystems, among other functions related to the conservation and integration of mountain ecosystems in the development of the lives of the people of the Andes (INAIGEM, 2017).

Although the management of glaciers and deglaciation related hazards resulting from climate change is addressed in an intersectoral and decentralized manner by the Peruvian State, the Ministry of the Environment and INAIGEM have technical-regulatory leadership. However,

ANA also monitors and studies glaciers, being responsible for their evaluation and monitoring (MINAM, 2021).

The relevance of glacier thematic was highlighted by the Peruvian State before the international community through its three national communiqués to the UNFCCC (Figure 1). Broadly speaking, they highlight the relevance of glaciers for the sustainability of development and the population's wellbeing while warning about the impacts of deglaciation, and emphasizing the decrease in freshwater volume for productive activities and domestic use.

At the regulatory level, the issue of glaciers and deglaciation is addressed through the National Strategy for Climate Change, the Framework Law on Climate Change, the Final Report of the temporary Multisectoral Working Group responsible for producing technical information to guide the implementation of Nationally Determined

## Glaciers and deglaciation in Peru's national communiqués to the UNFCCC

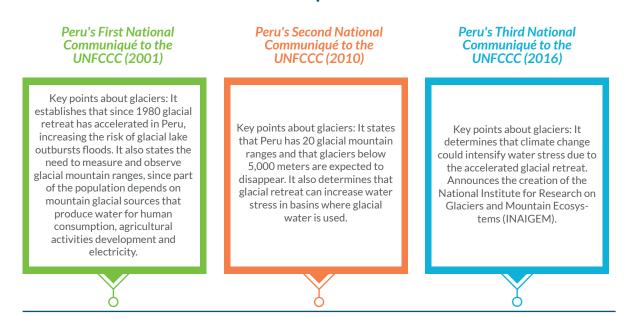


Figure 1. Glaciers and deglaciation in Peru's national communiqués to the UNFCCC.

Contributions (GTM-NDC), the National Plan for Climate Change Adaptation, the National Environment Policy to 2050 and the NDC of Peru towards 2030. In addition, the INAIGEM is in the process of drafting the National Policy on Glaciers and Mountain Ecosystems (Figure 2).



Figure 2. Glaciers and deglaciation in Peru's main climate policy instruments

Glaciers and mountain ecosystems management is interdependent, although in general terms they are addressed through public policy instruments developed within the commitments made by the Peruvian State to the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). Glacier issues treatment also contributes to the Sendai Framework for Disaster Risk Reduction

(hereinafter, the Sendai Framework). The interconnection between these instruments is possible due to the adaptation perspective developed by the Ministry of Environment, as lead agency on climate change.

#### Climate Change Adaptation in Peru

- The Peruvian State, through the Ministry of Environment, recognizes that the main interest regarding adaptation is to anticipate and respond to the full range of effects of the changing climatic conditions. In this regard, the Framework Law on Climate Change (LMCC) defines adaptation as a process of adjustments to climate and its effects on human and natural systems, to avoid or mitigate damage and take advantage of potential positive impacts of the average climate temperature increase. In addition, the National Adaptation Plan affirms that adaptation seeks to anticipate the future effects of climate change on society and ecosystems, as well as respond to the impacts that are already being experienced in Peru. To this effect, it states that adaptation offers perspectives and capabilities related to disaster risk management, which allow information on current and future climate to be incorporated into the estimation and subsequent risk management (MINAM, 2021, p. 47).
- In accordance with its Law on Climate Change and the National Adaptation Plan, Peru's NDCs have established before the UNFCCC that "climate change adaptation seeks to reduce and/or avoid current and future damage, losses and alterations caused by climate change dangers in the populations livelihoods, ecosystems, basins, territories, infrastructure, goods and/or services, among others; as well as taking advantage of the opportunities offered by climate change for sustainable and resilient development" (ibidem, p. 15).
- To implement climate change adaptation, the Peruvian State has identified 92 measures: 17 measures focus on agriculture, 12 on forests, 14 on health, 31 on water and 18 on fisheries and aquaculture. Approximately 60% of these incorporate a gender perspective and 44 measures take cultural diversity into account.

Along with the regulatory and technical framework on climate change, Peru has an institutional framework in climate governance that contributes to recommendations for actions to adapt and mitigate climate change. This is constituted by the High Level Commission on Climate Change (CANCC)<sup>9</sup>, the National Commission on Climate Change (CNCC)<sup>10</sup> and the Indigenous Peoples' Platform to Address Climate Change (PPICC)<sup>11</sup>. From this governance framework, different topics and challenges related to climate change, such as glaciers loss, are addressed.

### 2.3. Glacier Adaptation and Retreat

25% of the adaptation measures identified, adopted and prioritized by Peru to meet the adaptation goals established in its NDCs correspond to disaster risk reduction measures (MINAM, 2021).

One of these measures focuses on glacial retreat: Implementation of Early Warning Systems for floods, droughts, landslides and glacier-related hazards in basins vulnerable to climate change (hereinafter SAT measure).

The SAT measure is part of the adaptation measures of the water thematic scope. Its design incorporates a gender and intercultural approach, as well as an intergenerational perspective. It seeks to "alert residents to the potential impact and damage of severe droughts, floods and alluviums, hazards related to climate change on their livelihoods, economic activities, natural capital, among others, providing information and protocols to implement preventive actions to reduce vulnerability and increase the response capability of the population" (Government of Peru, 2018, p. 406).

As co-benefits, this measure is expected to reduce risks that may delay the country's development process (Ibid). To achieve its implementation, there is a number of challenges and opportunities (Figure 3).



Photographic archive of the Glaciers+ Project of the Swiss Agency for Development and Cooperation.

<sup>&</sup>lt;sup>9</sup> Permanent multi-sectoral space – the National Assembly of Regional Governments and the Association of Municipalities of Peru also participate – whose purpose is to propose measures for adaptation and mitigation to climate change within the framework of the NDCs.

<sup>&</sup>lt;sup>10</sup> It promotes the involvement of civil society in the comprehensive management of climate change, for which it has been coordinating with youth, women's and Afro-Peruvian organisations since 2019.

<sup>&</sup>lt;sup>11</sup> Made up of the 7 national organisations representing the indigenous or native peoples of Peru. The participation of the indigenous or native peoples of Peru in climate change takes into account the law developed by the Peruvian state to implement Convention 169 of the International Labour Organisation.



Figure 3. Opportunities and Challenges of Addressing Glaciers in Peru's Adaptation Agenda<sup>12</sup>

Beyond the challenges and opportunities of implementing the SAT measure, it constitutes an inter-institutional action that promotes dialogue and cooperation between different sectors at the national level of the Peruvian State with its regional and local governments. It also highlights Peru's preparation facing the effects that the country, its regions and localities will experience, as a result of the gradual glaciers loss.

<sup>&</sup>lt;sup>12</sup> Prepared by the authors based on the presentation of Mrs. Cristina Rodríguez, director of the Directorate of Climate Change Adaptation and Desertification of the Ministry of Environment of Peru, during the event "Peer Dialogue: Perspectives and Agenda on Glacier Retreat in the Tropical Andes", organized by the Water Program of the Department of Sustainable Development of the Executive Secretariat for Integrated Development of the General Secretariat of the OAS, held on December 2, 2020.



# 3.1. General Overview of Deglaciation

Bolivia is home to approximately 20% of the tropical glaciers of the Andean region (Francou et al., 2013). Located in the Western and Eastern Andes mountain Cordilleras, they constitute the landscape of four smaller mountain ranges: Real, Tres Cruces, Apolobamba and Nevado Santa Vera Cruz (Schoolmeester et al., 2018).

