Human Development Report **2007/2008**

Fighting climate change:
Human solidarity in a divided world

Human Development Report Office
OCCASIONAL PAPER

Deglaciation in the Andean Region

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2007/55

Summary

1. Studies predict there will be a dramatic decline, in the long-term, in water availability in the dry season in areas fed by glaciers. The accelerated melting of the tropical Andean glaciers is an undisputed fact. Dozens of articles in scientific journals have charted the demise of the ‘water towers of the world’ as a result mainly of rising air temperatures. Different modelling methods predict small increases in overall water availability in many areas fed by glaciers over the next 25-50 years due to increased glacial melt. However, the same models strongly suggest that water availability will diminish significantly during the months of the dry season, when the glaciers act as a type of buffer providing water for drinking, irrigation for agriculture, energy, and industry.

2. Few studies have been carried out on the impact of glacial melt, even though Peru and Bolivia are very vulnerable. While there is an abundance of articles on glacial retreat, there are only a few studies on the possible impact on the social and economic development of the South American countries most likely to be affected by predicted seasonal water shortages, and in particular on the rural and urban poor. For example, Peru and Bolivia have more than 90 per cent of the world’s tropical glaciers within their territories, and are also two of the poorest countries in Latin America (with 49 per cent and 63 per cent respectively of their populations living below the national poverty line). From the early 1970s to 2006, the surface area of glaciers in Peru and Bolivia decreased by 30 per cent. A long-term decline in water availability during the dry season would have very significant consequences for millions of poor people in both countries.

3. If the models are correct, growing conflict over the distribution of water resources is very likely, particularly during the dry season. Peru is widely considered as the South American country most vulnerable to water shortages, while in Bolivia the issues of universal access to water and the price low-income urban consumers should pay have provoked serious political confrontation since 2000. In both countries there are already competing demands: inter- and intra-departmental; urban versus rural consumers; and competition between commercial export agriculture, small-scale rural producers, hydroelectric power and mining companies. Conflicts between sectors will become more intense as water becomes less available.

4. Funding adaptation and mitigation measures will be critical. There will be a pressing need for more dams, tunnels or reservoirs (be they small- or large-scale) to collect and store more of the precipitation during the wet seasons. Short-term water supply deficits produced by increased demand from growing urban populations will be exacerbated by a long-term decline in seasonal water availability. Higher-income groups and donor countries or agencies should be the priorities for absorbing the cost of such infrastructure works.

5. The poor are likely to be worst hit by water shortages. In the past, poor communities in Peru and Bolivia have been prejudiced by inequitable water access, pricing policies and quality, and scant protection or legal rights over water usage. Large economic concerns have usually enjoyed de facto priority, or have been given it by regional and national authorities. This historical situation is unlikely to change in a context of reduced water availability. For the urban poor in Peru, there are few signs that the government is considering policies of targeted subsidies or prices which could distribute future water stress more equitably.

The rural poor are also likely to bear a disproportionate share of the cost of glacial retreat and water shortages, when compared to other sectors. This is for three reasons: hundreds of thousands of poor people will be in the front-line of increased exposure to the possibility of natural disasters in high-altitude glacial-fed areas. Small producers in the agro-export sector will be less able to adapt to less water availability compared to larger agro-industrial concerns. And political decisions over priorities for water usage are unlikely to favour small-scale upstream farmers over demands from the mining, agro-export, and hydroelectricity sectors, and from downstream cities needing a regular supply of drinking water.

2. The state of the melt

South America contains more than 99 per cent of the world's tropical glaciers. The others are found in Africa (most notably Mount Kilimanjaro) and Irian Jaya in western New Guinea. Table 1 shows the 2006 estimates per country for glacial area in the five main South American countries which have tropical, low-latitude glaciers. Of these Peru has more than 71 per cent of the surface area, and Bolivia about 20 per cent. Most of the glaciers are over 5,000m high. In mid- and high-latitudes, Chile and Argentina has a glacial area of 23,300 km², with more than 85 per cent located in Patagonia and Tierra del Fuego.

Various techniques have been used over the last three decades to measure glacial retreat including satellite imagery and measurements of the mass balance, surface area and length of the glaciers. In the Andean tropical latitudes, glaciers have shown a general retreat and wasting, which has become particularly pronounced since the beginning of the 1980s. Glaciers that are thousands of years old have registered some of the fastest losses in their mass and surface area anywhere in the world. This is best illustrated by the research of an international group of scientists working with the IRD (Institut de recherche por le Développement) who have been closely monitoring ten glaciers spread throughout Bolivia, Ecuador and Peru for several years. Chart 1 shows their accelerated glacial loss, measured by both length and surface area since the period 1976-1980.

Many other recent studies of South American tropical glaciers confirm the trend. For example, aerial photography of the Cotopaxi Volcano ice cap in Ecuador shows a loss of surface area of 30 per cent between 1976 and 1997. In the north-east of Colombia, glaciers in the Cocuy National Park, which is home to the country's largest glacial mass, are shrinking by 15 metres a year, and are expected to be lost completely by 2030. The Quelcayya ice cap in Peru, which is the largest in the world, has lost thirty per cent of its glacier area since the early 1970s. The Qori Kalis glacier, which is part of the ice cap, is losing its surface area at a rate ten times faster than in the 1970s. (see box)

Table 1 also shows the surface area decline in five South American countries with tropical glaciers. Although the start years vary between countries, overall the decline is 30 per cent. Several of the smaller, lower-altitude glaciers are in the final stages of wasting and will disappear completely soon.(see box on Chacaltaya) Scientists say that whatever measures are taken by the international community in the immediate future, lower elevation glaciers will not be able to recover after thousands of years of existence. Once a glacier is lost, it does not come back.

