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Adapting to Climate Hazards in the Peruvian Andes

MARK CAREY AND HOLLY MOULTON

Changing with the Climate

Fifth in a series

In November 2017, lawmakers and climate activists from around the world met in Bonn, Germany, for the twenty-third annual United Nations Climate Change Conference, or conference of the parties (COP 23). US President Donald Trump's recent withdrawal from the Paris Climate Agreement had created a palpable sense of anxiety. Media coverage echoed this concern: to limit future atmospheric warming to 2 degrees Celsius, the world's largest emitters, including the United States, China, and Europe, would need to achieve strict emissions-reduction goals. The Bonn meeting also included discussions on climate adaptation, local communities, and indigenous peoples. Yet the mainstream media barely covered these meetings, focusing instead on the status of the Paris Agreement and emissions targets. While such an emphasis on mitigation is critical for global climate policy, it tends to eclipse consideration of the human dimensions of climate change.

The emissions framing can cast climate change as an issue to be solved with technologies and policy instruments by the Global North—by the same countries and companies that created the climate problem in the first place. In this portrayal, local communities and developing nations are pushed to the sidelines to watch passively as their fate is decided in places like Bonn and Washington. Such a narrative overlooks local and regional histories of adaptation to environmental change. It neglects the root causes of human vulnerability to climate change. And it perpetuates global power imbalances that privilege the Global North, leaving behind the rest of the world.

News coverage beyond the COP meetings has often featured similar narratives: that people on the front lines of climate change, especially those in developing nations, are victims waiting helplessly or ineptly for outsiders to fix the problem. They are credited with no ingenuity and little successful collective action.

One locale that often appears in the mainstream media as a bellwether of climate change is Peru's Cordillera Blanca mountain range, including the communities at the base of its 6,000-meter (22,000-foot) peaks, which have borne witness to the catastrophic effects of melting glaciers in floods, avalanches, and water scarcity. An August 2017 *Washington Post* article, for example, referred to the Cordillera Blanca as “a laboratory for adapting to climate change.” The headline asserted that “it's not going well,” which the article suggested is due to a confluence of Peruvian ineptitude, superstitious beliefs, and unstoppable glacier melting.

Efforts to prevent glacial lake outburst floods in the Cordillera Blanca and protect the downstream city of Huaraz have indeed faced setbacks in recent years. Yet the *Post*'s account lacked historical perspective and misrepresented the Peruvian government's active and innovative responses to climate change and ice loss since the 1940s. Peruvian engineers have studied glaciers, monitored glacial lakes, and developed comprehensive flood-prevention techniques that led to the partial drainage and damming of 35 dangerous Cordillera Blanca glacial lakes. These engineers have prevented numerous deadly outburst floods, be-

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coming world leaders in the fight against unstable glacial lakes from the Andes to the Alps, Alaska, and the Himalayas.

Sweeping generalizations about Peruvian incompetence ignore more than 75 years of engineering projects, scientific monitoring, and dozens of highly successful climate change adaptation projects that have saved lives by preventing cataclysmic floods. And Peru is only one example: societies worldwide have long been adapting to global environmental changes, including climatic shifts. But their achievements—or even lessons learned from setbacks—are often overlooked when the problem of ever-increasing emissions becomes the dominant narrative.

Alongside Peruvian engineering innovations, there is another important lesson to be learned from Cordillera Blanca adaptation efforts: climate change solutions cannot just be technical or scientific. While crucial for reducing risk, technoscientific approaches neglect the societal dimensions of vulnerability. This includes the ways in which politics, power imbalances, and social inequality shape human responses, how cultural values and beliefs inspire or foreclose certain behaviors, and how long-term historical processes like land use and urban development increase exposure. Despite all the successes around the Cordillera Blanca, Peruvian adaptation agendas have also faced many obstacles.

Peruvians have been paying the price for climate change for decades.