Glaciers play a fundamental role for the sustainable development of Bolivia. These glaciers mainly supply water for agricultural and energy activities and water intended for human consumption in high Andean communities and cities such as La Paz.



# Glacier contribution to the water system and electricity

The Illimani, Mururata, Huayna Potosí and Illampu mountains are the most important in Bolivia for the ecosystem services they provide. These are located in the Cordillera Real, where there are also glaciers that comprise the Tuni Condoriri basin. Thanks to these, La Paz and El Alto have water.

Estimates of the contribution of glaciers to water and sanitation can vary. On the one hand, it is considered that the melting of glaciers contributes up to 61% of the water supply in La Paz during rainy seasons; while in dry periods or periods with little precipitation, the maximum monthly contribution reaches 85 (Schoolmeester et al., 2018). However, it has also been considered that, in the annual average, 15% of the water consumed in La Paz and El Alto is from glacial sources: during rainy seasons its contribution is 14% and in the dry season it reaches 27%.

Although the numbers may vary according to methodological, academic and technical considerations, the relevance of Bolivian glaciers to the drinking water system is undeniable. In addition, the glaciers of the Zongo and Takesi basins – located in the Cordillera Real – contribute to power generation for La Paz and El Alto, which constitute important urban centers for political and economic activities in Bolivia (Andersen, 2014). Under these considerations, glaciers loss and the damage on the ecosystem services they provide jeopardize water security for approximately 2 million people.

In Bolivia, glaciers also play an important role in biodiversity conservation and high Andean landscapes. They contribute to the hydrological regulation and vital ecosystems health – such as wetlands and grazing areas – , for family economies dedicated to agriculture and livestock (Andersen, 2014). Thus, they promote local economic dynamics whose sustainability depends on the effects of deglaciation on mountain ecosystems biodiversity. Hence, deglaciation is one of the factors linked to climate change, which will lead to greater migration from the countryside to the city and increase pressure on the use of urban infrastructure (ibidem).



#### Effects of deglaciation on wetlands in Sajama National Park

Sajama National Park is located in the extreme northwest of the department of Oruro, in the province of Sajama. It borders with the department of La Paz on the north side and with Chile on the west side. Part of the reason why it is considered a tourist attraction lies in the scenic beauty of the Sajama mountain, the Pomerape and the Parinacota, as well as in its wetlands. These wetlands are regulators of the hydrological regime, as well as food sources for wild and domestic Andean camelids. In addition, they are the most important vegetation unit and are mainly located in glacier valleys.

Despite the importance of wetlands in Sajama National Park, they are deteriorating as a result of a number of factors. Some of these factors are related to the impacts of climate change on the Sajama mountain and the decrease in rainfall volume, according to local people's perceptions (Bolivian Mountain Institute, 2014).

While the Bolivian Mountain Institute suggests that there are no detailed research papers on the Sajama Glacier and the volume of water it stores, meltwater is known to feed the tributaries of the Sajama, Tomarapi and Esquillani basins (ibidem, p. 14). However, it is considered that some of the effects of the gradual Sajama loss produce degradation of wetlands and the ecosystem services they provide. This would affect, in terms of local socio-economic systems, the small high Andean economies dependent on domestic livestock farming.

Despite the relevance of glaciers, rising temperatures have turned them into fragile ecosystems. According to the national circumstances of its NDCs, "during the past 50 years, the country has lost approximately 50% of its glacier surface" (Plurinational State of Bolivia, 2015, p. 4). In addition, glaciers in the Tuni Condoriri basins, critical to the water supply to La Paz and El Alto, are expected to disappear between 2025 and 2045 (Andersen, 2014).

Bolivian glaciers are mainly distributed between the Apolobamba, Real and Tres Cruces mountain ranges. Knowledge about them has been developed through two glacial census. The first was conducted in the 1980s by the German geographer Ekkehard Jordan, while the second was conducted within the Project "Adaptation to the Impact of the Accelerated Retreat of Glaciers in the Tropical Andes" (PRAA) framework. which involved the Ministry of Environment and Water (MMAyA) of Bolivia and the Institute of Hydraulics and Hydrology of the Universidad Mayor de San Andrés.

Although the national average glacier mass loss is 50%, census show that the deglaciation process varies between mountain ranges and regions. The Apolobamba Range lost 40.01% of its glacial area, while the Cordillera Real experienced a retreat of 37.4%. The latter holds glaciers that provide water to La Paz and El Alto and produce electricity for both cities. Despite its relevance, glacial melt water is expected to decrease between 25% and 45% in the Tuni Condoriri basin over the next three decades, compared to the current period.

It is also estimated that the Tres Cruces mountain range is likely to lose 37.3% of its glaciers. Other research suggest that glacier contraction is even greater. Therefore, it is estimated that the Tres Cruces mountain range lost 47.3% of its glacier mass, while the Apolobamba and Real mountain ranges experienced a deglaciation process of 43.1% and 41.9%, respectively (Cook *et al.*, 2016).

Regardless of the differences between the results on glacial retreat in the Bolivian

mountain ranges, there is a consensus that glaciers loss will cause water deficit scenarios in which different economic activities and the right to water will be affected by climate change. In addition, deglaciation also poses a context of potential glacial lake outburst or outflow (ibidem), which put at risks the fundamental human rights of populations living in high mountain areas.

#### Dangerous glacial lakes in Bolivia

Glaciers retreat not only jeopardizes Bolivia's water security and sustainable development. It is also causing a scenario in which several lakes could burst their banks.

One of the documented cases of glacial lake outburst in Bolivia dates back to 2009, when the town of Keara – a small town located in the Pelochuco Valley, in the Apolobamba Mountain Range – was affected by the overflow of a lake. Roads and farmland, as well as livestock, were lost. Communication and a number of basic services were interrupted for several months (Robertson, 2014; Martins, 2016).

Currently in Bolivia, the possibility of 25 glacial lakes overflowing and affecting communities living in the Andes has been reported (Cook et al., 2016; Hoffmann, 2016 and 2020).

Although there is no specific regulation in Bolivia regarding glaciers, it can be suggested that Bolivian glaciers are regulated through water regulations and through protected natural areas regulations, where some of them are located (Iza and Rovere, 2006). However, taking into account that deglaciation is an adverse effect of climate change, the Plurinational State of Bolivia developed a regulatory and action framework based on good living, the rights of Mother Earth, and climate change, with water resources being a fundamental dimension (Depuits, 2021).

# 3.2. Climatic Public Policies: The Plurinational State of Bolivia Against Deglaciation

The Plurinational State of Bolivia has informed the international community about the impacts of climate change on Bolivian glaciers and the consequences of their retraction on the country's sustainable development, through its three official communiqués to the UNFCCC (Figure 4). These constitute public policy instruments that present deglaciation as a damage that jeopardizes the availability of water for multiple economic activities. They also reflect a number of considerations established by the Bolivian State through its national framework for environmental and climate change issues.

At the national level, the management of Bolivian glaciers is seen through the nexus between public policies focused on climate change and water resources, from a living well perspective.

Although within the Bolivian government institutions there is no body specialized in glaciers, the State apparatus has a normative and organizational structure that recognizes deglaciation as an adverse effect of climate change.