The process by which various factors have contributed to the accelerated decline of the tropical glaciers is complex. However, the main cause is generally considered to be the rise in near-surface average air temperatures, which have significantly increased over the last 60 years. Studies show an average increase of about 0.10°C per decade since 1939, with the bulk of the warming occurring over the last two decades. The rate of warming has almost tripled since the mid 1970s' to between 0.32 and 0.34°C per decade.(Vuille M., CONAM/World Bank 2007)

Box: Three icons of glacial retreat

Quelccaya, Peru:
Since the mid-1970s Professor Lonnie Thompson of Ohio State University has been measuring the Qori Kalis glacier, the main outlet for the Quelccaya Ice Cap, the largest tropical ice cap in the world. It is situated in south-eastern Peru in the Vilcanota cordillera, at a height of 5,670 metres. When Professor Thompson first started, the annual glacial retreat was about 6 metres, but in recent years it has been 60 metres or more, equivalent to a ten-fold increase. As the glacier has melted, it has created a large lake at its foot.(see picture) Ancient plant beds which have been buried for thousands of years have recently been uncovered due to glacial retreat. This suggests that the glacier has probably never been as small as it is now in the last 5,000 years. A popular ritual known as Qoyllur Riti, whereby local people climbed another glacier (Ausangate) in the Vilcanota cordillera, has been suspended due to the melting of the glacier. Local people used to take pieces of ice from the glacier which they believed could cure them of illnesses or help the fertility of their fields.

Chacaltaya, Bolivia:
Situated just 20 kilometres north-east of La Paz in the *cordillera real*, the Chacaltaya glacier has become an icon of the effects of global warming, and a laboratory for predicting what may befall other small Andean glaciers. It used to be the world's highest ski run at 5,360 metres. Meaning 'Cold Road' in Aymara, Chacaltaya is thought be about 18,000 years-old, but it has lost 82 per cent of its area since 1982. When its decline first began to be measured in 1991, it was predicted that it might disappear altogether in 2015. It is now predicted to be completely lost in 2007 or 2008. In 2006, what was once a 500 metre-long glacier had been reduced to two small areas of about 60 metres by 20 metres.(see picture)

Antizana, Ecuador:
Antizana is a volcano 5,760 metres-high situated on the equator near the Ecuadorean capital of Quito. Two of its glacial tongues have been monitored by the World Glacier Monitoring Service (WGMS) and the IRD for several years. Their surface area and volume has declined by at least 30 per cent since 1956. Just in the period 1996-98, the glacier shrunk 100 metres and lost 8 per cent of its area. Quito gets about 10 per cent of its water from surrounding ice caps. Scientists at the IRD calculate that the complete disappearance of Antizana could result in a 40-70 per cent decrease in water run-off from the glacier. Below Antizana is the La Mica glacial lake which alone provides drinking water to a third of the city. The lake's water level is reported to have dropped 5 meters a year recently due to increased demand.

3. Predicting the future

Every glacier has an accumulation zone, where it gains mass, and an ablation zone where it loses mass to evaporation and liquid water run-off. Between the two zones is what is known as an ‘equilibrium line altitude’ (ELA) above which accumulation outstrips ablation. The height of the ELA of glaciers in the tropical Andes has been constantly rising in recent decades, by as much as 300 metres in some cases. The best analogy is that of a bank account built up over thousands of years. Once you start taking out of the account more than you are paying in, eventually you go bankrupt. Only glaciers higher than 5,400-5,500 metres are thought to be able to recover their mass in the current climate variability.

The central point is that unlike for example glaciers in the European Alps, which do not usually melt during the winter months but accumulate snow, glaciers in the tropical Andes melt and feed the rivers all year round during both the wet and dry seasons (which vary according to geographical region). During the months of the dry seasons (roughly in the tropical Andes between April/May and September/October), the glaciers provide most of the water as glacial run-off. They act as a vast store of water, which is slowly released during the months when there is no precipitation. They are like a buffer zone which smoothes out seasonal variations in water supply.

Many basins fed by glaciers have experienced an increase in runoff in recent years, which researchers ascribe to increased glacial melt or retreat because precipitation has not changed. In other words, there may be more water in the rivers due to glacial melt, but the cost is a reduction in the storage of frozen water in the glaciers. The key question is how many years this temporary increase in runoff is likely to last, and what happens when the more of the glaciers melt or disappear completely.

Much of the research on how glacial melt is affecting current water availability and the modelling for the future has been carried out in Peru, using data taken from the vast Cordillera Blanca. The range includes Peru’s highest mountain (Huascarán at 6,768 metres) and contains more than 600 km² of glacial area, or a quarter of the world’s tropical glaciers. The research suggests that in the Cordillera Blanca there has been a net annual increase in hydrological runoff, particularly in watersheds or valleys beneath glaciers. In one area, glacial melt now accounts for 58 per cent of the annual mean discharge, a 23 per cent increase since 1998-9.(Mark et al., 2005)

Researchers predict this is a temporary effect due to current rates of ablation. In the longer-term, some models suggest a dramatic decline in water availability some time this century as the glaciers disappear and precipitation becomes the only source of water.(CONAM, 2005) Chart 2 shows the predicted water flow from the 12 glaciers in the Rio Santa valley beneath the Cordillera Blanca from 2000 onwards, and depicts a rapid fall-off after 2050.

However, these results have been called into question. A more sophisticated model taking into account more variables suggests that overall annual discharge may not vary that much (due to increased direct run-off in the wet season) but that seasonality intensifies significantly.(Juen et al, 2007)

One of the central questions in assessing future water availability is what percentage of the water supply to any particular zone comes from glacial melt, as opposed to other sources such as precipitation in the wet season or underground wells and aquifers. In many regions the research is yet to be carried out. But one study of the Rio Santa valley suggests that glacial melt can provide 10 to 20 per cent of the total annual water run-off. This figure can rise to 40 per cent in the dry season, when water is most in demand.(Mark et al, 2005)

An equally important issue is how much the water supply varies during the wet and dry seasons. The study of the Rio Santa valley (by Juen et al., 2007) concluded that water supply during the dry season is significantly reduced. Based on IPCC estimates of future temperature rises, the study predicted that by 2050 the glacial area above the valley would have been reduced by between 38 and 60 per cent, and the volume of glacial melt by 35 to 53 per cent. It calculated that seasonality would intensify: runoff would increase in the one to three months of the wet season by between 10-26 per cent, but it would drop by 11-23 per cent in the dry season (which could last a longer period of months than previously). This, the study concluded, was a ‘most dramatic change’ predicted for the dry season which would ‘challenge future water management drastically’.

Whatever the exact projected figures, there is consensus amongst scientists that at some point in the future there will be much less water available during the dry season as a result of glacial retreat. This seasonality could be exacerbated by less dry season precipitation: many of the climate change models – though not all – predict more precipitation for the tropical Andes towards the end of the century during the wet season, and less precipitation during the dry season.

