ABSTRACT

In today’s globalized world, cross-cultural research is vital in expanding the boundaries of current knowledge. Last summer, two Purdue programs joined forces, the Center for the Environment’s Arequipa Nexus Institute for Food, Energy, Water, and the Environment (the Nexus Institute) and the Discovery Park Undergraduate Research Internship (DURI), to create an immersive, cross-cultural research internship for Purdue undergraduates. The objective of this internship was twofold: to contribute to a growing library of environmental data for Arequipa, Peru, and to provide undergraduates with intercultural leadership opportunities.

I was one of twelve Purdue undergraduates to participate in this internship, and my research project focused on soil health in Arequipa’s desert agricultural system—particularly, the accumulation of heavy metals in vineyards. Other interns worked on developing soil sensors, mapping landcover changes over time, and analyzing carbon distribution in soils.

BACKGROUND

Arequipa, Peru is a bustling city of 1 million people and is nestled between towering volcanoes and vast expanses of desert. It is a hub for education and economic advancement in this water-scarce region, and the area contains rich mineral and ecological resources that exist in a delicate balance with an extremely arid environment and degradation by human consumption. One major economic activity of the Arequipa region is agriculture, which faces complex challenges in the desert ecosystem. With an annual average precipitation of just ten centimeters (Holmgren et al., 2001), water must be transported from great distances, which raises local tensions surrounding water security. In an effort to create jobs and expand Arequipa’s agricultural exports, the Peruvian government funded the Majes-Siguas Irrigation Project, which has converted 15,000 hectares of arid soil into productive agricultural fields (Stensrud, 2016). However, in an area not naturally suited for agriculture, it is vital to fully understand its consequences. Difficult questions must be explored, such as: can desert agriculture be sustainable with the right practices, and if not, what are the implications for Arequipa’s food security and economy? In response to the growing need for sustainable natural resource management, the Nexus Institute was established. The Nexus Institute is a research collaboration between the Universidad Nacional de San Agustín (UNSA) in Arequipa, Peru, and Purdue University. This collaboration allows the two universities to combine knowledge and resources for the advancement of environmental research, with the overall goal of guiding sustainable development in Arequipa.

Morning fog evaporating from Arequipa’s desert valleys.

Banner. Sunset view of Arequipa’s Plaza de Armas, featuring Basílica Cathedral and the volcano Chachani.
Undergraduate Involvement—Soil Health in Arequipa

The purpose of my summer research project was to analyze soil metal content along with a DURI team that was also looking at organic carbon, mineralogy, and salinity in vineyard soils from UNSA’s Center for Agricultural Research, Education and Production (CIEPA). This site is part of the Majes Irrigation Project, and some of its fields have been under production for decades—making it an ideal location to conduct long-term studies on crop productivity, soil health, and irrigation effects in a desert environment. Our team hypothesized that these soils could contain heavy metals due to the continual application of fertilizers, pesticides, and fungicides, that are used to make the desert soil viable for crop production. With minimal background and historical data on the site, the study serves as a valuable baseline for future soil health evaluation.

Before beginning data collection, it was important to understand the context of our research, especially since the international setting required us to broaden our worldview to encompass the unique challenges and assets of our host country. To truly understand the underlying complexities of the research, the internship began with a two-week visit to Arequipa. The Purdue research team, consisting of undergraduates, postdoctoral researchers, and professors, spent the first few days learning about the local culture, environmental challenges, and socioeconomic landscape. We met with our UNSA colleagues and toured various sites to observe the soils, geology, and agricultural practices of the region. The majority of the soils we encountered were classified as aridisols, which are extremely dry and contain very little organic matter—a necessary component for crop growth. We met with a farmer who irrigates land in the middle of the desert, where we got a firsthand look at one of the biggest challenges to desert agriculture—soil salinization. Soil salinization is a common but complicated global issue that often occurs after transforming desert land into agricultural fields. Aridisols tend to naturally accumulate salts over decades of low precipitation; therefore, when the land is artificially irrigated, large amounts of salts are washed out. We observed the salt and irrigation water collecting in “salt lagoons” due to a shallow, impermeable geological layer beneath the fields. This phenomenon poses a great threat to crops because, over time, the salt from these lagoons encroaches into the fields and renders the soils useless for agriculture, since the crops cannot tolerate high levels of salinity. In this particular area, entire fields had already been lost to saline soil. However, many small farmers do not have the resources to properly drain the fields or recycle irrigation water to prevent this issue, and there are no easy or cost-effective solutions in many areas.