## Glaciers and deglaciation in Bolivia's national communiqués to the UNFCCC

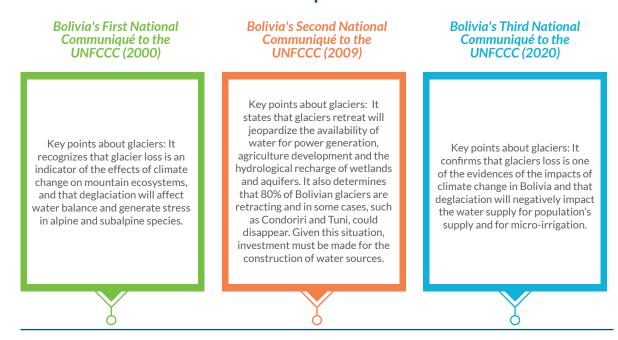


Figure 4. Glaciers and deglaciation in Bolivia's national communiqués to the UNFCCC

On a normative level, the issue of glaciers and deglaciation is addressed by Bolivia through the Framework Law of the Mother Earth, the Patriotic Agenda from the Bicentennial to 2025, the National Mechanism for Climate Change Adaptation, the National Forest and Climate Change Strategy and the NDCs (Figure 5)<sup>13</sup>. In addition, glaciers – as in the case of Apolobamba, Madidi, Cota Pata, Tuni Condoriri and Sajama – are indirectly protected through the National System of Protected Areas.



Figure 5. Glaciers and deglaciation in the main instruments of climate public policy in Bolivia

<sup>&</sup>lt;sup>13</sup> In 2015, the Plurinational Climate Change Policy was presented as a working document. It is still under discussion.

Overall and generally speaking, the Bolivian regulatory framework recognizes the significance of glaciers as high mountain ecosystems, which are relevant for their hydrological services for hydroelectric power generation, small agriculture sustainability, provision of water for human consumption and biodiversity conservation of high Andean ecosystems, such as wetlands.

Although Bolivia's Plurinational Climate Change Policy is under discussion and is available as a working paper, its text extracts central considerations on deglaciation, which are addressed in the regulatory framework regarding glaciers. In this regard, it highlights their importance for the Bolivian economy, as well as their vulnerability to the increase in average temperatures.



Alexandra Carlier, 2016, Ascent to the Chuecón glacier, Peru.

## Main Glacier Considerations in the Plurinational Climate Change Policy (working paper)

- Diagnosis of the impact of climate change: [...] The retreat of tropical glaciers has been recognized early as an indicator of climate change and presents evidence regarding the relationship between glacier mass balance and various climatic parameters, such as precipitation, temperature, albedo (among others). The case of the disappearance of the Chacaltaya snowy peak mountain is emblematic [...] The impacts related to changes in the last 30 years, attributed to climate change, are expressed in glacial area loss, appearance of new glacial lakes and changes in wetlands surface. (p.41).
- Integrated water management: Significant ice masses are lost annually in high mountain glaciers due to rising temperatures, experiencing a decline, increases in river flows during rainy seasons and accentuating the reduction of flows during the dry season, a factor that will significantly affect the availability of water for human consumption in populated centers and for hydroelectric power generation plants in the future [...] (p.54).

• Glacier retreat: Lower availability of water resources is expected in the face of glaciers retreat. The accelerated melting of glaciers began early in the decade of 1980s and it is presumed that, in the last 25 years, a significant number of small glaciers have disappeared. Given this situation, one of the most important issues is the reduction of glacial water reserves that provide drinking water. Likewise, many rivers that come from glaciers supply major cities and agricultural areas, affecting availability for consumption, irrigation, industry, power generation, among other uses. (p. 108).

At the organizational level, Bolivia's governmental structure does not have organizations or units specialized or focused on glacier issues. That is why knowledge management about glaciers and their retreat is promoted, mainly, through strategic alliances between the Bolivian State and academic institutions, as well as with multilateral organizations (Figure 6). However, within the Bolivian government apparatus, the Plurinational Authority of Mother Earth (APMT), the General Directorate of Environment and Climate Change, the General Directorate of Watersheds and the Vice Ministry of Territorial and Environmental Planning constitute technical and political bodies with competencies related to regulatory instruments that take into consideration glaciers and deglaciation as topics of interest and public management.

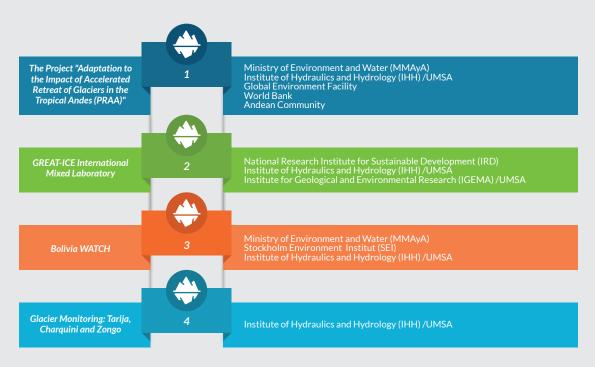


Figure 6. Main projects related to glaciers in Bolivia

The importance of glaciers for the Plurinational State of Bolivia is not only reflected in its regulatory and organizational framework. There are experiences, objectives and measures promoted by the government apparatus, which constitute relevant actions to promote adaptation to glaciers loss.



Alexandra Carlier, 2016, Visit to the Huayna Potosi glacier, Bolivia.

## 3.3. Glacier Adaptation and Retreat

As part of future actions related to glacier retreat, the Bolivian State has contemplated the need to produce and consolidate a national database of information on glaciers, in coordination with research institutions, the National Meteorology and Hydrology Service (SENAMHI) and the Ministry of Environment and Water (MMAyA). It also contemplates carrying out the third National Census of Glaciers and Periglacial Environments, and developing a National Glacier Information and Monitoring System (SIMOG) that will be integrated into Bolivia's Environmental and Water Resources Information System (SIARH). This general framework of actions is oriented towards knowledge management for decision-making in climate change adaptation, within the framework established by the National Mechanism for Adaptation to Climate Change (MNACC), which established as a priority that research on the impacts of climate change on water resources must take into account glacial retreat and its effects on different sectors.

### Climate Change Adaptation in Bolivia

- Adaptation responds to extreme events such as disruptions of the hydrological cycle, periodic droughts, storms, floods among others; as well as chronic problems emerging from climate change, which do not necessarily have resources (economic, human, etc.), for adaptation actions (Ministry of Development Planning, 2007, p. 14).
- Climate change adaptation responds to four fundamental principles that provide the basis for developing various initiatives and are integrated into characteristics that distinguish the Adaptation Policy Framework: i) Climate variability and short-term extreme weather events are included as a basis for reducing long-term vulnerability to climate change; ii) Adaptation policies and measures are assessed in a development context: iii) Adaptation occurs at different levels in society, including at the local level; iv). Both the strategy and the process by which adaptation is implemented are equally important. (lbid.: 16)
- The Climate Change Adaptation Policy Framework is oriented to conducting studies, planning processes, preparation of programs and projects to respond to climate change; preliminarily, responding to the occurrence of extreme events and complementing these mechanisms with long-term adaptation strategies. (Ibid.: 16)

As part of the actions related to glacial retreat and climate change adaptation, the Bolivian State has implemented adaptation projects for the benefit of populations potentially affected by glacier retreat, including the Integrated Management Project of the Tuni Condoriri Basin and the Integrated Management Pilot of Microwatersheds Affected by Glacier Retraction (Andersen, 2014).

The first of them sought to implement actions that compensate for the reduction of water supply and reduce water demand in the supply systems of El Alto and the slopes of La Paz; while the second focused on establishing pilot models for integrated management of the Khullu Cachi, Tacapaya and Amachuma Grande microbasins that increase the resilience of agricultural production against the retraction of glaciers (ibidem, pp. 69-70).

Bolivia's experience and knowledge on glacial retreat and its impacts have allowed objectives, measures and strategies to be identified in the face of deglaciation, as part of the programs within the MNACC.

The MNACC Sectoral Program for Adaptation of Water Resources to Climate Change establishes among its objectives the need to produce energy alternatives, to replace the deficit in glacier water supply used for power generation. To this effect, as an adaptation measure, it determines the production of information on water deficit vulnerability of population centers during dry seasons, the relationship between glacier retreat, wetland recharge and extreme hydrometeorological events during the rainy season. Finally, it raises the need to encourage the development of clean

energy alternatives to cover the deficit of hydroelectric energy, resulting from glaciers retreat.