4. Future water conflicts are more likely

There is a severe risk that conflicts over water availability in glacier-fed areas could become more likely in the context of less water availability in the dry season. Short-term increases due to glacial retreat could encourage governments, planners and business sectors to assume greater water availability. But in the long-term, as glacial retreat progresses, all the signs are that there will be less water available in the dry season. This will be compounded by increasing populations and therefore demand not just in the many large cities in the Andes located over 2,500 metres high but in downstream cities like the Peruvian capital of Lima.

Chart 3 depicts in a simple way how one recent study sees the increased likelihood of potential conflict over water in the future.

There are already plenty of examples in Peru, Bolivia and Ecuador of significant water disputes in the last few years between urban and rural consumers, mining companies and local farmers, hydro-electric plants and downstream consumers, or large-scale commercial agriculture and small producers. The disappearance of the snow on the Cotacachi volcano near Quito in Ecuador is often seen as a warning of conflicts to come. There has been a decline there in agriculture, tourism and biodiversity, and disputes have intensified as a result of less or no water in local streams and rivers.(Rhoades and Zapata 2006)

In Bolivia, access to water and the price of water for low-income groups have become highly politicised issues. The focus of two recent disputes has been between low-income consumer groups and the pricing policies of foreign utility companies. The widely-publicised ‘water wars’ in Cochabamba in 2000 caused intense civil disturbance as the Aguas del Tunari consortium led by the US company Bechtel raised prices by 35 per cent on average (and up to 200 per cent), way beyond what many poor consumers could afford. A major element of the water conflict in Cochabamba was a general shortage of water resources.

Another multinational company, Suez, who took over water provision in El Alto after privatisation in 1997, also faced sustained protests from community groups. Suez maintains that it increased water and sewage connections to thousands of new consumers. But the protestors argued that prices had risen by 35 per cent since the consortium led by Suez took over; that more than 200,000 people were left with no possibility of access to water because of a failure to expand water infrastructure to the outskirts of the city; and that connection charges for water and sewage had risen to US$445, more than six months of income at the national minimum wage.

Whether a repetition of such sustained protests over water takes place in the future will depend on a wide variety of social, political and economic factors, including government policies. However, it is not too alarmist to argue that given the past history of water disputes, given the fact that significant sectors of Peru’s and Bolivia’s social movements are organizing around water issues, and given a future of less dry season water availability, municipal and national authorities will need to pay considerable attention to this issue to avoid serious social unrest.

5. The impact on macro-development

Falls in dry season runoff are likely to have a major impact on the macro-economic development of Peru, Bolivia and Ecuador. The three countries are to a significant degree dependent on glacial melt for a whole range of economic activities and for drinking water to some of their cities. They also depend on hydro-electric power (historically over 50 per cent in Ecuador, 70 per cent in Bolivia, and more than 80 per cent in Peru, although this last figure will drop with the coming on-stream of gas-powered stations).

Peru is particularly vulnerable to projected water shortages largely due to the geography of the country. It is thought to be the South American country most vulnerable to water stress in the future. A study published by the Tyndall centre in 2003 placed Peru in the top 10 countries in the world most subject to climate-related natural disasters in the decade 1991-2000.(Brooks and Adger 2003)

70 per cent of Peru's population live along the Pacific coast, which is also where much of the country's economic activity is based. Yet it is one of the most arid regions in the world. It is almost totally dependent on water flowing down from the Andes via 50 or so rivers fed by snowmelt, precipitation or glacial melt. Without that water the coastal area would be a virtual desert as it has less than 2 per cent of the country's water resources. In contrast, the Atlantic or eastern side of the Andes has 98 per cent of Peru's available water and 26 per cent of the population. Much of the water is 'on the wrong side of the wall'.

Peru's boom sectors: Moreover, the boom sectors of the Peruvian economy in recent years have been water-intensive. The value of non-traditional agro-exports has risen three-fold from US$302m in 1998 to US$1,008 million in 2005. In the same year asparagus exports for example were worth US$263m, compared to US$396m for Peru's traditional coffee exports. But unlike coffee, asparagus requires constant irrigation. Artichokes too require more watering than non-export crops such as potatoes. Production of sugar cane, another thirsty crop, is also set to increase because of international demand for bio-fuels. Indeed, in general the boom in agro-exports has meant a huge increase in demand for irrigation in the desert coastal strip which already had a precarious water supply. An estimated US$5bn has been invested in irrigation in recent years, of which US$3.5bn was invested in coastal areas. More than 1.2 million hectares have been planted with crops that need irrigation, significant parts of which currently come from glacial melt.

Likewise, the mining sector has received massive foreign investment recently due to high world prices driven by demand from China. Mining exports accounted for two-thirds of Peru's increased export revenue between 2001 and 2005 (about $6.5 billion of the $10 billion increase). But mining too demands high usage of water to wash and treat the minerals. For example, exploration at the world's largest gold mine at Yanacocha, Cajamarca has provoked conflict for several years between the mine owners (principally the Newmont Mining Corporation) and local farmers over the quantity and quality of the water available locally as a result of the heap leaching process used in the mine to extract the gold.

Peru's Rio Santa valley: The Rio Santa valley is illustrative of the enormous pressure on future water supplies that could affect areas of Peru where water supply is in part glacier-fed. The waters from the Cordillera Blanca drain into the Rio Santa via several tributary valleys which then flows into the Pacific Ocean. As already mentioned, potentially up to 40 per cent of the dry season discharge from the river is estimated to come from melting ice which is not replenished by annual precipitation. A significant drop in water availability would massively affect drinking water supplies, hydroelectric power and irrigation for commercial and small-scale agriculture. Most of these sectors, and particularly energy, need a supply of water all year round.

The water from this one river supplies all of the following: a large area of mostly small-scale, intense agricultural activity at between 2,000 and 4,000 metres; a power production plant representing 5 per cent of Peru's total energy production capacity; what would be a very dry area of large-scale intensive commercial agriculture worth about US$100m a year in the lower valleys including two special irrigation projects for export crops (Chavimochic and Chinecas); and a large part of the drinking water to two major urban areas on the Pacific coast with a combined population of more than one million people (Chimbote and Trujillo).(see chart 4) One recent study calculated that the dry season flow of the river was already insufficient to satisfy the needs just of Chavimochic and Chinecas.(Vergara et al., 2006) Any attempt in the future to capture more of the precipitation could be seriously hampered by the topography of the valley which makes the building of more reservoirs very difficult.