A focus on the various factors shaping climate adaptation over time—particularly the social, economic, and political dimensions—fosters a reframing and broadening of the climate change problem. The evolution of Peru's Lake Palcacocha over three-quarters of a century, and the various responses to the lake's growth and instability, illustrate the necessity of both reducing global emissions and pursuing local adaptation strategies.

DEADLY OMEN

On Saturday morning, December 13, 1941, just after dawn, a massive block of ice calved off a melting glacier in the Cordillera Blanca and splashed into Lake Palcacocha. The lake had grown significantly over previous decades as the surrounding glacier shrank and meltwater pooled where ice had previously covered the valley floor. As though a cement block had been tossed into a bathtub, the splash immediately generated massive waves that toppled the lake's natural moraine dam of stones and soil and burst out of the lakebed. Most of the kilometer-long lake poured out and began a deadly rush toward the city of Huaraz and its 11,000 residents in the valley below.

Ever since the Spaniards founded the city in the sixteenth century, Huaraz had served as the commercial and administrative center for the Ancash region and the Callejón de Huaylas valley, which sits at the base of the Cordillera Blanca, the country's highest and most glaciated mountain range with more than 700 glaciers. Huaraz grew and modernized quickly during the first decades of the twentieth century. By 1941, it boasted a new women's school and tourist hotel. There was a lawn-tennis club for the city's wealthiest residents, markets where indigenous people sold their goods, and government offices, hospitals, and schools that drew everyone into the city center.

However, Huaraz's rapid modernization belied socioeconomic disparities that had existed for centuries. Highland communities, especially Quechua-speaking indigenous people living above the valley floor where Huaraz is located, were—and continue to be—marginalized. Many of the benefits of modernization were unlikely to reach them, even if they moved to the city to gain access to urban services.

On that December Saturday morning in 1941, less than a week after the Japanese bombed Pearl Harbor, Lake Palcacocha was rushing toward Huaraz like an alpine tsunami. Witnesses later recalled that the approaching flood sounded like a squadron of airplanes or an epic stampede of thousands of crazed beasts. The raucous mass of water, mud, trees, and boulders plowed into the city in a wave of destruction several meters high. One-third of the city and 1,800 people were literally wiped off the face of the earth. The deadly onslaught continued for 220 kilometers down the Santa River to the Pacific Ocean. This torrent of destruction became the deadliest glacial lake outburst flood in world history.

Today these kinds of dangerous, unstable glacial lakes are well known to scientists, policy makers, and local residents worldwide, from Nepal and Pakistan to Switzerland, Canada, and Chile. In 1941, however, no one really understood what had hit Huaraz. Why had the lake grown so large and unstable? What caused it to burst out of its bed? It was, it turned out, an early indication that glacier melt and climate change could have devastating impacts on Peru's mountain communities, an omen that foreshadowed similar events in mountain regions worldwide.

ENGINEERING SUCCESSES

Peruvians went to work immediately after the 1941 flood to learn about Palcacocha. Local and national authorities sent engineers to the lake while workers were still extracting mud-encased bodies from the disaster zone. They also set out to find other Cordillera Blanca glacier hazards and, ultimately, to devise engineering strategies that would reduce the ever-increasing glacial lake threats. By 1943, Peruvian geologist Jorge Broggi already understood that climate change since the Little Ice Age (a period from approximately 1400 to 1850) had been causing the Andean glaciers to shrink. The retreating glacier tongues often left behind unstable lakes, held precariously behind weak moraine dams of loose rocks and debris.

The Peruvian national government set up a glaciology and lakes security office in 1951, which is still in existence today—though it is now called the Glaciology and Hydrological Resources Unit. This institution has had an uneven history, with budget fluctuations and management changes. But overall it has been an important and enduring hub for glacier research and glacial lake security projects. Since 2014, a new government agency, the National Institute for Research in Glaciers and Mountain Ecosystems, has also been studying these topics, among other aspects of the Andean environment. But neither agency today has the same mission or the funding to carry out disaster prevention engineering projects that the national government provided in previous decades.