Meanwhile, the MNACC Sectoral Program for Ecosystem Adaptation to Climate Change states, among its objectives, the need to establish systems for the protection of wetlands as a strategy for biodiversity conservation, through actions to recharge aquifers in areas under glaciers influence.

Finally, the MNACC Scientific Research Program establishes among its objectives, the development of research studies on the impacts of glacier retreat and the identification of adaptation measures in the hydroelectric power generation sector. In addition, its 11 adaptation measures include the determination of the socio-economic impacts and the identification of measures for climate change adaptation against glacier retreat.

In short, in terms of glaciers, climate change adaptation, as promoted by the MNACC, seeks to foster the resilience of Bolivia's energy matrix and its citizens, as well as its water supply for human consumption and agricultural activities. To this effect, the conservation of the biodiversity of ecosystems that provide hydrological services is critical.





# 4.1. General Overview of Deglaciation

Ecuador maintains a total of 43.5 km² of glacier mass, which represents approximately 4% of the glaciers of the tropics. According to the most recent data, it is estimated that it is distributed among 103 glacial ice tongues located along seven ice caps¹⁴. Four of these are located in the Western Cordillera, while three lie in the Eastern Cordillera (Francou *et al.*, 2011).

During the second decade of the 20th century, Ecuador experienced the loss of a large part of its glacier mass. Some estimates show that glacier retreat ranges from 30% to 50% over the period from 1976 to 2006 (Ibid.). However, the State of the Republic of Ecuador has determined, through its NDCs, that they have lost about 50% of their glacial surface. This has led to a number of impacts related to water

availability that affect water security of high Andean communities, including the city of Quito.

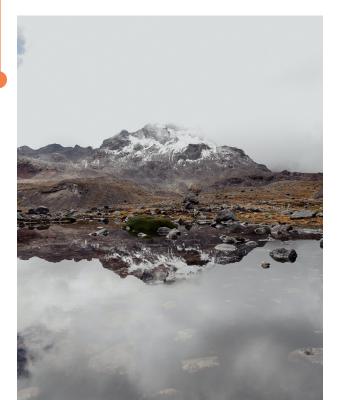
The Impact of Deglaciation on Water Resources, According to Ecuador's NDCs

"[...] Another impact associated with water resources is the retreat of glaciers, which have lost more than 50% of their surface in the last 50 years, causing significant repercussions for water users, in Andean communities, especially related to landslide risks". (Republic of Ecuador, 2019, p. 29).

The glaciers located in the Antisana<sup>15</sup> and Cotopaxi volcanoes are especially relevant because of the hydrological service they provide to the city of Quito (Francou et al., 2000), which, according to the National Institute of Statistics and Censuses (INEC), is inhabited by 2,781,641 people and whose water and sanitation system depends on the water collection carried out by the Metropolitan Sewerage and Drinking Water Company (EMAAP).

According to estimates made by UNESCO and GRID-ARENDAL, in a regular year, glacial melting represents approximately 5% of Quito's water supply, while, during a year of drought, the maximum monthly contribution reaches 15% (Schoolmeester et al., 2018, p. 9). However, information generated by Ecuador's INAMHI – based on official research papers conducted in the Nevado Antisana basin – suggests that the volume of water from the glacier melting and contributing to the basin is between 2% and 3%, while in the dry season its value can be a maximum of  $10\%^{16}$ .

Despite the relevance of the Antisana and Cotopaxi glaciers, the former experienced an approximate 72% retraction between 1962 and 2016 (Cáceres *et al.*, 2007; Cáceres *et al.*, 2008; Schoolmeester *et al.*, 2018), while Cotopaxi lost approximately 52% of its glacier surface between 1962 and 2006 alone. In the case of the Chimborazo glacier, it lost about 72% of its glacier mass between 1962 and 2016 (Francou *et al.*, 2011)<sup>17</sup>.



<sup>&</sup>lt;sup>14</sup> Antisana, Cotopaxi, Chimborazo, Cayambe, Altar, Illiniza and Carihuairazo..

<sup>&</sup>lt;sup>15</sup> In the Antisana there are two systems that supply drinking water to the city of Quito: the Papallacta system and the Mica/Quito Sur system.

<sup>&</sup>lt;sup>16</sup> Information shared by Mr. Bolívar Cáceres of INAMHI through verbal and written communications between INAMIH and the Water Programme of the Department of Sustainable Development of the Executive Secretariat for Integral Development of the Organization of American States.

<sup>&</sup>lt;sup>17</sup> In the case of Ecuador, it must be taken into consideration that the loss of snow and ice is not only a phenomenon associated with climate change. Eruptions and volcanic ash are also factors in understanding deglaciation.

Ecuadorian glaciers loss impacts the availability of water for human consumption. As snow and glacier mass melting accelerate as a result of climate change, lake formation increases and, thus, moraines that function as their dams can collapse over time, generating sudden overflows of glacial lakes, such as the one that occurred in December 2016, when a lake located on Glacier No. 13 of Chimborazo suddenly overflowed (Schoolmeester et al., 2018)

In summary, the general scenario of deglaciation in Ecuador not only shows glacier mass loss, but also its impact on water availability and the increase of overflow risks. Therefore, the Republic of Ecuador has promoted relevant national processes facing deglaciation that summarize decades of learning and experiences.



Alexandra Carlier, 2016, Visit to the Huayna Potosi glacier, Bolivia.

# 4.2. Climate Public Policies: The Republic of Ecuador facing deglaciation

Glaciers loss is a phenomenon recognized by the Republic of Ecuador before the international community as an indicator of the adverse effects of climate change within the Ecuadorian territory through its three official communiqués to the UNFCCC and its NDCs (Figure 7).

Glaciers and deglaciation in Ecuador's

#### national communiqués to the UNFCCC **Ecuador's First National Ecuador's Second National** Communiqué to the UNFCCC (2001) Communiqué to the UNFCCC (2011) Key points about glaciers: It determines that Ecuadorian Key points about glaciers: It states that INAMHI, with the tropical glaciers are affected by the increase in average support of the French Institute for Research and temperature and establishes a Climate Change Development (IRD), are the main institutions responsible Measurement and Data Collection System, within which the for studying glaciers and the impacts of climate change, implementation of specific measurement systems such as although there is no national institution responsible for glaciers, among other ecosystems is encouraged. It states monitoring and observing glaciers in the country. It also that glaciers are important because of their contribution to highlights that research on glaciers in Ecuador shows an water supply for the irrigation of central Ecuadorian valleys accelerated loss process. and for human consumption in Quito. Key points about glaciers: It suggests that Ecuadorian glaciers will continue to collapse and may disappear as a result of climate change, so a long-term glacier monitoring program must be maintained. It also highlights the link Key points about glaciers: It recognizes that Ecuador lost between glaciers and mountain ecosystems - with special approximately 50% of its glacial surface, which affects water emphasis on páramos -, emphasizing that they influence resources availability and leads to negative repercussions the dynamics of mountain biodiversity. In this framework. for water users in Andean communities. it establishes that the reduction or disappearance of glaciers would negatively affect water production and regulation capacity, increasing the vulnerability of populations and ecosystems depending on water from glacial melting. NDC (2019) **Ecuador's Third National**

Figure 7. Glaciers and deglaciation in Ecuador's national communiqués to the UNFCCC

Communiqué to the UNFCCC(2017)

Although Ecuador's official communiqués to the UNFCCC and the NDC highlight deglaciation as a public problem, it is not specifically addressed or recognized in the Organic Code of the Environment or in the National Plan for Good Living 2017-2021.