Calculating the potential economic cost of glacial melt is an imprecise science. However, in one of the few studies to attempt it, a 2006 World Bank study estimated that the annual cost of reduced glacial melting just for the hydroelectric plant in the Rio Santa valley was between US$6m and US$72m.(Vergara et al., 2006) This figure rose to between US$12m-US$144m, if there was no glacial melt at all. For the whole of the country's energy sector, the cost was calculated to be between US$60-US$748m for reduced melting, and US$120-US$1,500 for no glacial melt.

Lima: a crisis waiting to happen. The same World Bank study attempted to calculate the cost of replacing the water lost from glacial melt to the supply of drinking water to the 8 million people living in Lima, the capital of Peru. This was estimated to exceed US$116m a year once the glacial melt ceased. Lima is particularly vulnerable to water shortages, largely because it is built on a desert. The city **already** has a serious water deficit. Figures from Lima's municipal water company, SEDAPAL, show a shortfall of 3.4 m^3/s of water in 2005 between supply and demand.(SEDAPAL 2006) This figure was for drinking water alone, and did not include sanitation. SEDAPAL projections predict a very significant increase in the shortfall between 2005 and 2035 (unless new public works are carried out), partly as a result of increasing demand from new arrivals to the city currently estimated at 130,000 people a year.

Lima gets its water from three rivers in the Cordillera Central, of which the Rio Rimac is the most important. It is not certain what percentage of the water flowing into the three rivers comes from glacial melt. It is generally thought that it is less for example than the Rio Santa, but still a significant amount. In other words, the loss of water from glacial melt will in the long-term undoubtedly exacerbate an already acute situation facing Lima. To give an idea of the scale of the problem, the drought in 2004 caused a serious shortfall in water supply. The total amount of water held in the reservoirs serving Lima is normally the equivalent of about 280 million cubic metres (mm^3), less than a year's demand and far less for example, than the reserves of Santiago or Bogota which have smaller populations. This fell to only 80 mm^3 in one month during the drought. The authorities resorted to rationing and to using more of the water from wells (which currently represents about 20 per cent of Lima's water supply) extracted at a lower depth. The amount of water taken out of the wells far exceeded the recommended usage (set in part by the risk of salinisation).

The absence of sufficient reserves, the likelihood of more frequent weather extremes such as drought, and the reliance on one 60-kilometre Transandean tunnel (which carries water from the eastern side of the Andes) already makes Lima very vulnerable to water shortages. Long-term reduction due to glacial melt compounds the vulnerability. It is worth pointing out the amount of water Peru has **already** lost to glacial melt. One recent calculation suggests that on the assumption that 22 per cent of glacial area has disappeared in the last 30 years, the country has 'lost' the equivalent of about 7,000 mm^3 of water in glacial melt, or 10 years' water supply to Lima. (CONAM, Al día, December 2004)

La Paz, Bolivia: The water shortage facing Bolivia's main city, La Paz, is not as acute as Lima's partly because of its smaller population, but it is still an urgent challenge. 80 per cent of the drinking water supply for El Alto, the large sprawling city above La Paz, and the two sides of upper La Paz comes from the Tuni Condoriri range of glaciers. Various measurements show the area of the 15 original glaciers in the range has reduced by more than a third from 1983 to 2006. Five glaciers may have already disappeared completely and at current rate of depletion, the others could disappear some time between

2025 and 2050. It is not known how much of the annual water supply comes from glacial melt, but it could be as much as 60 per cent.

Even now La Paz and El Alto, with a combined population of nearly 2 million people, face a pressing need for more water. The arrival of several thousand migrants from rural areas to El Alto every year means demand for water increases. One detailed study carried out in 2007 predicts that as early as 2009 there will be more demand than water available in the reservoirs feeding the two cities assuming the supply remains the same.(Ramírez, 2007) Based on a predicted annual population increase of about 4 per cent in El Alto, projections of connection rates and demand, plus estimates of water currently available in the reservoirs, the study concludes that from 2009 onwards water supplies will enter a situation of 'stress', though not of 'crisis'. La Paz is also dependent for virtually all of its energy supplies on hydroelectric power. The water driving the generators comes mainly from the two glacier ranges of the Zongo valley and Charquiri, both of which have been subject to accelerated glacial loss in the last 30 years.

Quito: About 10 per cent of the water supply to Quito, the capital of Ecuador, is also estimated to come from surrounding ice caps. The Cotacachi volcano near Quito (at 4,996 metres) lost its permanent snow at the turn of the century, while the glaciers of Cotopaxi and Antizana are calculated to have lost about a third of their surface areas in the last 50 years.(see box) The flow of the Rio Pita, which is one of the rivers feeding the city's main hydroelectric plant, is estimated to have decreased by about 50 per cent in the last 20 years. Scientists based in Quito predict the country is likely to lose at least four of its eight most important glaciers over the next 10 to 20 years.

6. The impact on poverty and livelihoods

Overview: The above discussion shows Peru's, and to a lesser extent Bolivia's, high vulnerability to less water availability in the dry season. The two countries are very dependent on hydro-electric power. A significant percentage of urban drinking water supplies come from glacial melt. Moreover, in Peru's case, its macro-economic development could be seriously hampered as a result of its reliance on water-sensitive sectors. The country is currently wedded to an economic model heavily dependent on year-round irrigation for its agro-export sector, and on a regular supply of water for its mining industry.

It is hard to predict accurately what will be the effect of a less reliable water supply on different sectors of the economy, and on the poor within them. Any reduction in economic activity as a result of water shortages will of course affect all sectors of society. For example, a significant downturn in Peru's agro-export sector would have wide ranging effects on private companies, low income migrant workers, small-scale producers and government revenues. However, there is a strong likelihood that higher income groups and large economic concerns will be, as they have been in the past, politically favoured and better resourced to be able to protect their interests.