Starting in the 1950s, Peruvian engineers in the glaciology office undertook comprehensive glacial lake studies and monitoring, as well as important projects to partially drain and dam a total of 35 Cordillera Blanca glacial lakes. When a catastrophic 1970 earthquake—the Western Hemisphere's deadliest natural disaster in history—demolished homes, communities, and infrastructure in Ancash and the Callejón de Huaylas, no glacial lakes spilled into the towns below. Several nearly flooded, such as Lake Safuna, where the earthquake caused the entire submerged glacier tongue to bob to the surface like a fifty-million-ton submarine. But previous lake drainage projects had lowered the lake level enough so that the ensuing 60-meter-high waves at Safuna did not destroy the moraine dam.

There are more recent examples of averted catastrophes, when past engineering projects saved lives and protected populations. In 2010, glacial Lake 513 caused a small outburst flood that inundated the city of Carhuaz, destroyed croplands and pastures along the lake's outlet river, and damaged irrigation canals, bridges, and other infrastructure. There were no fatalities, but the flood could have been catastrophic if engineers had not lowered the lake level by more than 20 meters in the early 1990s.

Even at Palcacocha, previous engineering projects protected the Huaraz population from a deadly outburst flood in 2003, when water overtopped the security dam and spilled into the valley below, knocking out potable water supplies for a week. Although it is impossible to know for sure, it is likely that the engineering work at Palcacocha and Lake 513 transformed the 2003 and 2010 events into minor lake overflows instead of cataclysmic floods. Still, Peruvians have been paying the price for climate change for decades—with their lives and through expensive disaster-prevention projects.

The loss of Andean ice could have far-reaching impacts on Peru's coast, a desert region where much of the country's population resides.

Scientists and engineers play pivotal roles in long-term climate change adaptation initiatives, especially when governments provide adequate resources. International aid did not fund the Peruvian adaptation measures, yet many of these efforts became global models for glacial lake hazard reduction in other mountain systems. Peruvian engineers like Jaime Fernández Concha, Benjamín Morales, Alcides Ames, César Portocarrero, Marco Zapata, Marino Zamora, Jesús Gómez, Nelson Santillán, Alejo Cochachín, and many others devoted much of their lives to protecting the region's residents. They became international leaders in the field, later traveling to other countries like Nepal to provide advice on glacial lake outburst flood prevention.

Peruvians took matters into their own hands at an early point in time. Having experienced the detrimental effects of climate change before many other nations, they hastened to develop plans and technological fixes that would protect local populations. This was done without fanfare and out of the international spotlight, but was nonetheless an early example of the kind of climate change adaptation that is obscured by recent media coverage focusing only on emissions and atmospheric warming, without considering local contexts and achievements.

ZONING HAZARDS

Lessons from Peru show that technoscientific approaches to climate change and glacier shrinkage are insufficient on their own, especially when social, political, economic, and cultural factors undermine such efforts or pose additional—often more substantive and pressing—risks to the vulnerable populations. The risk from Cordillera Blanca glacial lake outburst floods stems not only from the changing glacier conditions and the technical aspects of the security dams and drainage system, but also from the exposure of the people living downstream along the Santa River.

In Huaraz, for example, more than 120,000 people now inhabit the city, many of whom live in the potential path of glacial lake floods. The most vulnerable inhabitants cluster along the Quillcay River and are spread out in Huaraz on the alluvial fan where the Quillcay meets the Santa, in the Centenario neighborhood, which was decimated by the 1941 flood. In the past few decades, people have also been building in the Nueva Florida district along the Quillcay.

Authorities had initially prohibited construction in this so-called *cono aluviónico*, the path of the 1941 flood. The government again forbade reconstruction in the Huaraz hazard zone after the 1970 earthquake, due to lingering concerns about unstable glacial lakes above the city, particularly Lake Palcacocha. In both cases, however, local residents ignored the zoning laws—and in some cases actively petitioned against them—while the government neglected to enforce the laws. People rebuilt and significantly expanded the neighborhoods in the hazard zone. Meanwhile, changing climatic conditions shrank the Palcaraju Glacier and Lake Palcacocha expanded, increasing the likelihood of an outburst flood.