In this last document, several considerations related to the right of people to live in a healthy environment and to the protection of the rights of nature are established to guarantee good living in a context of climate change. However, glaciers and deglaciation are addressed as specific national policy issues through Ecuador's National Climate Change Strategy 2012-2015 (ENCCE) and the National Climate Finance Strategy (ENFC) (Figure 8).

In general terms, the considerations established in the ENCCE and the ENFC, on the relevance of glaciers and the impact of deglaciation on the sustainable development of Ecuador endorse the central points that the Republic of Ecuador has stated through its national communiqués to the UNFCCC. Thus, under this framework. from its environmental institutions, the country has been promoting a systematic process of glacier and hydrometeorological monitoring since 1994.

In addition, Ecuador has a Glacier Monitoring Program, whose objectives are focused on studying the causes of glacial retreat; documenting atmospheric evolution over 4,000 meters above sea level; doing research on the impact of glacial retreat on water resources and the páramo ecosystem; and, emphasizing the relationship between local and regional glacier and hydrometeorological information. To this end, the State has focused its efforts on research initiatives located in the Antisana Glacier and Carihuayrazo and has conducted specific studies in Cotopaxi and Chimborazo.

### **Ecuador's National Climate Change Strategy** 2012-2015 Key points about glaciers: Due to their location, it states that glaciers melting leads to impacts on human settlements since they rely on glacial water. At the same time, it recognizes that mountain ecosystems are particularly vulnerable to the effects of climate change. Glaciers and deglaciation in Ecuador's main climate policy instruments. **National Strategy** for Climate Finance Key points about glaciers: Among the adaptation actions linked to the Ecuadorian water heritage, it establishes the need to manage and operate water collection and storage in strategic areas affected by the effects of climate change, such as glaciers, aquifers, among other ecosystems.

Figure 8. Glaciers and deglaciation in

Ecuador's main climate policy instruments.

Currently, Ecuador has a total of 43.5 km² of glacier mass, having lost approximately 50% of its glaciers over the past 50 years. Despite this situation, Ecuador has been able to gain experience and information and has a glacio-hydrometeorological database in Antisana that holds approximately 20 years of information. In addition, the country has generated information for decision-making, building national capabilities in science and technology, encouraging the training of professionals with doctoral and master's

degrees specialized in glaciers within government institutions.

Knowledge management about Ecuadorian glaciers has been mainly promoted by the National Institute of Meteorology and Hydrology (INAMHI). However, government institutions do not have an agency focused on glacier and mountain issues. Nevertheless, as part of its adaptation initiatives, Ecuador has promoted initiatives aimed at managing the challenges of deglaciation.



## 4.3 Glacier Adaptation and Retreat

The Ecuadorian State is in the process of preparing its National Adaptation Plan to ensure that climate change adaptation is integrated into sectoral and local development planning, as well as to reduce the vulnerability and climate risk of social, economic and environmental systems that are exposed to the adverse effects of climate change.

#### Climate Change Adaptation in Ecuador<sup>18</sup>

Within the process of preparation of Ecuador's National Adaptation Plan, climate change adaptation is defined as a set of actions and decisions that aim to address the impacts of climate on people's lives and health, human settlements, livelihoods, ecosystems, infrastructure and other human or natural systems. Under this consideration, the main goal of adaptation is to reduce vulnerability and strengthen the capacity to deal with climate threats and seek the recovery from their adverse effects.

<sup>&</sup>lt;sup>18</sup> For further reference, visit: https://www.adaptacioncc.com/ (Last visited: January 13, 2022).

Although the ENFC establishes activity 158 in the water heritage subsector, as a climate change adaptation initiative aimed at managing, operating and handling water collection and storage in strategic areas affected by the effects of climate change, such as glaciers (among other ecosystems), the glacier agenda in Ecuador has a strong research component.



# Major Glacier Research Projects in Ecuador, According to Ecuador's Third National Communiqué to the UNFCCC

- Ecuador Glaciers Program: Operating since 1994. Through it, research and monitoring processes have been promoted in Antisana, Cotopaxi, Chimborazo and Carihuayrazo. It has the technical and scientific support of the Research Institute for Development of France and the support of the Metropolitan Public Company for Drinking Water and Sanitation of Quito (EPMAPS).
- Project CATCOS I (2012-2014) and CATCOS II (2014-2016): It was implemented with the purpose of providing logistical support in the mass-balance measurements of Glacier 15 of Antisana, with the technical leadership of Meteoswiss.
- Andean Regional Project for Climate change adaptation/Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes Project (PRAA): Financed by the World Fund and the World Bank, it was executed by the General Secretariat of the Andean Community, with the participation of the Ministry of Environment, Water and Ecological Transition, among other environmental sectors of the Andean countries. As part of its knowledge management actions, the PRAA installed automatic stations in the Los Crespos glacier microbasin, in the Antisana. It also contributed furnishing equipment to three hydrological stations, three meteorological and four rainfall stations, as well as a communication system between the meteorological stations of glaciers 12 and 15 of Antisana.
- Andean Tropical Glacier Monitoring Project: With funding from the Inter-American Development Bank (IDB) and under the implementation of Conservation International, the project was established in Ecuador, Peru, Bolivia and Colombia. In Ecuador, the project encouraged the monitoring of Chimborazo and Carihuayrazo, to produce evidence on the effects of climate change on mountain ecosystems and their relationship with risks related to deglaciation. Its implementation involved the participation of INAMHI.

• Estimation of the Mass Balance on the Quito Glacier: It was implemented to highlight the relationship of glacier mass variations between glaciers in the Antarctic Peninsula and the continental ones. To this end, it implemented a measuring device on the Quito Glacier with the collaboration of the University of Zurich.

Ecuador's experience facing deglaciation goes beyond research and glacier monitoring.

The country has also promoted the implementation of climate change adaptation projects in glacial basins, to incorporate the affected communities' knowledge into public policy instruments, and strengthen the resilience of mountain ecosystems and local economic systems to the impacts of glacier retreat (Ministry of Environment of Ecuador, 2017). In this general context, the Ecuadorian State has generated knowledge and experiences for climate change adaptation in the light of deglaciation, which constitute benchmarks for the implementation of activity 158 of the ENFC.





# 5.1. General Overview of Deglaciation

High mountains are an integral and fundamental ecosystem for the sustainable development of Colombia, due to their biodiversity, the ecosystem services they provide to the rural and urban population and the population that lives in it. Despite this, it is vulnerable to the effects of climate change (IDEAM, IAvH and Condesan, 2018).



# The high mountains in Colombia<sup>19</sup>

The Colombian high mountain range is fundamentally constituted by three types of ecosystems: high Andean forests, located between 2,800 and 3,400 meters above sea level (m a.s.l.), páramos that lie between 3,400 and 4,800 m a.s.l., and glaciers with an altitudinal range ranging between 4,800 and 5,700 m a.s.l.

In addition to the richness of its biodiversity, Colombia's high mountains are an engine for the development and general well-being of people, due to their hydrological wealth. The water regulation service provided by the páramos, generates water that is used by more than 70% of the of the Colombian population, for human consumption and the development of economic activities (World Bank, 2021).

It is estimated that by 2011, 58% of Colombians lived in or had some kind of link or involvement in the high mountains (IDEAM, 2011). It is also estimated that approximately 20 million Colombians live in municipalities located in páramos, while 36% of Colombia's municipalities have their territories in the high mountains. Of these, 24% are in a situation of "very high" and "high" threat to the effects of climate change (IDEAM and UNDP, 2017).