There are other reasons beyond historical precedent why the poorer sectors are more likely to bear the brunt of water shortages. Current pricing policies and water distribution in urban areas of Peru are inequitable. It is unlikely that low income urban dweller or settlers will be given priority for water access when there is less water available. Peru does not have in place a system of targeted subsidies for connections and water use, as developed in Chile and Colombia. Moreover, there is high likelihood that any projected tariff increases to pay for infrastructure works would be applied as a flat rate increase rather than means-tested. High-income groups will be better able to mitigate the effects of reductions in drinking water availability, as they have done in the past, by buying home-based storage capacity or paying for extra water delivered by other means than a piped connection.

In Peru's rural sector, small-scale producers of agro-export crops are already at a disadvantage in terms of access to irrigation. Thousands of small-holders living in glacier-fed areas are more vulnerable to the increased likelihood of natural disasters due to glacial retreat. And irrigation for upstream small-scale agricultural activity is unlikely to take political precedence over the multiple demands for water, including downstream drinking water for large cities.

The urban poor

Currently, water distribution in most parts of urban Peru and Bolivia is inequitable. For example in Cochabamba, the richest 20 per cent of the population had 93 per cent coverage compared to only 32 per cent amongst the poorest 20 per cent. In Lima about 90 per cent of homes are estimated to have a water connection, but the distribution is uneven. 95 per cent of homes in the north and central parts of the city had connections in 2004, but this figure drops to between 58 and 69 per cent in the south and east. Those who don't have connections have to depend on stand-pipes or trucks that deliver water. Water delivered by trucks is more expensive, less clean and less reliable. In general, in both countries poorer communities who depend on informal water sellers usually pay more for their water, both as a percentage of their household income and on a per litre basis, than those with connections to a central network. Lack of access to clean water and sanitation makes poor income groups more prone to child illnesses.

Recent research estimated that those living in Lima's slums or low income settlements paid on average between 5 and 10 times more for their water than high-income residents. (UNDP 2006) If a home does have a water pipe connection, the same rate is paid by consumers in better-off or poorer suburbs. Average daily use is calculated to be in 30 litres a day for a shanty town dweller receiving their water via a truck. In contrast, it rises to 405 litres a day in Lima's richest suburb of San Isidro, where it is possible to visit a well-watered 18-hole golf course and see servants frequently watering ubiquitous lawns and even the pavement.

In a context of greater water scarcity, lower income groups will be less able to pay for extra water supplies from bottles or trucks compared to higher income groups. Many of the houses in San Isidro for example have supplementary tanks to store water at times of rationing, an option not open to poorer families.

Paying for public works: The long-term effects of glacial retreat can be mitigated by capturing and storing more of the wet season precipitation. However, this means significant investment in more dams, tunnels or reservoirs (whether they be large, medium or small-scale), as this will reduce vulnerability to seasonal variations in the decades to come. In Peru engineers and independent consultants have long urged the municipal and national authorities to build a second tunnel through the Andes (to capture water from the Atlantic side) and/or to construct more dams and reservoirs in order to ease the pressure on Lima. The building of a second tunnel alone would cost at least US$100m. This figure rises to nearly US$300m if all the projected works necessary to have a more secure supply are carried out.

In Bolivia it is highly likely at least one new dam will be necessary to capture more precipitation for the projected increase in demand for drinking water in El Alto alone. Connections to homes that lack water in El Alto are estimated to cost at least $25 million, on top of the costs of expanding the basic water infrastructure to the thousands of new arrivals every year. And in Ecuador, Quito's municipal water company is reported to be planning a multi-million dollar project to get water to the city from the Rios Orientales, a river east of the Andes.

In Cochabamba (a city of 600,000 people) water provision is currently back in the hands of a municipal company, albeit with more social control from local communities. However, the number of people with water connections and access to sewage had still not improved significantly by 2007 – more than five years after the expulsion of Aguas del Tunari and despite a return to lower water charges. It is estimated that the cost of building a new dam and aqueducts necessary to increase supply to the city would be between US$100-200 million, an enormous amount for the municipal company whose capital budget is around US$5m.(Forero, 2005)

Such public works are much more pressing in the context of a long-term decline in water availability during the dry season. But even before the long-term impact of glacial retreat is felt, increasing demand from urban populations will put great pressure on water supplies. For example, the important policy aim of bringing water connections to the estimated 900,000 inhabitants of Lima currently without water would considerably raise the demands on reservoirs, partly because the average daily use rises from 30 litres a day without a connection to 110 litres a day with a connection. Again, more large-scale investment is needed to ensure sufficient water reserves to meet the demand.

Public works are expensive. Who will pay? It is possible that in-country urban consumers will be asked to pay increased water tariffs to fund such works. All consumers, both high and low-income, are likely to be affected. However, it would be a more equitable approach to ask high-income consumers to pay more of the burden. Such an approach has the dual advantages of spreading the costs more evenly and mitigating the chances of more social conflict over water. Studies from Colombia and Chile show that subsidy schemes can be highly effective in reducing inequalities. Chile has used means testing to identify low-income residents for the receipt of water subsidies, while Colombia uses property values and residency to identify then help low-income households.(UNDP, 2006) Both schemes are predicated on high-income groups paying more for their water.

More revenue from wealthier water users can help to subsidize poor ones, but would probably not cover the substantial costs of constructing the infrastructure necessary for new water systems. Donor countries and agencies will have to help finance such adaptation projects. Poor countries such as Bolivia, Peru and Ecuador already have huge pressure on their budgets to fund a wide range of basic services such as education and health. They are also at the forefront of suffering the impact of man-made climate change and will have to pay what amounts to a type of tax for the carbon emissions of industrialised countries. Yet they have low-carbon economies and are hardly responsible. Peru for example is estimated to be responsible for only 0.1 per cent of the world's carbon emissions (compared to the USA's 22 per cent).

National governments and political leaders in such countries will also have to embrace a long-term view of the national interest beyond the cycle of five-year presidential terms. Much of the investment in infrastructure only bears fruit several years later.

The rural poor

Agro-export sector: It is likely that in the context of reduced water availability, small-scale agricultural producers in Peru will come lower in the pecking order than urban consumers, hydroelectric projects, commercial agriculture and mining companies. The last two sectors have in the recent past enjoyed favourable investment legislation, tax breaks, credit facilities and cheap water availability to foster their growth. This order of priorities is unlikely to be reversed.

