Analysis of Climate Data in Southern Peru Using Geographic Information System Tools

Sarah Kunch
2012 Borlaug-Ruan International Intern
El Centro Intronacional de La Papa
La Molina, Lima, Peru
Holy Trinity Catholic High School
Fort Madison, Iowa

Introduction

The 2011 Global Youth Institute was an event that shaped my mindset from the very beginning. Being able to attend such a fantastic conference with some of the world's leaders in food security was a life changing experience. Listening to the speeches of the 2011 World Food Prize laureates as they accepted the prestigious and well-deserved award from Ambassador Quinn is something I will never forget. For me, the most memorable part of the 2011 Global Youth Institute was when former Brazilian President Lula da Silva talked to the students before going to the Capital to receive his award. Even though I knew nothing he directly spoke because he spoke in Portuguese, I was moved by the passion he conveyed for his work in combating hunger in poverty in Brazil during and after his presidency. Listening to Lula da Silva say that our generation would be the one to end hunger and poverty motivated and inspired me to apply to be a 2012 Borlaug-Ruan International Intern.

Lula da Silva was not the only inspiration to my application. I attend a Catholic high school in Fort Madison, Iowa. I am grateful to have the opportunity to attend such an institution where issues such as world hunger and poverty are discussed in Theology curriculums. Attacking the issue from the ethical standpoint by questioning if basic needs, both physically and spiritually, are being met by those who suffer from malnutrition, starvation, and poverty. As a student attending a Catholic high school I am familiar with the term stewardship, serving ones community as a follower of Jesus. When presented with the opportunity of applying for the Borlaug-Ruan International Internship, I saw this not only as an opportunity to improve food security, but also as an opportunity to serve my global community.

Almost immediately after the 2011 World Food Prize and Global Youth Institute I began to start my application. The process consisted of much waiting. It seemed as though every day from January to March I would hurry home from school to the mailbox to check the status of my application and placement. The anticipation was brutal, but the days when I would open the mailbox to find a beige envelope with gold stationary addressed in my name were well worth the wait. Receiving news that I had moved forward to the interview portion of the application, of my acceptance, and, finally, of my placement were, arguably, the most celebrated days of my junior year in high school. The remainder of my junior year seemed to go on endlessly. Finally, on the first of June, 2012 I finished my final exams only to go home and finalize my packing for Peru. I said goodbye to my parents and America the following morning and started my two month adventure.

El Centro Intronacional de La Papa

El Centro Intronacional de la Papa, the International Potato Center, is known by its Spanish acronym CIP. CIP was founded in 1971 as a root and tuber research-for-development institution delivering sustainable solutions to the pressing world problems of hunger, poverty, and the degradation of natural resources. CIP's mission is to achieve food security, well-being, and gender equity for poor people in root and tuber farming and food systems in the developing world through research and innovation in science, technology, and capacity strengthening. Headquartered in Lima, Peru, CIP has over thirty offices in developing countries in Asia, Africa, and Latin America.

CIP is part of the 15-center research alliance known as the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is a strategic global partnership dedicated to sustainable agricultural development and the preservation of Earth's precious resources and biodiversity. Its aim is to reduce hunger, malnutrition, poverty, and environmental degradation in developing countries by generating and spreading agricultural knowledge, technologies, and policies.

Since the year 2000, the International Potato Center has hosted 13 interns. These interns have had the opportunity to work in various labs researching topics such as biodiversity, plant breeding, crop management, natural resource systems, and human health related to agriculture. For my two months at CIP, I worked in the Production Systems and the Environment Division, specifically in the Integrated Crop and Systems Research Global Science Program.

The Integrated Crop and Systems Research division at CIP focuses on research to develop tools for assessing and understanding potential shocks and vulnerabilities in potato and sweet potato-based livelihood systems, which could help to get the full benefit for small scale farmers from the genetic materials that CIP develops. Potato and sweet potato cropping systems are located in poverty belts and pockets of extreme poverty that are characterized by their extreme vulnerability to natural stresses and external factors that are beyond the capacity of local people to address using existing technology. As we move into an uncertain future – a period that will be marked by climate change, globalization, and newly emerging pests and diseases – the vulnerability of smallholder farmers will increase. With these challenges in mind, the Integrated Crop and Systems Research division attempts to develop and apply methods and tools that will help to design research and development interventions that consider the complexity and dynamism of current systems.

Agriculture and its interaction with the environment are often referred to as a complex system. Limited effort has been made to take advantage of the complexity science and its tools to seek for solutions to the increasing complexity farmers face. The Integrated Crop and Systems Research division at CIP implements nonlinear science, statistical physics and numerical simulations to assess present and expected challenges of potato and sweet potato based systems in a changing environment. It includes ten outputs comprising the validation and availability of growth models, assessing impact of climate variability, developing climate downscaling methods and climate interpolation algorithms, the development of statistics for target areas, web-based tools for visual 3D representation of land use scenarios, and methods for assessing agricultural-system changes.