Glacier loss is one of the indicators of the fragility of high mountain ecosystems in Colombia due to the effects of climate change. While they have lost 90% of their area since the mid 19th century (IDEAM, 2020), between 1950 and 2019, Colombian glaciers went from 109 km² of glacial surface to 36 km² (Ibid.). In other words, in 69 years, more than 65% of the glaciers that provided several ecosystem services to people and nature were lost. In addition, the most recent estimates suggest that between 2010 and 2019, there was a reduction of 11.4 km² (Ibid.).

In this context, the harsh impact of the El Niño Phenomenon on glacier dynamics between 2015 and 2016 is specially evident, especially on the Santa Isabel Glacier, located in the Los Nevados National Natural Park. It experienced a rapid process of glacier mass melting, this event was interpreted as a warning about the possible future of Colombian glaciers (Ceballos, Carlier and Cerna 2022). It is estimated that, between January 2016 and February 2018, the Santa Isabel Glacier lost approximately 48% of its area. In addition, if extreme weather phenomena such as El Niño occur again, their extinction will accelerate (IDEAM, 2020)

Currently, the 36 km<sup>2</sup> of glacial area in Colombia is distributed along six glaciers that, in their entirety, represent between 3% and 4% of South American tropical glaciers (CAN, UNEP and AECID 2007, Ceballos, 2012).

<sup>&</sup>lt;sup>19</sup> Some of the information on high mountains in Colombia was presented by the Executive Director of IDEAM, during a conference on July 6, 2021, as part of the webinar "Multidimensional Impacts of Deglaciation in South America", organized by the Water Program of the Department of Sustainable Development of the Executive Secretariat for Integral Development of the General Secretariat of the Organization of American States, in partnership with the Consortium for the Development of the Andean Ecoregion (CONDESAN).

Of Colombia's six glaciers, four lie on active volcanic structures, while the rest are located on non-volcanic rocks<sup>20</sup>. All of them are highly sensitive to climate and could disappear over the next three decades (IDEAM, 2012), generating impacts on ecosystems interdependent on glaciers. such as páramos and high Andean forests<sup>21</sup>. In this regard, one of the relevant topics of analysis from the IDEAM facing Colombian glaciers loss, is the impacts of glacial retreat on other mountain ecosystems, such as wetlands, which play an important role in water regulation and aquifer recharge in high mountain areas (IDEAM, IAvH and CONDENSAN, 2018).

Unlike other countries with tropical glaciers, the Colombian population does not depend on glacier water, they do though on the ecosystems of the hydrological regulation services provided by the high Andean páramos and forests. Indeed, although glacial melt water is not quantitatively relevant to Colombia's overall balance of water supply and demand, the IDEAM has identified that glaciers provide water to rural high Andean populations. Such is the case of Ibagué, the capital of the department of Tolima, which uses water from the Combeima River, which in turn receives contributions from glaciers melting (IDEAM, 2012).

In addition to the glaciers' role as sources of water, they are also important because of their scenic beauty for tourist activities. But also, they are ecosystems that hold cultural, spiritual and identity relevance for Colombian indigenous peoples (Ibid.).

The cause of glacial melting, according to residents of Colombian snowy mountains

Understanding a potentially harmful phenomenon from the local communities point of view, is a necessary step in defining effective actions that avoid adverse impacts on people and ecosystems. Understanding the local conception of threats allows us to know and understand the set of decisions that would be taken locally to address, for example, the accelerated retreat of glaciers (Heyd 2011). Indigenous groups such as the Nasa and Arahuacos have been perceiving changes in their mountains and, in general, in their territories, but they ascertain causality differently from what is the norm in Western

<sup>20</sup> The six remaining glaciers in Colombia are Sierra Nevada de Santa Marta, Sierra Nevada El Cocuy or Güicán, Volcán Nevado del Ruíz, Volcán Nevado Santa Isabel, Volcán Nevado del Tolima and Volcán Nevado del Huila.
<sup>21</sup> In relation to phenomena associated with climate change and inherent climate variability, the strong impacts of the El Niño phenomenon in 2015-2016 on glaciers, especially on the Santa Isabel glacier, stand out in Colombia. In this regard, a rapid process of glacier mass melting was recorded and this event was interpreted as a warning about the possible future of Colombian glaciers (Ceballos, Carlier and Cerna 2022).

thought. In a process structured based on processes of cultural and territorial vindication, the indigenous people of the Sierra Nevada de Santa Marta and the snowy volcano of Huila understand changes in climate and glaciers as a result of a serious fault on our behavior with other humans and non-humans. For the U'wa of Sierra Nevada de El Cocuy, glaciers melting in their territory is due to the constant passage of hikers through the highlands of the mountain, where man should not set foot. The peasants who live on the western side of the Sierra seem to appropriate in their own way part of the U'wa perception regarding glacial retreat (syncretism). When questioned about possible causes of the retreat, it is generally associated with the fall of ash from the Nevado del Ruíz, during the eruption of 85 and the glacier trampling [...] (IDEAM 2012, p. 140).

The cultural relevance of Colombian glaciers means that they have immeasurable value for local communities and indigenous peoples.

This has allowed civil society to suggest initiatives such as Cumbres Blancas, that among their objectives state to contribute to the promotion of awareness of Colombian citizens about the importance of glaciers, as well as the interest in promoting their conservation. This means that the national scenario that revolves around Colombian glaciers contemplates a participatory richness that also involves parliamentarians, through the Accidental Commission on High Mountain Ecosystems, whose objective is to raise public awareness regarding the relevance of glaciers -and other mountain ecosystems-, to promote their protection and study (Ceballos, Carlier and Cerna, 2022).





Alexandra Carlier, 2016, Ascent to the Chuecón glacier, Peru.

The State and Civil Society facing Deglaciation and Conservation of Colombia's High Mountain Ecosystems<sup>22</sup>

As part of Colombia's participatory community monitoring (PCM), three processes related to the implementation of glacier PCM networks emerged around 2018, as a result of the project "Andean Tropical Glaciers in a Context of Climate Change", financed by the Inter-American Development Bank (IDB). The first of these encouraged the creation of a group conformed by students, young professionals, technicians and mountaineers, in order to conduct, in a participatory manner, the glacier mass balance of the Nevado del Tolima volcano.

The second process is the emergence of the civil society collective Cumbres Blancas, whose aims revolve around raising public awareness and promoting knowledge about glaciers.

The third case consists of a joint action promoted by Colombia's National Natural Parks and the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), which was named Climate Change Trail. This consisted of installing high Andean roads that lead to three glaciers located in National Natural Parks, as well as information on the history of climate change and its impacts on Colombia's high mountain ecosystems, to sensitize the local population and tourists.

The relevance of the role of civil society in the conservation of mountain ecosystems in Colombia allowed the Cumbres Blancas collective to promote an advocacy process in the House of Representatives. Thus, with the support of IDEAM, the Accidental Commission on High Mountain Ecosystems was created, to give political sustainability to the technical processes promoted by the institutions of the Colombian State and the citizen awareness promoted by civil society.

<sup>&</sup>lt;sup>22</sup> Information provided by the IDEAM of Colombia, as part of technical meetings and information exchange organized by the Department of Sustainable Development of the Executive Secretariat for Integral Development of the OAS, through its Water Program.

The study of Colombian glaciers is not only relevant in environmental, hydrological and sociocultural terms. It is also important within the risk management agenda, because avalanches and glacial melting can be caused by rising temperatures during volcanic eruptions and seismic movements. In this regard, Colombia experienced a disaster that led to the death of more than 23,000 people when approximately 10 km<sup>2</sup> of ice broke off after the eruption of Nevado del Ruiz in 1985. The disaster also resulted in the total and partial destruction of crop fields, as well as damage to the infrastructure of different population centers (IDEAM, 2012; Schoolmeester et al., 2018).