In the agro-export sector, most of the new crops are produced by large-scale farmers or industrial concerns. For example, there are around 2,000 producers of asparagus in the country, and about 60,000 people employed directly by the industry. 56 per cent of the land cultivated with asparagus belongs to 200 producers owning more than 50 hectares of land. There are some smaller coastal producers, but they have a relatively high level of education and resources. The asparagus sector is markedly different to the coffee sector where around 85 per cent of the 150,000 coffee producers have less than five hectares.(Frazer and Rojas 2007)

Large-scale concerns have benefited from the opening of new areas for cultivation. For example, agro-industrial companies on the coast took advantage of large irrigation projects such as the Chavimochic project in the Rio Santa valley mentioned above. They had the capital to buy newly irrigated areas that were unavailable to small producers. Moreover, in many areas, companies have the capital to invest in their own wells, whereas smaller producers have to pay for their surface water or pay high charges to well owners.

Small-scale producers that are currently involved in growing crops for export are likely to be less able to continue in a future when less water is available. For example, one recent study found that in the Mantaro valley, which is partly glacial-fed, water shortages are <u>already</u> restricting farmers to growing only 1-2 hectares of artichokes each.(Frazer and Rojas 2007) Many do not own their own land so there is less incentive for them to invest in better irrigation. Moreover, the current government's laudable efforts to promote agricultural export production in the sierra (the 'Sierra Exportadora' programme) may also be affected by reduced water availability.

The general point is that in the past large-scale agro-industrial interests in Peru have benefited from the heavy extraction of water at a much lower cost than for smaller producers. The whole sector has of course generated several thousand jobs and increased revenue for the state, but large concerns have benefited disproportionately. In a future of water shortages, it would be surprising if large-scale producers were not better able to adapt and were not given priority from the state.

Disaster mitigation: One area of particular concern is the vulnerability of poor rural highland communities to the increased probability of 'natural' disasters as a result of accelerated glacial melt. The rapid melting of the glaciers can lead to rivers bursting their banks or to the formation of glacial melt-water lakes which can suddenly burst as a result of excessive volume or large ice chunks collapsing into them. Landscapes also become destabilized as a result of glacial melt, one of whose consequences can be major rock-slides.

The region under the Cordillera Blanca is particularly vulnerable. Five major glacier disasters (outburst floods and avalanches) have killed nearly 30,000 people in the area since 1941.(Carey M., 2005) The two most deadly were in 1941 when Lake Palcacocha produced an outburst flood that killed 5,000 people and destroyed a third of the city of Huaráz, and in 1970 when an earthquake caused an avalanche-landslide from Mt. Huascarán. The town of Yungay at the foot of Huascarán was destroyed in just a few minutes with the death of 18,000 people.

At least half a million people live directly below the Cordillera Blanca's glaciers and hundreds of glacial lakes, many of which are recently formed. There have been no major disasters since 1970 despite the accelerated glacial retreat. However, one recent study found that local people lack faith in government officials to protect them, and do not trust information from Peruvian scientists. It also pointed out that local scientists have miniscule budgets to investigate glacier-related threats and initiate disaster mitigation projects.(Carey M., 2005) In general, poorer rural communities are likely to be disproportionately affected. Being able to expand their pastoral lands to higher elevations may also expose them to more risk of landslides. As in many other parts of the world, they do not have the necessary warning systems, emergency plans, infrastructure or financial support to avoid bearing the brunt of any disaster.

Small-scale highland agriculture: Much of Peru's and Bolivia's poverty is found in rural departments, and particularly in the highland *altiplano.* Six million people in Peru alone are estimated to be dependent on small-scale agriculture situated at between 2,500 and 4,000 metres of altitude. The vast majority of agricultural activity there is dependent on precipitation rather than irrigation from glacial melt. It is probably safe to assume that in the long-term these areas will become even more dependent on rainfall for their agriculture, but it is not known with any degree of certainty if precipitation is likely to be more or less intense, and whether it will be more or less easy to predict.

It is well-documented that rural Andean communities have a centuries-old culture of being able to adapt to changing environments, including water shortages and the unpredictability of rainfall.(e.g. Earls J., 2006) Nevertheless, more information on the possible impact of glacial retreat and other climate change on the rural poor could help both communities and regional/national governments to plan better to mitigate these effects.

The few studies that have been carried out suggest that the perceptions of low-income rural inhabitants in both countries about climate change centre on the recent changes to local climate patterns. This seems to be a more immediate and pressing (weather-related) concern than the long-term availability of water due to glacial melt. Small-scale farmers interviewed in the studies in different parts of the Peruvian and Bolivian *altiplano* stress the increasingly erratic nature of the local climate. There are of course differing perceptions of what is changing, but there is consensus about the increased extremes of weather (for example more intense hailstorms, drought, or frosts depending on the region), and about the much greater unpredictability in weather patterns. This has seriously affected planting cycles as traditional indicators of forthcoming weather patterns have become more unreliable.

However, one detailed study published in 2006 by two US academics does point to some of the key issues that will impinge on rural inhabitants and their livelihoods specifically as a result of glacial melt.(Young and Lipton, 2006) Interviews were carried out in 2002-3 with more than 100 people in the

Huascarán National Park (HNP) in Peru which includes much of the Cordillera Blanca, where more than 330,000 people live. The head of one typical family living at 4,290m noted that:

'As glaciers have receded, some drainage and runoff channels that were accessed <…> diminished in flow and were now either intermittent or dry. As a result of this change, he needed to obtain water from sources further away where runoff and glacial melt had increased. Also, he related how, in some valley bottoms, lakes and wetland areas increased in size, so they had changed the sites where they took their sheep for pasturing.'

Changing areas for pasture and growing crops at higher altitudes are two commonly-observed features of communities or families adapting to climate change in the *altiplano*. In the HNP study, some farmers in the eastern region were integrating different varieties of maize, which were in demand and could be grown at slightly higher elevations. The authors of the study also note that farmers are very concerned about an increase in pests spreading to cattle and sheep in higher pasture zones. In addition, farmers claimed that crops did not produce the same yields because of a loss of harvest to fungi and pests. Women, they write, are primarily concerned with the declining quality of water, as it is usually they who have to do the water fetching for cooking. Women in the area of study commented that regular water sources had become increasingly high in sediment. More time was needed to filter the water.

