Research Summary:

Potential contributions of pre-Inca water infiltration infrastructure for water security in the Andes

Published in Nature Sustainability, vol. 2, pp. 584–593, 2019.

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Lima, Peru currently experiences a water deficit of approximately 43 million cubic meters during the dry season. The city depends on artificial storage capacity for its water supply, totaling approximately 330 million cubic meters. The source of this water comes from the Andean rivers that provide water to Lima and the coastal region in general, and which are characterized by a regime of highly variable seasonal flows. This results in large water deficits during the dry season and surpluses during the rainy season that are not fully captured. Climate change is putting additional pressure on existing water resources exacerbated by the effect of human activities, in particular soil degradation and land use change.

This situation demands a rethinking of Lima's current strategies to increase water security. The limitations of conventional solutions based on "grey" infrastructure of artificial dams and reservoirs are becoming apparent: they involve long-term investments, with high upfront (and often unrecoverable) costs. These large-scale projects require complex planning and implementation. As an added challenge, uncertainties in future rainfall projections and water availability complicate the design of large fixed infrastructure systems with a long lifespan.

As a result, there is great interest in Peru in nature-based solutions and "green" infrastructure, which can be gradually implemented, adjusted after implementation, and can provide several benefits that make them compatible with adapting to climate change. This research summary describes results from a study investigating the potential contributions of pre-Inca water infiltration infrastructure for water security in the Andes. The study's results show that alternative approaches that integrate elements of indigenous practices and solutions based on natural hydrological functions can safeguard water security.

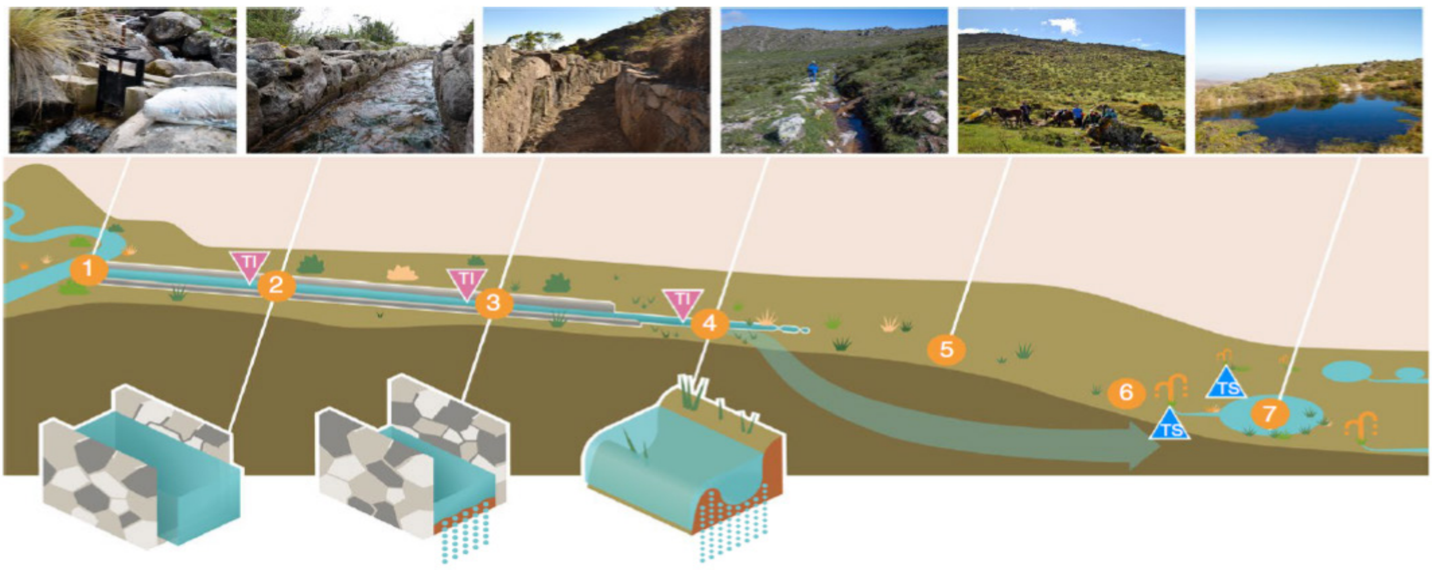
This research was carried out by the project Mountain-EVO and the Natural Infrastructure for Water Security Project by researchers at Imperial College London, the Regional Initiative for Hydrological Monitoring of Andean Ecosystems (iMHEA), CONDESAN, SUNASS, FONAG, Forest Trends, Pontifical Catholic University of Peru, University of Birmingham, University Putra Malaysia, University of Leeds, and the Institute for Applied Sustainability Research.