To address glacier issue, the Colombian State has a number of public policy instruments. Although there is no regulatory framework specifically focused on glaciers, they are managed through an Integrated Monitoring Strategy for High Mountain Ecosystems (EMA) that evaluates the impact of changes in the political-economic context on biodiversity and ecosystem services, as well as providing inputs for territorial planning, taking into account climate change adaptation and the restoration of degraded ecosystems.

# 5.2. Climate Policies: The Republic of Colombia Against Deglaciation

Colombia has made the relevance of glaciers known to the international community, through its three national communiqués to the UNFCCC. They state general information about the deglaciation landscape, emphasizing the relationship between glacial retreat and water resources. In addition, the Colombian State has established within the revision of its NDCs that glaciers are strategic ecosystems (Figure 9).

The central considerations on glaciers – established in the national communiqués to the UNFCCC – collect information used and produced by Colombia's environmental and climatic institutions. The latter has policy instruments that, although they do not directly address the



Alexandra Carlier, 2016, Nevado Suiricocha, Peru.

# Glaciers and deglaciation in Colombia's national communiqués to the UNFCCC

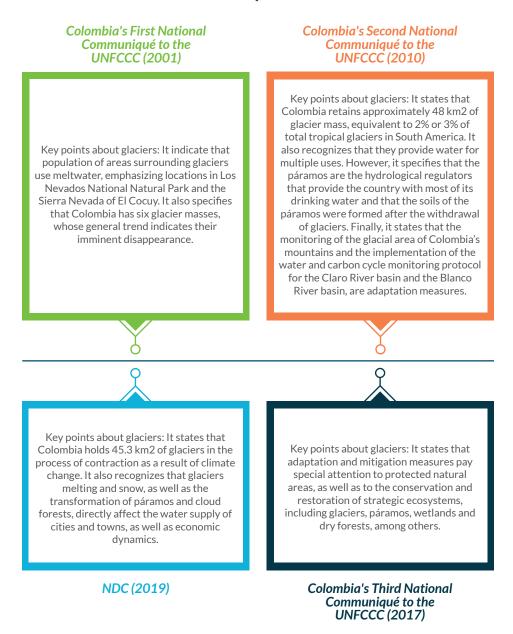


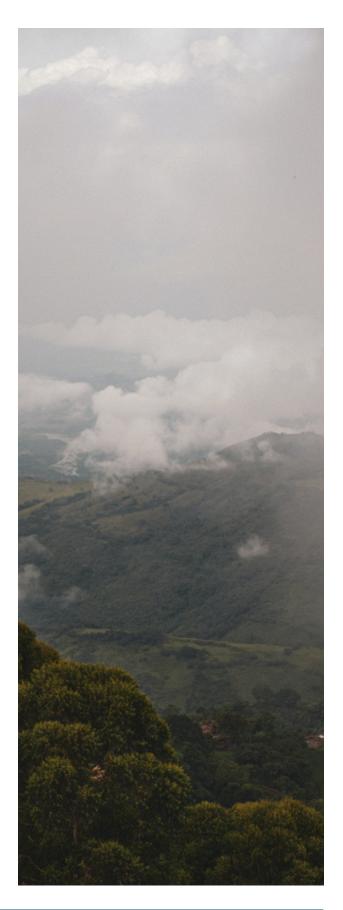
Figure 9. Glaciers and deglaciation in Colombia's national communiqués to the UNFCCC

glacier issue, provide a general framework for climate action. The 2018-2022 National Development Plan establishes that all departments of the country must implement actions to adapt to climate change, keeping an ethnic or cultural diversity focus on climate change adaptation.

On the other hand, and as an instrument focused on climate change, there is Law 1931, which determines that climate change management is defined as a "coordinated process of design. implementation and evaluation of actions to mitigate greenhouse gases and climate change adaptation aimed at reducing the vulnerability of the population, infrastructure and ecosystems to the effects of climate change"23. Thus, the National Climate Change Policy - whose purpose is to incorporate climate change management into public and private decisions so that development is climate-resilient and low in carbon emissions, and reduces the risks generated by climate change - recognizes that semi-arid regions and those that depend on the contribution of glaciers will have lower water availability.

In this general context, there are other instruments such as the Climate Change Adaptation National Plan (PNACC) and the 2050 Long-Term Strategy to comply with the Paris Agreement, which incorporate general references related to glaciers and their retraction. In addition. glaciers are also recognized as strategic ecosystems in the National Policy for Integral Water Resource Management and the 2015-2025 National Disaster Risk Management Plan, which incorporates climate change as a risk management approach, recognizing that glacier melting is a threat. It also identifies that at least 1.9 million people live in areas of influence of the Ruiz. Galeras and Huila volcanoes where there may be lahars and avalanches caused by volcanic eruptions, while 240,000 live in areas exposed to a high threat.

<sup>23</sup> Article 3(9) of Law 1931.



#### **Climate Change Adaptation** National Plan (PNACC) Key points about glaciers: It states the need to develop actions to reduce ecosystems transformations and losses, such as glaciers (among others), due to climate change. In addition, as part of Objective 2 of the PNACC (which incorporates climate change adaptation into environmental, territorial and sectoral planning), it determines that, through coordination with regional environmental authorities, adaptation measures should be formulated in high mountain ecosystems, such as high Andean forests, páramos, 2050 Long-Term Strategy to comply wetlands and glaciers, as well as allocating with the Paris Agreement budgets at all budgetary levels. Key Points About Glaciers: It recognize glaciers as part of Colombia's strategic ecosystems. Glaciers and deglaciation in Colombia's main climate policy instruments National Policy for the Integrated **Management of Water Resources** Key Points About Glaciers: It states that glaciers are part of the natural water supply systems. In addition, it establishes as part of strategy 1.3 (conservation) the implementation of actions aimed at the 2015-2025 National Disaster Risk restoration and conservation of ecosystems that are key to the Management Plan regulation of hydrological supply, Key points about glaciers: It recognize glacial retreat as a such as glaciers, páramos, threat. It also identifies that there may be lahars and wetlands, mangroves, among avalanches at the Ruiz, Galeras and Huila volcanoes, as a other ecosystems. result of eruptions. These may affect approximately 1.9 million people who live in areas of influence of volcanoes.

Figure 10. Glaciers and deglaciation in Colombia's main climate policy instruments

<sup>&</sup>lt;sup>24</sup> The implementation of multilevel processes takes place through the Regional Climate Change Nodes, as bodies in charge of promoting, accompanying and implementing the SISCLIMA instruments in the regions, according to the provisions of Article 10 of Decree No. 298. In this sense, they play a relevant role as they promote inter-institutional coordination between the central and territorial levels.

The implementation of climate action and its policy instruments in Colombia is multilevel and intersectoral. In addition, it is part of the National Climate Change System (SISCLIMA)<sup>24</sup>, which is defined by Decree No. 298 of 2016, as the set of policies, rules, processes, governmental and private entities, resources, plans, strategies and mechanisms that contribute to mitigation and climate change adaptation. This allows issues such as glaciers and deglaciation to be managed through the link between climate change, water resource management and risk management, as action lines for sustainable development. Hence, the Intersectoral Commission on Climate Change (CICC), as part of SISCLIMA, has a number of fundamental roles. These include their roles in concluding cross-sectoral commitments on climate change, as well as encouraging the use of instruments for mitigation and adaptation.



Alexandra Carlier, 2016, Suiricocha - Pampa Paccha Route, Peru.

## 5.3. Glacier Adaptation and Retreat

Climate change adaptation in Colombia seeks to reduce the risks associated with the adverse effects of climate change, as well as socioeconomic impacts related to climate change and variability. In this regard, the PNACC establishes that disaster risk management and climate change adaptation are complementary strategies, particularly in the processes of knowledge gathering and reduction of climate or ocean related risks.