Poorer communities linked to tourism were also affected. The authors found that:

'For the communities that take tourists to glacial areas, many individuals were concerned that due to the rapid retreat of glaciers they may eventually lose what has become an important income source from tourism. Porters, cooks, and merchants selling handicrafts and supplies at key locations for glacial visits discussed the added travel time to sites where tourists are now able to walk on the glaciers. There are more risks involved for accommodating tourists to visit the higher elevations and therefore, it requires a slower ascent. Thus, it reduces the number of tourists per day that the porters can satisfy and accommodate.'

The adaptation by individual families to a changing local environment as a result of glacial melt and more general climate change is typical of thousands of highland families. In a highly complex decision-making process, families weigh up different options in the face of multiple changing circumstances of which glacial retreat is just one. There is already considerable evidence, for example, of families or communities in other regions of the *altiplano* integrating, or changing to, different varieties of crops such as maize and potatoes which can be grown at higher altitudes, or are more resistant to extremes of weather (including less irrigation), or grow better or faster in warmer temperatures.

A major concern of the interviewees in the HNP study was over future conflicts around water use in the area. The study reported that:

'In one northern valley where water was being diverted for hydroelectric purposes, informants discussed their concerns about the lack of sufficient water for household use and for irrigation of mid-elevation crops. In other areas, freshwater primarily from glacial melt was channeled for mining and industrial needs that would otherwise be used by the rural populations for agriculture and consumption.'

The study was in no doubt as to the potential losers in a situation of water scarcity:

'Private, transnational corporate institutions with political and economic clout have access to water resources and are assured of compliance from national and regional institutions that manage <the park's> natural resources and protect its biodiversity. Informants commented in interviews and in public meetings that, given the private, regional, and national interests associated with water usage, the local communities will be the first affected by water scarcity and imposed restrictions, while potentially the last to have their needs addressed.'

This endorses the expectation mentioned above that conflicts over water are likely to become more acute. Political decisions by which some interest groups get priority treatment over others will become more contested. Historically, poor communities in Bolivia and Peru have usually had much less resources and legal or other forms of protection than other sectors involved in water disputes. In Bolivia, where 80 per cent of the country's water is used in agriculture and nearly 40 per cent of the population is rural, uncertainty around rural water rights for small farmers and indigenous groups increased as a result of the neo-liberal reforms introduced in the 1980s and '90s. However, a national organization of irrigators has been formed in recent years in order to try to put small-scale agriculture on a more equal footing with the influence other sectors like mining, manufacturing, hydroelectricity and urban consumers have traditionally enjoyed when deciding priorities over water usage. (Perreault T.)

Peru too has a national committee of irrigators, committed to protecting the water interests of small-scale producers mostly in the coastal area. Other social sectors have also begun to organize more around water issues. FENTAP (the Federation of Potable Water and Sewage Workers of Peru) is primarily concerned with keeping water companies in public hands in Huancayo and other cities, but they have also started to make proposals about how to deal with water shortages in the future. The National Commission of Communities Affected by Mining (CONACAMI) is also concerned about access to enough water unpolluted by mining companies, mostly in the *altiplano*.

Such groups will have to be consulted when national, regional, and municipal governments are devising water management policies designed to adapt to, or mitigate, the effects of glacial melt. This would be one significant way of reducing the possibility that low-income groups bear a disproportionate amount of the cost of adapting to climate change.

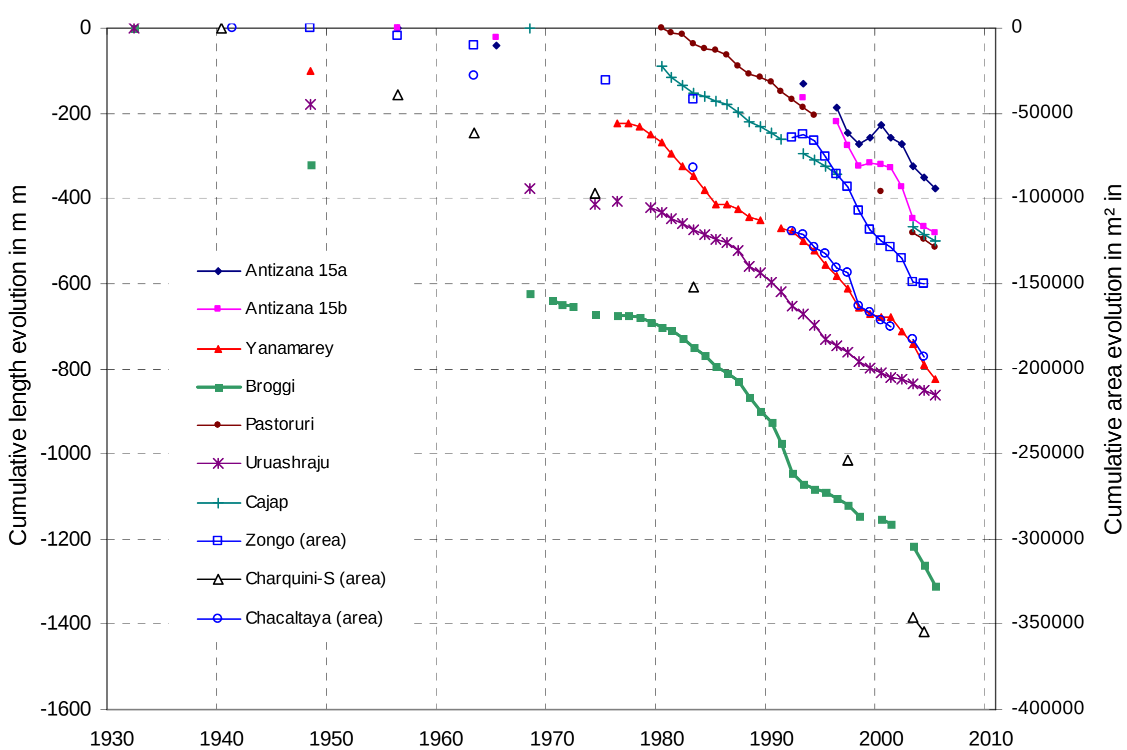
Charts and Tables

Table 1: Loss of glacial surface area in five South American countries.