This summary and editorial review of this document was carried out by Alfonso Carrasco Valencia for Forest Trends.

Water sowing and harvesting

The adoption of nature-based solutions is particularly high in Latin America, in the form of watershed interventions and source-water protection initiatives that seek to enhance a variety of ecosystem services in a flexible and cost-effective manner. Yet, quantitative evidence of the effect of these interventions is still limited. Such evidence is necessary to incorporate these interventions into an effective water resources management strategy at the basin level. Pre-Incan systems for enhancing natural water infiltration are receiving increasing attention from conservation organizations and policy-makers. These systems are known locally as *mamanteo*, the Spanish word for breastfeeding, or *amunas*, the Quechua word meaning "to retain."

This investigation studied in detail one of the last intact pre-Incan systems for enhancing natural infiltration, located in the agropastoral community of Huamantanga (Province of Canta). This system has been built at around an elevation of 3300 meters, in the center of the Peruvian Andes. The community depends on seasonal flows carried through drainage gullies for their livelihood activities, including raising livestock for cheese production and irrigated subsistence farming.



Conceptual model of the pre-Inca infiltration enhancement system. Features of the system: diversion canals (1 and 2), infiltration canals (3 and 4), infiltration hillslopes (5), springs (6) and ponds (7). Tracer injection (TI) and sampling (TS) points are marked schematically in the diagram.

The infiltration system captures water during the rainy season 3800 meters above sea level, and channels it through ditches and canals to prime areas for natural infiltration into the soil. After it enters the ground, the water moves slowly downhill, later emerging in springs and streams. By extending the subsurface retention time, these upslope infiltration systems have the effect of increasing the yield and the reliability of lower-elevation springs during the dry months.

THE INFILTRATION CANALS OF HUAMANTANGA

The infiltration system of the community of Huamantanga, designed to increase water available for irrigation during the dry season, and consists of the following elements:

Diversion canals: These include two types of structures: (1) long channels that divert water flow into infiltration canals and slopes, and (2) short canals that direct the excess water towards basins or other watercourses downstream.

Infiltration canals: These transport water toward the infiltration slopes, while simultaneously allowing infiltration into the subsoil.

Infiltration hillslopes: These are rocky or stony areas that receive water from the canals and spread it across the field, effectively using the soil as a natural reservoir of water and at the same time slowing down the water's exit.

Springs: The water emerges downslope in springs, which usually form naturally and whose volumes are increased by the resurfacing of infiltrated water.

Ponds: Small bodies of water (around 300m³ each) are used to regulate the flow of water through the infiltration system. They serve two purposes: (1) to store water for direct access, and (2) to further increase subsurface water infiltration.

For this study, a dye tracer was injected into an upstream diverting and infiltration canal, and its resurgence was monitored in downstream springs using active carbon samplers. The experiment revealed a clear hydrological connection between the canal and the springs, with retention time of the color tracer ranging from 2 weeks to 8 months, at an average of 45 days. These results show that the system can store water during the rainy season efficiently and recover it during part of the dry season. Modeling indicates that the infiltration system in Huamantanga can increase the natural flow of watercourses in the dry season between 3% and 554%.

