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CLAG Field Study Award Report

Future of periglacial landscape:

Alpine ecosystems and deglaciation in the Tropical Andes and French Alps

Summary

My long-term research goals are to examine the future of the periglacial environment and how land management and ecosystem rehabilitation can reduce risk vulnerability and enhance climate resilience. Part of my doctoral dissertation focuses on the study of primary succession in recently deglaciated landscapes (70-80 years) and periglacial ecosystem formation. This work is a biogeographical comparison between two mountain systems: The Peruvian Tropical Andes and the French Alps and relies on both empirical and experimental approaches. I examine how physical, ecological, and social processes interact to drive ecosystem changes in alpine proglacial landscapes and what these tell us about adaptation to sustain livelihoods and downstream services in future glacier free valleys.

The empirical approach is applied in both mountain systems and at multi-scale. We combine in situ observations and measurements (i.e., floristic survey, soil moisture, soil temperature, roughness, and landform identification) with high-resolution aerial imagery acquired by a drone, i.e., unmanned aerial vehicle (UAV). The experimental approach is a grazing experiment set up at the foot of the Uruashraju glacier in the Cordillera Blanca, Peru, using *Lama Glama*, an Andean Camelid.

Last summer to start my first field campaign as a Ph.D. student, I led research teams to both the Andes and Alps. We performed floristic and geomorphological inventories in our seven glacier forelands: Uruashraju, Yanamarey, and Broggi in the Cordillera Blanca in Peru, and the Gebroulaz (Vanoise massif), Glacier Blanc (Ecrins massif), and the Tour and Pelerins (Mont-Blanc massif) in the French Alps. Across postglacial soil/ ecosystem chronosequences—from a series of plots differing in age—starting in 1970 at the acceleration of glacier retreat, we surveyed a total of 396 plots (2x2m). From these plots we have collected floristic data (i.e., species, height, cover, fertility, and spatial association), took Red-Green-near-Infrared Photographs, and surveyed geomorphological characteristics (i.e., slope, aspect, landform, geomorphic processes, coarse elements). Several grants, including the CLAG Field Research Award, made this work possible.

Andean Field Work

The first part of this fieldwork campaign was carried out in the Cordillera Blanca in Peru. We were based in the city of Huaraz for 2 months, between May and July 2019. There we carried out the sampling in our three Andean Postglacial chronosequences: Broggi, Yanamarey, and Uruashraju, and we set up the *Lama Glama* grazing experiment at the foot of the Uruashraju glacier.

Across the three chronosequences, we have sampled 212 plots of 4m2 each, using an average of 15 plots per band of deglaciation (Figure. 1 & 2). We use a Red-Green-Infrared (RGN) bands camera to take infrared photographs of all our plots, to further calculate NDVI value along the chronosequences. We have collected around 25 soil samples per glacier (total of 152 samples) to calculate the bulk density and analyze basic soil properties as pH, magnetic susceptibility, texture, CHNPS contents, and other micronutrient content. For each plot, we have listed all vascular species present and measured their height, cover, fertility and spatial association with vascular plants, biological crust, or rock. Additionally, we surveyed the geomorphological characteristic of the plot, reporting parameters like slope, aspect, landform, geomorphic processes, and percentage of coarse elements, etc. To characterize our study sites across the Andes an Alps and obtain an energy budget we have buried 15 temperature sensors (Hobo 8K data logger) at each glacier site.

Figure 1: Floristic evaluation at the Broggi Glacier Foreland, Cordillera Blanca.

Figure 2: Floristic evaluation at the Uruashraju Glacier Foreland, Cordillera Blanca.

In parallel, we carried out an aerial survey using a UAV, in the three glacier forelands.
We use a multirotor UAV Platform (Phantom 4 Pro DJI) equipped with two sensors, a normal color Red-Green-Blue (RGB) and the Red-Green-Infrared (RGN) bands (Figure. 3). The RGB sensor was the UAV camera and the RGN sensor was a Mapir Survey3W Camera that we purchased last year to pre-test this methodology. The drone was lent by the Cayetano Heredia University of Lima. Unfortunately, the surveys didn't well perfectly mainly because of harsh weather conditions. We will first have to analyze the data doing some photogrammetric work to understand if we need to re-program these surveys for next year. However, we built the 20 wood plates as highly visible targets for use as Ground Control Points (GCP) and organize some other important components of the survey that will be very helpful if you need to reconsider the work. The GCPs serve to georectify the photogrammetric point cloud and to generate a set of "checkpoints" for accuracy assessment of the derived digital elevation models. This work requires the use of a differential GPS and a total station. To do so, we worked in collaboration with the Glaciological and Hydrological Resources Unit (UGRH) in Huaraz who helped us to survey the GCPs in the fields.