After becoming acquainted with our surroundings, we visited our research site at CIEPA, where the fields were an oasis of green in the middle of the barren desert. It was astounding that crop production was so bountiful in the harsh climate. Our team spent three days collecting soil samples at our vineyard field sites. We used hand augers to dig 40 centimeters down into the soil, which is a lot more difficult than it might seem due to the rocky terrain. Samples were extracted from three separate vineyards of differing ages, and within the vineyards, samples were taken at two different depths (0–20 centimeters and 20–40 centimeters) and two different field positions (within the rows and between the rows of vines). These three differing factors were important to consider in our study because each could influence metal accumulation. For example, the proximity of the soil to the vines (field position) could influence heavy metal concentration due to possible uptake of metals by the vines. In total, 193 samples were collected, packaged, and forwarded to Purdue for laboratory analysis.

Laboratory Analysis

Once the samples arrived at Purdue, they had to be processed according to USDA APHIS (Animal and Plant Health Inspection Service) quarantine protocols for international soils. This protocol must be strictly followed to prevent the spread of invasive species and dangerous contaminants between countries. As per the protocol, the soils were unpackaged in a quarantine room and exposed to high temperatures in order to kill any possible bacteria and microorganisms.

After following APHIS protocol, a portable X-ray fluorescence analyzer (pXRF) was utilized to analyze the soils’ metal content. This instrument is capable
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at agricultural sites in Peru to quickly gauge metal accumulation and evaluate soil health.

This project is ongoing, and, almost a year after the initial laboratory analysis, the data is still being analyzed and compared with a complex data set compiled by the other DURI and UNSA students. The preliminary pXRF results indicated that, in general, the concentrations of potentially harmful heavy metals were well below the maximum permissible limits for healthy soils. However, these results lead to more questions, such as: are the metals simply leaching through and accumulating deeper in the soil profile, and if so, could this accumulation lead to negative impacts on the environment or crops in the future? In sandy soils with low concentrations of organic matter, such as the CIEPA fields, the downward movement of metals is possible due to the sand’s low cation exchange capacity (ability to hold cations), meaning that the soil has an inhibited ability to bind to and retain metals. Furthermore, irrigation can contribute to the downward migration of water-soluble metals (Zhenbin & Shuman, 1996). Soil samples deeper than 40 centimeters would need to be analyzed to complete our understanding of downward metal movement in these fields.

RESULTS

The pXRF analysis of all 193 soil samples was completed in less than two weeks, proving that it is an effective tool in the rapid assessment of metal concentrations. Furthermore, this instrument is versatile and can be used in both laboratory and field settings, which opens the possibility of operating it of identifying the elemental composition of samples (from elements Mg-U), which it accomplishes using energy waves. The instrument scans the sample with X-rays, and then the detector measures the difference in energy between electron shells. This energy difference is emitted as radiation and is unique to each element. The sample preparation for this procedure was simple. The soil was placed in a plastic sample cup and covered by a very thin, clear film. Then the sample was set on the pXRF detector, which took about two minutes to analyze and display metal concentrations. This study gave preliminary results as it was the very first metal analysis on these soils, and it is suggested that the samples should also be analyzed using other methods, such as inductively coupled plasma spectrometry, to confirm the pXRF results.

Ally Jacoby sieves a soil sample before bagging it for transport.

The SHIVA team collecting vineyard soil samples at the CIEPA Research Station, Arequipa, Peru.
and pH tests to give them a better understanding of the soil and crop interactions. We worked side by side, and it was a fascinating exchange of knowledge through three different languages (Quechua, Spanish, and English).

