Evaluating the ability of human communities and environmental systems to adapt and recover to Late Holocene climate change in the Peruvian Andes

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During the Late Holocene (last 4250 years), past climatic reconstructions from Peruvian archives (ice, marine, speleothems and lakes) have provided high-resolution records of precipitation and temperature changes, which reflect the varying influences of the Intertropical Convergence Zone, South American Summer Monsoon and El Nino Southern Oscillation (ENSO). In the highland zone (Andes), the records indicate three distinct periods of short-term climate change: rising precipitation until AD 800, lower precipitation and higher temperatures from AD 800-1350 (Medieval Climate Anomaly), and finally increased variability from AD 1350 to the present day due to enhanced ENSO frequency. The records of human history in the Peruvian Andes suggest that these periods coincided with demographic changes (e.g. population rise, out-migration, increased mortality), development/failure of agricultural water management infrastructure (e.g. irrigation canals), and transformation of the landscape and environment (e.g. agricultural terrace construction, soil erosion). These climate and socio-economic records therefore tentatively suggest that highland communities and their food systems were at risk and may have been highly vulnerable in the past, but that the level of vulnerability may have varied through time due to changing environmental, social and economic factors. Our project will seek to characterise the importance of each these factors across time and space, and therefore evaluate the ability of these communities and systems to adapt and recover. We will address the following research questions: What was the magnitude, frequency and characteristics of each climatic event? What was the social, economic and environmental exposure that may have increased the risk to each event? How did communities and food systems anticipate, cope, resist and recover, or even fail, with each event?

The approach to addressing these challenges will be unique in the Peruvian Andes by coupling agent-based modelling with high-resolution palaeoenvironmental data. The student will use the former to analyse the relationships between environmental, social and economic factors, especially changes in demography, agricultural infrastructure, and land-use and climate variability. They will underpin the model with empirical data of land-use, fire history, landscape disturbance and climate change placed within a precise geochronological framework. They will achieve this using a mixed method approach. (1) Integration of secondary data from archaeological sites with major changes in regional socio-economic development and cultural history to enable palaeo-agent-based modelling to evaluate the ability of communities and systems (physical and biological) to adapt and recover. They will develop models in the Netlogo programming environment to assess the implications of the combination of climate changes and resource strategies for the distribution and structure of humans in the landscape. The student will use existing palaeoclimate reanalyses, in conjunction with information derived from the palaeoenvironmental records to provide climatic boundary conditions, overlain on high-resolution topography and land cover. (2) To underpin (1), the student will collect continuous, undisturbed sediment core samples from peatlands in three climatically distinct zones - Cordillera Blanca (northern), Cordillera Viuda (central), and Cordillera Huanzo (southern). Core samples have already been collected and pilot laboratory analysis demonstrates sufficiently high temporal resolution to detect millennial-centennial scale events. Laboratory analysis of the geochemical and sedimentary properties using ITRAX μXRF, X-ray particle size analysis and mineral magnetics will act as indicators

of landscape erosion, and sub-fossil pollen grains and non-pollen palynomorphs as indicators of vegetation succession and land-use. This will be challenging but groundbreaking research. Age modelling will be based on a high-resolution radiocarbon chronology using Oxcal/Bacon modelling software to enable spatial and temporal correlation of events.

Figure 1: Huarca wetland in the Cordillera Blanca, Peruvian Andes. One of the key sites that will be the focus of the research

Training opportunities:

There will be numerous training opportunities during the PhD including fieldwork in Peru, supervisor training in pollen, NPP and sedimentological analyses, and attendance at training workshops in both techniques offered by the Integrated Microscopy Workshop at the University of Reading (organised by SAGES). Training courses offered by NERC at the Oxford University radiocarbon dating laboratory in age modelling, and at BOSCORF, National Oceanographic Centre, Southampton in ITRAX µXRF geochemical analysis. Attendance at seminars in Peruvian archaeology offered by the Peruvian Society and Institute for Latin American Studies in London to develop wider knowledge in the cultural history. Attendance at webinars organised by the partnership 'Food Production and Climate Resilience in Peru: Past, Present and Future' (https://foodclimateperu.com/). Supervisor led training in agent-based modelling using NetLogo, and modelling research group discussions and seminars related to agent-based modelling. Finally, project partners in Peru at Pontificia Universidad Católica del Perú, Lima (PUCP) - Dr Martin Timana and Dr Fernando Gonzalez – have specialist knowledge in mountain ecosystems and social science / ethnography. They will support the project in Peru with training in ecosystem and social science research specific to the Peruvian context and to host the student at PUCP whilst in Lima (UoR has an MoU with PUCP).

Student profile:

This project would suit a student with a quantitative background and a keen interest in past climate change, and the impact of climate change on the environment and human communities. Some knowledge of basic computer programming is desirable, e.g. Python, Matlab, R, Fortran, NetLogo, GIS. Similarly some knowledge of palaeoecological and/or geochemical techniques, including field methods, would be desirable, especially pollen and ITRAX µXRF. A degree in physical geography, biology or meteorology would be appropriate.

https://research.reading.ac.uk/scenario/