Pre-Inca systems of infiltration could benefit the water supply for Lima

Next, the study investigated whether a system with similar hydrological characteristics as Huamantanga's infiltration system, replicated on a larger scale in key source water areas in the Rímac watershed, could contribute to the water supply for Lima. Given the current levels of water stress in the basin, the estimated volumes represent a critical contribution to Lima's water supply. Increasing the base flow rate during the dry season could make existing built civil infrastructure function more efficiently and increase its ability to better support Lima during short periods of drought. This could allow the city to meet greater water demand with existing infrastructure. In addition, the system could recover and store excess water during wet periods at a higher rate.

The results suggest that scaling infiltration systems like Huamantanga's could divert and infiltrate approximately 35% of the rainy season flow of the entire Rímac basin (198 million cubic meters of water per year). This would equate to an additional downstream flow of 99 million meters, which would increase the volume of water available during the dry season by an average of 7.5% per year and up to 33% during the first dry months.

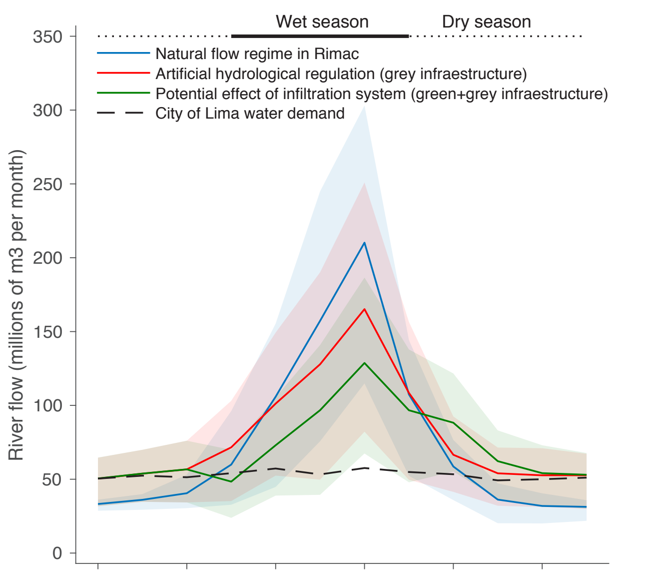
What does this mean for water security?

The restoration of a pre-Inca infiltration canal in Huamantanga has increased interest in Peru in other existing natural infrastructure for water security in the region. The results of this investigation show that re-evaluation of indigenous knowledge and traditional rural practices can complement engineered systems to contribute to the challenge of supplying water to large urban populations located in dry or hydrologically variable regions, thereby improving water security and climate resilience.

For these reasons, SUNASS, the drinking water regulator of Peru, is currently incentivizing and supporting public water services providers in Lima and other cities that seek to complement traditional engineered infrastructure with nature-based solutions. Funded by a special water tariff regulated by SUNASS, water services providers in Peru have designed and implemented of a portfolio of watershed interventions across Peru. A recent law on Compensation Mechanisms for Ecosystem Services (2014) provides the legal framework and establishes permissible interventions. It also places special emphasis on the integration of scientific and indigenous knowledge, which includes the rehabilitation of water "sowing" and harvesting infrastructure such as the infiltration systems described in this brief. This has led to a growing need to quantify the potential hydrological benefits of these practices and explicitly identify beneficiaries. A quantitative evidence base is an important prerequisite for combining grey and green infrastructure, and for optimizing cost-benefit ratios in the context of water supply and drought resilience.

Infiltration systems will need to be part of a more comprehensive water management strategy. This includes grassland conservation and livestock rotation, protection of herders, water sowing and harvesting practices, construction of terraces in lower climatic zones for sustainable agriculture and erosion control, aqueducts to extract and transport groundwater in the coastal region, and irrigation systems with earthern canals to increase aquifer recharge and promote water efficiency. Given the current pressure from water stress, this study provides the scientific evidence necessary to scale indigenous infrastructure. It also challenges the preconception that local water management traditions are outdated, and strengthens the case for the use of natural infrastructure for water security.

Potential contributions of pre-Inca infiltration systems to Lima´s water supply



This brochure was made possible through support provided by the U.S. Agency for International Development and the Government of Canada. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency for International Development or the Canadian Government.