Several key socioeconomic factors—which varied over time and among different social groups—help explain why people reconstructed their homes in destroyed areas along the Quillcay River. Overall, people ranked risks and decided that outburst floods were less significant than other sources of insecurity. Such decisions are common worldwide. People on every continent inhabit areas exposed to natural hazards, such as hurricane-prone coastal cities in Texas and Florida, flood plains in Bangladesh, tsunami zones in Chile and Indonesia, and earthquake fault zones in California and China. Generally, the poorest populations live in the locations most susceptible to natural disasters.

In Huaraz, however, the population exposed to Palcacocha floods is a mixture of wealthier residents in the downtown area and poorer communities on the outskirts, like Nueva Florida. Residents built (or rebuilt) their Huaraz homes in potential flood paths because the socioeconomic benefits of living in a hazard zone outweighed the perceived risks. Huaraz offered economic opportunities for people with few resources, limited or no job prospects, no access to land, and limited faith in post-disaster compensation. Vulnerability is a complicated web of socioceconomic, environmental, and geographic variables that intertwine in sometimes unexpected ways that are difficult to understand without contextual knowledge.

Issues of social status and race relations also motivated people to remain in or move to Huaraz despite the inherent risks. Cities like Huaraz had long been inhabited primarily by the ruling classes, Spanish-speaking residents, and supposedly nonindigenous people. In contrast, Peruvians often believed (stereotypically) that rural and upland populations consisted of Quechua-speaking indigenous people. A geo-racial binary emerged after the colonial era: living in the rural highlands signaled indigenousness and poverty, while living in Huaraz implied wealth and whiteness.

Post-disaster urban zoning after the 1941 flood and 1970 earthquake attempted to relocate the downtown Huaraz population to safe ground higher above the river and outside of town. But such proposals came to symbolize the threat of a reduction in socioeconomic status. Many Huaraz residents perceived government-imposed hazard zoning as an assault on ruling-class privilege, a rearrangement of race and class hierarchies, a heavy-handed intrusion of the national government into regional social relations, and an imposition of greater risks than any glacial lake posed. Moving, in other words, signified the loss of power, wealth, and status.

Zoning people out of the dangerous urban areas may have seemed logical and straightforward to policy makers and engineers. Yet for people living in these areas, adaptation to shrinking glaciers could not be divorced from the larger social, economic, and political contexts. This is an example of why the climate change conversation has to include an emphasis on local contexts and adaptation responses as well as emissions and temperature increases.

SYSTEMS UNDER STRAIN

The acceleration of climate change and worldwide glacier retreat means that Palcacocha and other glacial lakes continue to evolve, and the static infrastructure constructed to contain them is no longer able to effectively reduce the risk of some glacial lake outburst floods. In March 2003, Huaraz residents awoke to a city without running water. Market-goers along the Quillcay River watched with trepidation as rising waters rushed through fortified river embankments in the downtown area. It turned out that a landslide into Palcacocha had caused the lake to overflow, spilling over the two security dams and inundating the city's water treatment plant.

Older residents flashed back to December 1941, when Palcacocha obliterated their community. Would the treacherous lake attack them again? Would the security dams hold? These questions were more crucial than ever: compared with the 11,000 people living in Huaraz in 1941, there were more than 100,000 in 2003.

As scientists and engineers continued to monitor Palcacocha over the next several years, they were shocked to discover a quickly growing lake that contained about 17 million cubic meters of water by 2009, nearly forty times more water than it held when the security dams were completed in the 1970s. In the meantime, the national government had reduced the budget and resources for the glaciology office during the 1980s and 1990s, and even closed the unit from 1997 to 2001 after the state hydroelectric company that had previously managed it was privatized. As a result, the massive growth of Palcacocha from the 1970s to the early 2000s had gone undetected.