Furthermore, at the end of the summer, the Purdue team got the chance to return the hospitality when a group of UNSA professors and students traveled to Purdue for a two-week workshop. During this visit, Purdue and UNSA undergraduates collaborated on a research presentation and learned together by attending lectures by Purdue professors.

Farmers observing a soil texture test in their organic quinoa field.

SHARING KNOWLEDGE

To conclude the internship, Purdue hosted a cross-cultural research symposium. Researchers and undergraduates from both UNSA and Purdue presented posters on their work, which covered a broad range of topics from soil health, to water quality, to remote land cover sensing. The room was packed wall-to-wall with passionate scientists speaking both Spanish and English with excited

CROSS-CULTURAL COLLABORATION

This internship provided tremendous opportunities for the DURI and UNSA undergraduates to broaden their research skills while learning about the biogeochemistry of an ecosystem that is unlike anything in Indiana. However, the defining aspect of the experience was the opportunity for cross-cultural collaboration. The complete immersion in Arequipa provided an intense and engaging learning environment to develop intercultural competency, which is defined as the ability to effectively communicate across cultural differences (Perry & Southwell, 2011). Intercultural competency is imperative for effective research, and it can maximize collaboration efficiency by eliminating the barrier of one-dimensional thinking. Interculturally competent researchers can draw on various cultural frameworks to expand the possibilities for theories and techniques that enable them to approach problems with innovative, interdisciplinary mindsets. To develop intercultural competency, one must constructively engage with cultural differences and leave the comfort zone of familiarity. Throughout the entirety of the internship, the interns were encouraged to be curious and open-minded in order to maximize the learning opportunities presented by our Peruvian colleagues, and our daily interactions proved to be profound learning opportunities. We worked closely with our UNSA team members throughout our time in Arequipa. They shared knowledge of their city, and we participated in collaborative fieldwork and research discussions. We exchanged ideas regarding research techniques, and we spoke about the similarities and differences between our countries. One of my favorite intercultural learning moments of this internship was our trip to an organic quinoa field in the highlands. The fields were managed by Quechua women, the indigenous people of the Peruvian Andes. These women make their living growing and selling organic, premium quinoa. They shared their practices with us, and in turn we demonstrated soil texture

SHIVA team members at the final research poster presentation of the internship.
intensity. Throughout this evening of research discussions, scientists were able to make connections among projects and generate new ideas to propel the Nexus Institute forward. It was an extremely unique collaborative setting that encapsulated the interdisciplinary values on which the Nexus Institute was founded.

REFERENCES


**Student Author**

**Ally Jacoby** is a senior majoring in natural resources and environmental science with a minor in environmental and ecological engineering. She has worked in the Filley Biogeochemistry Lab since she was a sophomore, studying the accumulation and movement of heavy metals and carbon through soils. Her academic work is centered around water quality, and she is planning on pursuing a career in watershed management.

**Mentor**

**Timothy Filley**’s research program explores the biogeochemical processes that transform organic matter in terrestrial and riverine ecosystems within natural and intensively managed landscapes. An overarching goal of his work is to demonstrate that detailed mechanistic information about soil organic matter (SOM) dynamics can lead to better understanding of society’s vulnerability to climate and land use change, and to the potential risks from emerging pollutants. He has advised 19 graduate students, 6 postdoctoral scholars, and has published 107 peer-reviewed manuscripts. Since coming to Purdue in 2000, Filley has secured research support for 23 research projects supported by funding sources that include DOE, EPA, USDA, NSF, as well as international agencies. Filley is the Director of Purdue’s Center for the Environment (C4E) which connects over 150 Purdue faculty to promote proactive, interdisciplinary research, learning, and engagement addressing important global environmental challenges. Filley is the co-director of the Arequipa Nexus Institute for Sustainable Food, Energy, Water and the Environment (the Nexus Institute). The Nexus Institute is a technical and research alliance program between Purdue University and the Universidad Nacional de San Agustín (UNSA) in the Arequipa region of Peru designed to understand and address challenges to the region’s food, energy, and water production and delivery systems. This project includes participation from over 60 Purdue faculty, 100 UNSA faculty, and supports 30 postdoctoral researchers.