Figure 3: UAV survey at the Uruashraju, Yanamarey and Broggi Glacier Forelands, Cordillera Blanca

In the valley of the Uruashraju glacier, we worked with the Llama 2000 Association, an association of local farmers who own llamas and lives in the village of Canrey Chico, downstream the Uruashraju glacier. We made very good connections with the local community and were able to set up the *Lama glama* grazing experiment together (Figure. 4). The farmers helped us in constructing 4 fences and the respective control areas. Each fence and control measure 42 by 22 meters. We use eucalyptus wood stick and barbed wire.
Inside each delimited zone we established 8 permanent 1 by 1-meter plots and carried out the same floristic evaluations than for the three postglacial chronosequences. As well, we sampled 6 soils and buried 2 data loggers for each fence and control areas. Additionally, we sampled plant leaves for nitrogen and phosphorus laboratory analysis, setting up our experiment baseline.

A grazing calendar was established with the community and we wrote down an agreement: for the next three years, they will oversee the llama experiment, bringing the animals in the fence once a month for three days. This work is made in collaboration with the supervision of the National Park of Huascaran. Each month a park guard is going to the field with the community to supervise the experiment.

Next to the llama grazing experiment we also have implemented a similar protocol to test the effect of nutrient addition on proglacial soil and biodiversity. We installed 5 replications of a series of 3 permanent 1x1 plots and consider the following treatment: (1) nutrient addition using a commercial NKP solution, (2) nutrient addition using a dilution of llama dung, (3) watering – no treatment – control plots. This work was carried out in collaboration with Pier Smith Cisneros, a master’s student in the Ecology department of the National University of San Marcos, Lima, Peru.

Figure 4: Building the grazing fences and introduction of the llama in the fences for the first time at the Uruashraju, Glacier Foreland, Cordillera Blanca

Finally, we did some laboratory work at the Environmental Quality Laboratory of the local University in Huaraz, the UNASAM. Thanks to the help of several students we prepare all the leaf samples to be dried and weighed in the oven before nitrogen and phosphorus analysis. And we have weighted and dried our soil samples to send them to the University of Texas at Austin for further analysis in our laboratory.

Alps field Work & Next steps

Similar work was carried out in the French Alps between July and August, where we studied four glaciers forelands: the Gebroulaz Glacier in the Vanoise National Park, the Tour and Pelerins glaciers in the Mount Blanc Massif, and the Glacier Blanc foreland in the Ecrins National Park. As for the Andes, we carried out floristic and geomorphological evaluations,184 in total. We sampled 142 soils and installed a similar quantity of data loggers. The soils sampled were weighed, dried, sieved in a laboratory in France by myself, and sent to the University of Texas at Austin for further analysis.

I am incredibly grateful for CLAG's support, which makes this first field campaign possible.
Working in both French Alps and Tropical Andes, in remote places is very expensive. Through this Field Study Award, CLAG allowed me to carry out this first work in the Peruvian Tropical Andes. I used the funds mainly to pay for the construction of the grazing fences, it was more expensive than I expected, we needed more material and it took additional time to build them. I am very glad that CLAG's support help to set up this innovative experiment and I am looking forward to sharing future results.
I am now analyzing the data collected this summer and I hope to obtain preliminary results for our publications at the beginning of 2020. As well we start to work on the soil samples from the French Alps in the laboratory. The soils from the Cordillera Blanca are stored in the Ecology department of the History National Museum of Lima and have to be sent this week to the University of Austin Texas.
Additionally, I will travel to Peru at the beginning of January, following the CLAG Conference in Antigua, to supervise the llama grazing experiment and collect some additional soil samples for environmental DNA analysis. In the Alps, we worked in collaboration with the University of Milan, Italy, where I learned how to sample proglacial soils for eDNA analysis. I will replicate the sampling method in our proglacial terrain in Peru this winter and send the sample to Milan for analysis.

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