Since 2009, the government has installed a stopgap solution: siphons to drain water out of the lake. But major engineering works to drain and artificially dam the lake—the kind of projects that were so effective in saving lives and protecting communities over the previous 75 years—have not been pursued or supported consistently. Neoliberal economic reforms during the 1990s reduced government expenditures for social services and privatized the hydroelectric industry, which led to the closing of the glaciology office in 1997. It reopened in 2001, but President Alejandro Toledo's decentralization of the national government beginning in 2002 shifted significant responsibility (and funding) for disaster prevention and climate adaptation to regional governments. Thus, Ancash has been in charge of lake security project implementation at Palcacocha for the past decade.

Instead of focusing on engineering solutions, the government declares periodic states of emergency, especially in the rainy season when the lake's water level rises dangerously. This reactive, temporary approach fails to build on more than half a century of glacial lake engineering projects that Peruvians have become internationally famous for—and it shows how politics and governance often determine not just the type of adaptation agendas to be pursued, but also the level of risk and vulnerability populations face.

After 75 years of living under the threat of a deadly glacial lake outburst flood that could decimate their city, Huaraz residents have grown accustomed to seeing Lake Palcacocha in the news. Schoolchildren now participate in "flood drills" that teach them the proper direction to run—uphill and away from the river—to escape an approaching flood. Hazard maps are increasingly posted in local businesses. These precautions are necessary because the security siphons at Palcacocha often malfunction and require regular repair, while the pair of security dams need maintenance and may not be large enough.

The combination of the region's inherent seismicity and accelerating glacier melt requires, among other considerations, a nimble government that allocates sufficient resources to respond to the ever-changing climatic and glaciological conditions in the Cordillera Blanca. At the same time, it requires the recognition that Peruvians living in the region are vulnerable not only to glacier retreat and unstable glacial lakes, but also to a host of other political, economic, and social issues that influence climate change adaptation. Rather than being passive observers, Peruvians are acutely aware of these risks, and have taken action in a variety of ways to mitigate their vulnerability—though they often choose to address their economic or political vulnerability rather than the climate-related hazards from glacier shrinkage.

The Palcacocha problem also highlights tensions between Peru's highlands, where vital water sources are located, and lowland coastal regions where hydroelectric and farming companies use the water for energy generation and irrigation to support a booming export-oriented agricultural industry. The loss of Andean ice could have far-reaching impacts on Peru's coast, a desert region where much of the country's population resides, including 8 million people in Lima alone as well as other major cities such as Callao and Trujillo.

There is growing concern about real and imagined threats of dwindling water supplies, particularly related to the effects of highland glacier melt on lowland agriculture. This industry has undergone rapid expansion in recent decades. The Chavimochic Project in La Libertad, for example, relies heavily on Santa River water and Cordillera Blanca glacier runoff to irrigate crops. Since its origin in the 1980s, Chavimochic has been using glacier runoff to irrigate vast fields of asparagus, avocados, artichokes, mangoes, and passion fruit that large agricultural companies export. As a result, Peru is now the world's leading exporter of asparagus, which is paradoxically grown in a desert environment.

Climate change solutions cannot just be technical or scientific.

From job security and economic growth to drinking water and electricity, glacier meltwater affects the whole country, and the infrastructure and systems created to channel it can profoundly affect the livelihoods and water security of coastal residents. Yet water security involves more than the quantity of water flowing from Andean glaciers. Infrastructure projects to distribute water and adapt to climate change hinge on political decisions and economic resources. Construction on the major Palo Redondo reservoir project for Chavimochic, for example, was recently halted due to political corruption and bribery accusations against Odebrecht, the Brazilian company that had been building the reservoir. Water distribution in the desert depends on politics as much as hydrology.

