▼ Retreat of the Qoyllur Riti glacier near Cuzco, between 1930 (inset) and 2009.

Paolo Greer/Martin Chambi

High and dry in the Andes

Climate change is threatening water supplies in the highlands of Peru. But research into how indigenous cultures coped with limited water supplies in the past could suggest ways forward. Mick Frogley and colleagues explain how.

Against the background of global warming, the ready availability of fresh water is coming under increasing strain in many parts of the world. Peru is particularly vulnerable – between 60 and 70 per cent of the 28 million-strong population lives in a narrow strip of desert that runs along the Pacific coast. The communities here – including the capital Lima, home to more than nine million people – rely heavily on melt-water from the Andean glaciers to feed major rivers and lakes for drinking, agriculture, industry and health purposes.

But these glaciers are now disappearing at an alarming rate. A recent report by the Intergovernmental Panel on Climate Change (IPCC) suggests that over the past 35 years, the area covered by major Andean glaciers in Peru has fallen by around 22 per cent, with smaller glaciers experiencing reductions closer to 80 per cent. This has led to a significant decrease in the availability of fresh water both in the coastal zone and further inland – many rural highland areas also rely on glacially-fed rivers. Water supplies are expected to continue declining markedly over the next 20 years. While this situation has serious political, social and economic implications for Peru, it is by no means a new phenomenon.

Getting the most out of water

For centuries the forerunners of modern Peruvians realised that efficient management of water resources was the key to their survival and, ultimately, their success. We know from archaeological studies that the people of the Nazca culture, for example – creators of the famous Nazca lines – were able to occupy and exploit part of the southern coastal strip by building innovative covered aqueducts and underground water storage chambers.

In the highlands, problems of seasonal water availability were compounded by also having to cope with large temperature ranges and steep terrain. Here, in the first millennium AD, the Tiwanaku people built networks of raised fields to make the most of seasonal rainfall, whilst the Huari built extensive canal systems to irrigate their terraced slopes. Successful water management strategies have been employed in this region in the past, so can we learn any lessons about how to cope with water stress both now and in the future?

Our research has focused on understanding changes in climate and water availability in the Peruvian highlands, using evidence preserved in lake mud over the last few thousand years. We have to use indirect 'proxy' evidence like this because the Pre-Colombian cultures in the Andes never developed any form of writing, so history was only passed down orally. This has made it difficult for modern-day scientists to understand all the factors that allowed numerous Andean societies to develop, flourish and then disappear – often very rapidly.

Lakes often respond to climatic changes in predictable ways and maintain a record of these changes in their sediments. One lake that has behaved just like this is Marcacocha, located about 3350m above sea level in the Patacancha Valley, itself a tributary to the Sacred Valley of the Incas. A small lake has existed here for almost 4000 years, fed by the melt-waters from glaciers higher up the valley. In 1993, an 8m-long core was obtained from the centre of the lake site (which finally silted up after a drought in the early 1800s). This sequence has turned out to be a treasure-trove of information, having captured a continuous record of how the catchment has changed through time.

For example, variations in pollen from sedge vegetation, which normally colonises the marshy edge of the basin, have shown us how the lake has experienced seriously low water levels throughout its history, roughly every 500 years. This suggested the region went through sustained periods of aridity at these times – but were they warm or cold, and could people still live and farm in the valley under these conditions?

Sedimentary secrets

To try to answer these questions, we decided to concentrate initially on the last 1200 years or so of the lake sediment record, as this was the period when human activity on the landscape was most widespread. In piecing together the evidence, we again used pollen to show which plants were growing in the catchment, either naturally, or as arable crops. Charcoal particles indicated how often fires were being used to clear the landscape, and tiny mite fossils associated with livestock dung gave us a good idea about domestic animals being pastured around the lake.

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The sediments themselves also gave us clues about past conditions. The team at the NERC Isotope Geosciences Laboratory in Keyworth analysed the chemistry of the organic material in the lake muds to help us understand not only how the vegetation had changed through time – backing up and refining our pollen evidence – but also how the basin's soils had changed under different climatic conditions.

When we compared our data with the rich archaeological story from the area, we saw some interesting parallels. The Huari culture were successful predecessors to the Inca, dominant in the region from around AD 600 until their sudden demise around AD 1000. During their final century, the region experienced a sustained drought. Human activity around the catchment seems to have ground to a halt – there is very little evidence for any agriculture, burning of vegetation or the presence of livestock like llamas and alpacas. This suggests that these prolonged conditions were not only dry, but also too cold to successfully exploit these higher-altitude areas – perhaps contributing towards the fall of the Huari.

A similar dry period occurred some centuries later, but this time it was accompanied by warmer temperatures. This coincided with the rise of the Inca, who famously went on to establish the largest and most successful native empire in the Americas, stretching at its height from what is today southern Ecuador to central Chile and supporting a population in excess of eight million.

The Inca and the drought

The evidence from the Marcacocha sediments shows that human activity around the basin actually increased throughout this period. To us this suggests that, despite conditions of increasing water stress, temperatures were warm enough to let the Inca move up the valleys and apply their irrigation and landscaping technologies to exploit these higher altitudes. The pollen data from Marcacocha, supported independently by documents written immediately after the Spanish arrived, also suggests that the Inca cleverly employed agroforestry techniques to stabilise newly-terraced slopes and to increase soil fertility.

This ability to adapt means that the Inca were able to expand their population and develop food surpluses even when faced with difficult environmental conditions. It also let them maintain a standing army, which they employed ruthlessly to subjugate neighbouring cultures.

Were the Inca just in the right place at the right time? Perhaps. But there are also important lessons that can be learned for today. Although water stress is again a critical issue across Peru, many of the highland areas are currently lying derelict, with ancient terraces and irrigation systems left abandoned and decaying. Since the Spanish conquest, the slopes have been stripped of native trees, and today the trend is to plant faster-growing but incredibly thirsty exotic species like eucalyptus.

This is increasing pressure on already limited water resources and causing conflict in many Peruvian regions, both in the highlands and in the much more densely populated coastal strip. Replacing imported trees with hardy native species and repairing terraces and irrigation channels could help ease these problems.

As the glaciers continue to retreat and water stresses increase, Peruvians need to look to the past to see how their ancestors coped under changing environmental conditions. Native agroforestry and the restoration of formerly productive highland areas may help create a sustainable future.

MORE INFORMATION

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FURTHER READING

Chepstow-Lusty, AC, Frogley, MR, Bauer, BS, Leng, MJ, Boessenkool, KP, Carcaillet, C, Ali, AA & Gioda, A (2009). Putting the rise of the Inca Empire within a climatic and land management context. *Climate of the Past* 5, 375-388.
www.clim-past.net/5/375/2009/cp-5-375-2009.html