Country:	Area in km² (year)	Area in km² (2006)
Peru	1,958 (1970)	1,370
Bolivia	562 (1975)	393
Ecuador	113 (1976)	79
Colombia	109 (1950)	76
Venezuela	3 (1950)	2
Total	2,744	1,920

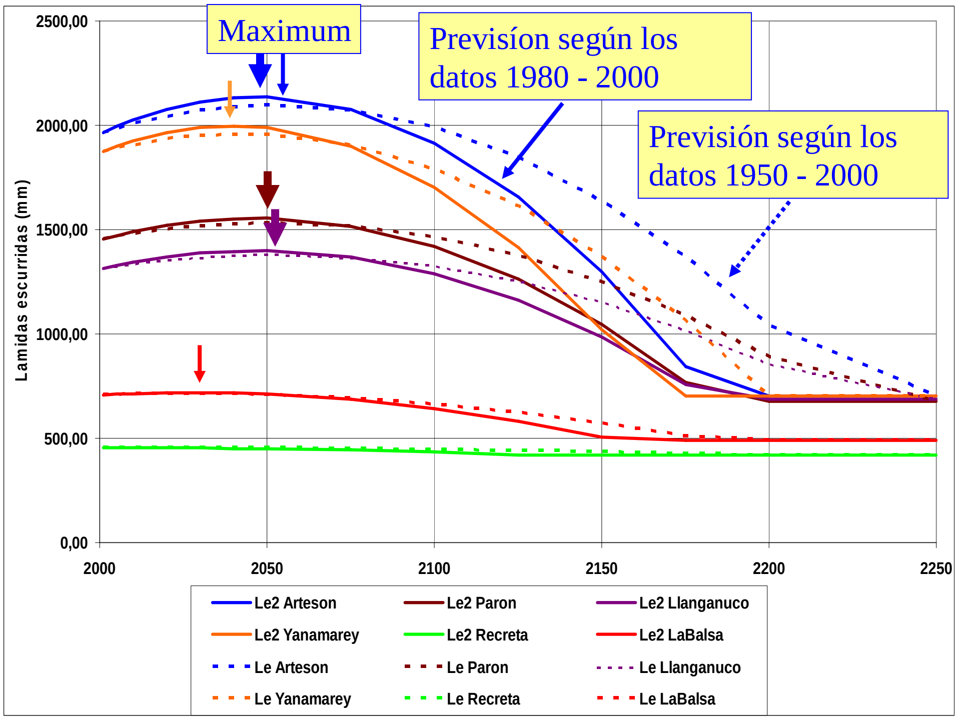
Source: Comunidad Andina, forthcoming 2007 publication

Chart 1: Retreat of 10 glaciers in the tropical Andes of Ecuador, Peru and Bolivia



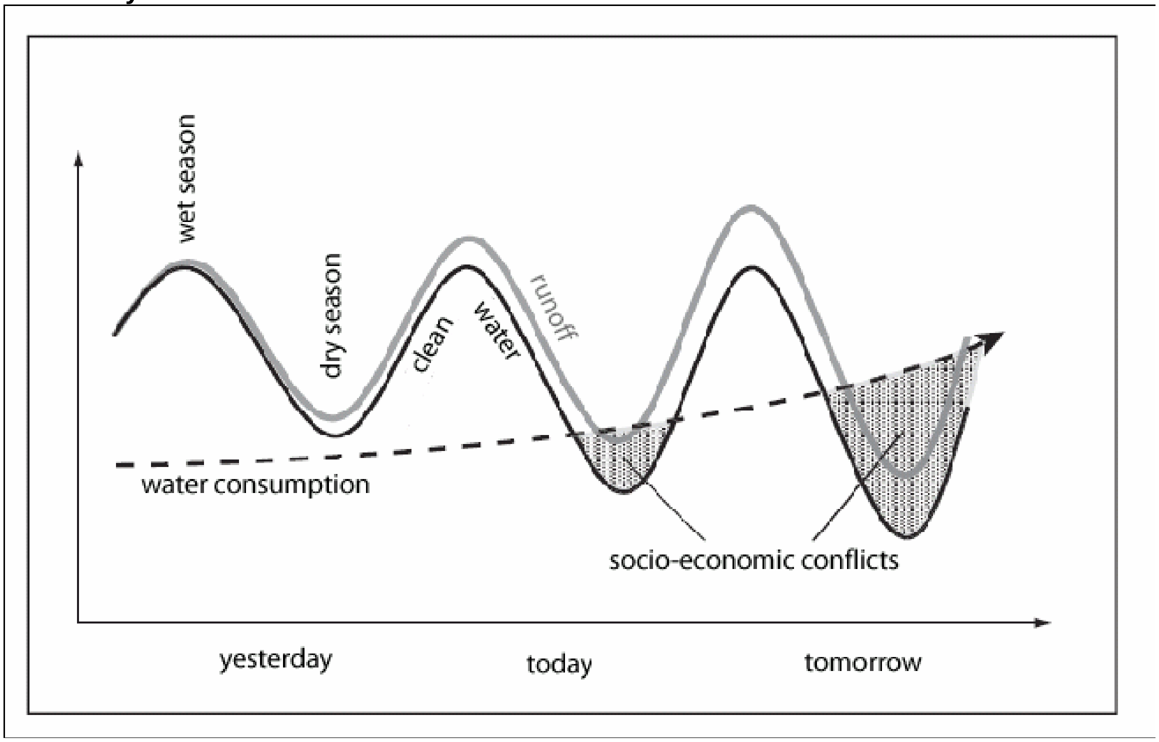
Source: Francou B. and Vincent C., *Les glaciers à l'épreuve du changement climatique*, IRD and Belin Editions, Paris, forthcoming 2007, p. 276.

Chart 2: Predictions for river flows with glacial run-off, 2000-2250, Cordillera Blanca, Peru



Source: CONAM/SENAMHI

Chart 3: Opposing trends in future water demand and availability



Source: Vuille M. (2007)

Chart 4: Water demands in Rio Santa valley, Peru

Source: Zapata M., presentation, Lima 2006

Sources:

(Author interviews in Lima and La Paz, February 2007, with representatives of several Peruvian and Bolivian government agencies, consultants and NGOs).

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