POWER IMBALANCES

While Peruvian achievements and limitations illustrate the need to shift our climate-change framing to include more local contexts and societal dimensions, it remains crucial to connect global processes to local impacts. This is precisely what Saúl Luciano Lliuya, a farmer and mountain guide from the Huaraz area, is doing. Palcacocha's continued instability means that the lake may be poised to destroy his home and much of his city if it were to trigger a glacial lake outburst flood. Luciano has sued the German energy company RWE in a German court because, he maintains, RWE has contributed approximately 0.5 percent of the global emissions that have led to anthropogenic climate change and the retreat of the Andean glaciers. Luciano is requesting that RWE cover 0.5 percent of the costs (about $20,000) of more permanent and effective flood-protection measures at Palcacocha to protect Huaraz.

Luciano and his attorneys with the nongovernmental organization Germanwatch have recently won the right to proceed with their case, a landmark court decision in itself. Luciano's arguments point out that emissions and temperature change caused by European companies far from Peru are linked to real climate change impacts in the Andes. This reinforces the importance of international measures such as the Paris Agreement, as well as contested demands for climate reparations from the West to the rest, in order to address these impacts.

And yet, as with the recent COP 23 meetings in Bonn, Luciano's case also reminds us that Peru's fate lies partly in foreign hands: German attorneys, a German company, and German courts are defining Peruvian vulnerability to Palcacocha as they debate culpability and the legal merits of the case. In this framing of the problem, the power to act on climate change still lies with the industrialized West, even as the impacts play out in Peru (and elsewhere).

As monumental as this case would be if RWE is required to pay reparations, it could not really shift power back to Peru and the developing world. Rather, it works within the same system of colonialism, consumption, and natural resource extraction that not only helped cause climate change, but also has been shaping both Peruvian history and international relations since the Spanish conquest. Success in Luciano's case would be a step in the right direction for identifying responsibility for climate change and sharing the burden of its impacts. Yet this legal approach still forces Peruvians to remain dependent on a German court to resolve a problem in which Europeans are implicated much more than Peruvians.

However, coverage of Luciano's case by major media outlets such as the *Guardian* reflects a growing popular interest in mountain environments, and could provide the leverage needed to break open a space for more nuanced discussions of local climate change impacts. Indeed, glaciers have become a contested space as their retreat exposes possibilities for new economic activities in a landscape devoid of ice. Just as glacier retreat in the Cordillera Blanca provides a temporary boon for irrigation projects on the Peruvian coast, loss of glacial ice can expose earthen substrate that is valuable for natural resource extraction, including gold mining.

Recently, the Argentine glaciologist Ricardo Villalba was falsely accused of doctoring a national glacier inventory to benefit Barrick Gold of Canada, the world's largest gold-mining corporation. His inventory excluded glaciers of less than a hectare in size, which is actually the international standard used for glacier inventories. A group of environmental activists filed a lawsuit contending that this was a deliberate stratagem to open these areas to extractive industries. The national and international community of glaciologists has rallied to support Villalba, calling the accusations baseless. Yet the case still stands in a federal court in Buenos Aires, demonstrating how shrinking glaciers are turning mountain landscapes into political and legal battlegrounds.

If the international community does not recognize local climate change impacts, it risks ignoring conflicts that could determine the success or failure of climate adaptation, including politically charged debates over land, water, and resource use. Technoscientific studies will continue to produce points of tension among governments, local communities, and corporations that wish to exploit beneficial aspects of climate change. It is crucial to reframe the climate narrative—and future research—around adaptation and societies at local and regional levels, including all their political, economic, and social relations.

While the world often views climate or weather-related events in terms of satellite images, the composition of the atmosphere, and international aid for unexpected disasters, a closer examination of local responses and historical processes often reveals a richer story of ongoing adaptation measures that transcend crises, as with the responses to glacier hazards in Peru's Cordillera Blanca and beyond over the past three-quarters of a century. This is why it is imperative to shift the predominant climate change discourse toward multidimensional adaptation measures and away from an exclusive concern with abstract temperature goals set by and regulated within the Global North. We must recognize that social relations, poverty, inequality, global power imbalances, governance, institutional capacity, and cultural values all must be taken into account in order to respond effectively to climate change. ■