#### Specific objectives of the PNACC



Objective 1: Manage knowledge about climate change and its potential consequences on communities, biodiversity and its ecosystem services, and the country's economy.

- Objective 2: Incorporate climate change adaptation into territorial and sectoral development planning.
- Objective 3: Promote the transformation of development for climate change adaptation following criteria of competitiveness, sustainability and equity.

One of the main characteristics of the PNACC is its integrality. Indeed, the Colombian State expressly states that its efforts in the area of climate change adaptation are articulated with global goals that contribute to resilience, such as the Convention on Biological Diversity, the 2030 Agenda, the Convention to Combat Desertification and the Sendai Framework for Action. For this, the PNACC establishes eight strategic lines<sup>25</sup>. Under this consideration, glaciers are addressed through the second and third specific objectives.

As part of the second specific objective of the PNACC, the incorporation of guidelines and actions for climate change adaptation in development planning instruments at the local, regional and national levels is determined as a priority. Within this framework, it is established that, in coordination with the Regional Environmental Authorities, development planning instruments must be created to contribute to the implementation of

adaptation measures in high mountain ecosystems, such as glaciers, considering an ecosystem-based adaptation approach. It also proposes a budget allocation in government institutions at the territorial level.

On the other hand, within the third specific objective of the PNACC, it recognizes as a necessity, to promote actions aimed at decreasing the transformation and reduction of strategic ecosystems according to their ecosystem relevance, such as glaciers, among others.



Alexandra Carlier, 2016, Visit to the Huayna Potosi glacier, Bolivia.

<sup>&</sup>lt;sup>25</sup> i) Synergies between adaptation and mitigation; ii) adaptation based on socio-ecosystems; iii) articulation of climate change adaptation and risk management, including the design and implementation of an early warning system, iv) adaptation of basic infrastructure and sectors of the economy; v) incorporation of adaptation and resilience considerations in sectoral, territorial and development planning; vi) strengthening of institutional capacities; vii) promotion of climate change education for the generation of behavioural changes; viii) consolidation of peace territories with climate change considerations.



## 6.1. Conclusions

In terms of hydrological supply, glaciers are not a sustainable source of access to freshwater for the development of multiple activities.

Each of the countries has lost more than 50% of its glacier mass, and the decline will continue. This leads to the need to identify and prioritize the implementation of climate change adaptation measures against glacier retreat, beyond country-driven knowledge management, as part of glacier mass monitoring. Thus, the questions about what to do against deglaciation in Andean countries with tropical glaciers should not revolve only around the future of glaciers in

the context of climate change. It is also essential to raise questions about what to about a future without – or with few – glaciers. In this regard, Bolivia has experience in implementing projects to adapt to climate change against glacial retreat. Peru has a glacier adaptation measure that can guide the design of projects that can be financed by cooperation agencies, development banks and environmental and climate funds. Under this framework, Andean countries with tropical glaciers have sufficient experience to promote a regional adaptation agenda and project portfolios.

recognizes the multidimensional relevance of glaciers for development sustainability and the well-being of citizens, therefore they have different institutional mechanisms focused on generating evidence and making recommendations. However, in most cases it is not clearly identified which adaptation measures, focused on the implementation of projects or actions in territories with glacier influence, are prioritized within the framework of national adaptation plans or NDCs.

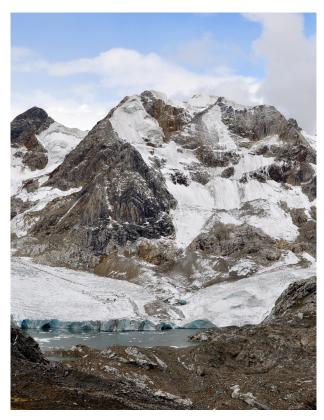
However, every national scenario follows a normative and institutional capacities context that facilitates the identification, prioritization and implementation of adaptation measures against glacier retreat. In this regard, among the cases analyzed, the efforts of the Peruvian State to design a catalog of adaptation measures framed within the adaptation goals established in the NDCs and the national agenda for adaptation to climate change, stand out as a knowledge management practice for public policy.



Photographic archive of the Glaciers+ Project of the Swiss Agency for Development and Cooperation.

• Although the NDCs are relevant instruments to address the glacier problematic – which is why all the countries analyzed report the status of their glaciers and their retraction through their NDCs and national Communiqués to the UNFCCC – national plans for climate change adaptation can be constituted as the main frameworks of action by each country against glacier retreat. This entails that, within the intersectoral technical dialogue exercises of every national State, the process of identifying adaptation measures or actions focused on managing the challenges of glacial retreat should be strengthened, taking into account the links between climate change adaptation, disaster risk management, integrated management of water resources and biodiversity conservation. Consequently, this consideration once again highlights the need to strengthen interinstitutional work against deglaciation.

Although countries share similar problems and have valuable experiences, there is no evidence of an articulated and sustainable integration work that would promote regional projects. Although there are cases which constitute a benchmark for integration, such as the The Project "Adaptation to the Impact of the Accelerated Retreat of Glaciers in the Tropical Andes" - which received a grant from the Global Environment Facility (GEF), the World Bank and the Government of Japan, managed by the General Secretariat of the Andean Community (SGCA) –, the glacier issue could become an issue to be institutionalized within the agenda of mountain ecosystems and adaptation to climate change.



Alexandra Carlier, 2016, Chuecón glacier, Peru.

### **6.2 Recommendations**

- Strengthening the framework of intersectoral public policies specialized on glaciers and high mountain ecosystems in the countries affected by glacial retreat in the tropical Andes –, represents an opportunity to promote climate change adaptation in a context of glacial retreat, taking national adaptation plans and their implementation in mountain ecosystems as a reference for action:
  - > Deglaciation is a phenomenon that impacts economic and human activities organized in different sectors at the national level in every country.
  - > Glaciers, as part of mountain ecosystems, do not have a specific regulatory and policy framework, except the case of Peru.
  - > The inclusion of glaciers and deglaciation within NDCs requires a specialized regulatory framework, more robust and focused on the

implementation of adaptation measures that promote water, food, and energy security, and that guarantee the observance of economic, social, cultural and environmental rights.

- > The glacier agenda requires further actions aimed at promoting climate change adaptation in basins that use water from melting glaciers with the help of sustainable development projects that take as reference the information and knowledge generated by government technical institutions and academia.
- Promoting investment in the design of projects with a focus on Nature-based Solutions represents an opportunity to promote climate change adaptation against a future without glaciers or with little glacier mass for water supply for human consumption, or agricultural and hydroenergy activities; whilst:
  - > Nature-based solutions are defined as actions aimed at protecting, sustainably managing and restoring natural or modified ecosystems, to address social challenges, generating human well-being and biodiversity benefits, within a framework of adaptation and mitigation to climate change (Cohen-Sacham *et al.*, 2016; Oliver *et al.*, 2021).
  - > Nature-based Solutions would encourage the development of green and gray infrastructures that contribute to water security, by restoring and conserving high mountain ecosystems that provide hydrological ecosystem services.
  - > Case evidence of projects that incorporate components of Nature-based Solutions suggests that these can generate co-benefits to different sectors (Oliver *et al.*, 2021), and therefore can contribute to the strengthening of interinstitutional framework.
- Enhancing dialogue and technical cooperation between countries with glaciers, on measures to adapt to climate change in basins affected by deglaciation, whilst:
  - > Countries that experience the retraction of their glaciers have experiences and knowledge that can be scalable regionally and replicable in different environments.
  - > Beyond the differences between national scenarios, there are common challenges, as well as regulatory frameworks for action.

> Dialogue and technical cooperation could encourage the co-design of regional projects that, within the mountain ecosystem agenda, prioritize climate change adaptation processes, in the face of a future with less ice, snow and water.

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