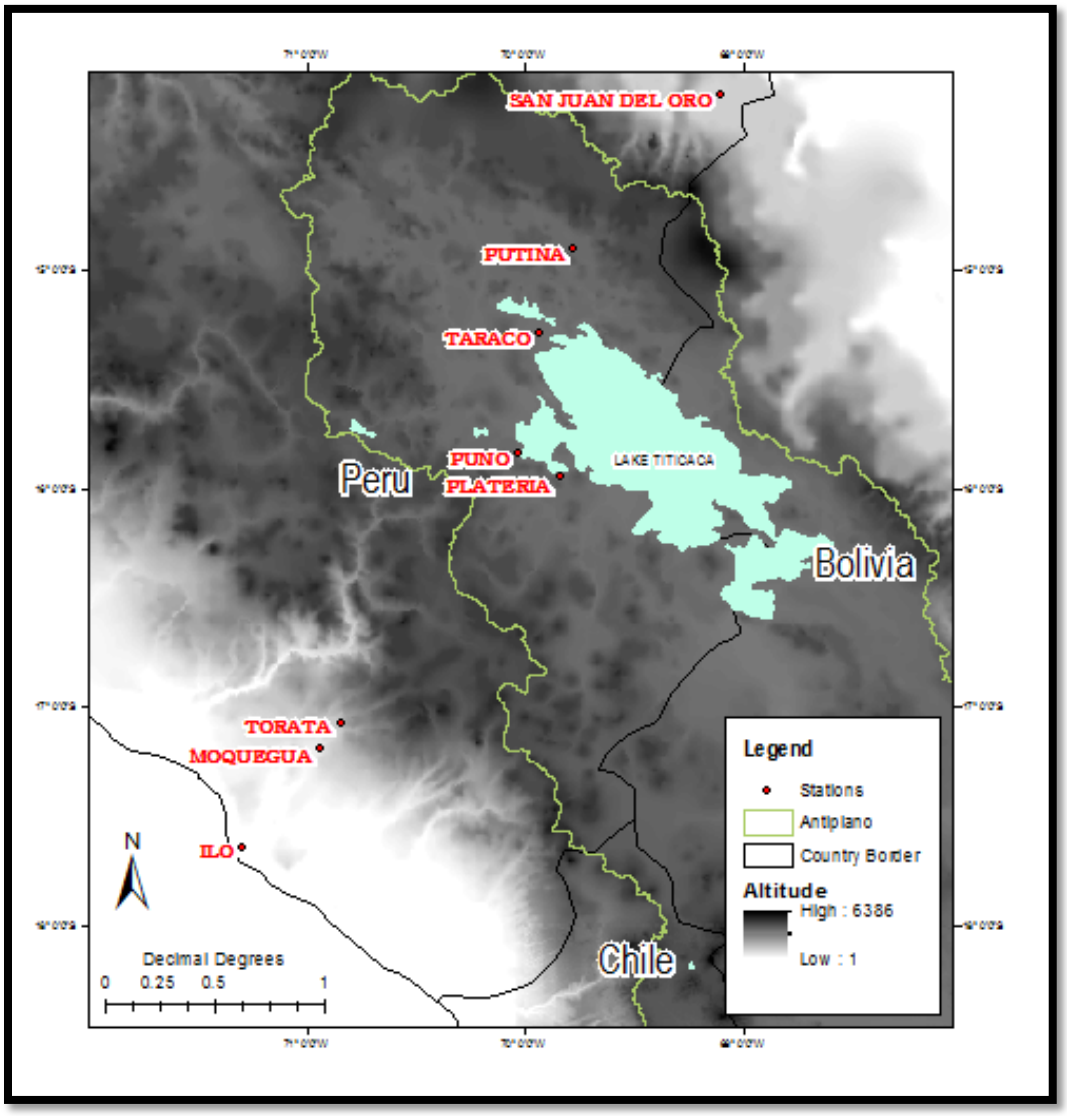
My Research

The specific project I was given at CIP involved accessing climate variability due to changes in soil carbon emissions. Soil represents one of the most important storehouses for carbon on earth and accounts for fifteen percent of carbon emissions related to greenhouse gasses. CIP and the Brazilian Agricultural Research Corporation (EMBRAPA) established a 1,000 km transect from the Pacific Ocean over the Andes to the jungle in Southern Peru, and then tested soil carbon levels in a variety of agricultural and land use systems. The samples represented the most common agro-ecosystems found in tropical areas worldwide. There were wide variations in the levels and stability of carbon stored in the soil, depending on land use, type of crop, climate, and elevation.

To correspond and compliment previous research, I examined climate and elevation data from eight points in Southern Peru. The points of interest expanded through all of the three main geographic areas of Peru: the coast, the highlands, and the jungle. Points of interest located in the coastal region included Ilo, Moquegua, and Torata. Ilo had an elevation of 15 meters above sea level, Moquegua had an elevation of 1,410 meters above sea level, and Torata had an elevation of 2,468 meters above sea level. The points of interest in the highland region lie on an elevated plateau known as the Antiplano. These points of interest also lie in close proximity to Lake Titicaca, the highest navigable lake in the world at an elevation of 3,812 meters above sea level. The points of interest for this area were Plateria, Puno, Taraco, and Putina. Plateria sits at an elevation of 3,830 meters above sea level. Puno has an elevation of 3,860 meters above sea level. Taraco sits at an elevation of 3,819 meters above sea level. Putina has an elevation of 3,878 meters above sea level. My final point was located in the

humid subtopic region of Peru, or the rainforest. This point, San Juan Del Oro, has an elevation of 1,320 meters above sea level.

Points of Interest in Southern Peru



This map shows the points of interest in Southern Peru with emphasis on elevation, location, and important geographic features such as Lake Titicaca and the Antiplano, which is outlined in green. Areas with higher elevation contain darker shades while areas of lower elevation have lighter shades of gray.

To conduct my research and to create my visual images and maps, such as the one on the previous page, I first had to become familiar with the computer software programs of ArcGIS. Geographic Information Systems, or GIS, is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The computer program ArcGIS is an online geographic information system for using maps and geographic information. All of my visual images and animations were created using the ArcGIS software.

The first part of my research involved analyzing temperature data from the eight points of interest for the year of 2006. To collect my data, I downloaded raster datasets from MODIS, or Moderate Resolution Imaging Spectroradiometer, for the entire year of 2006. The MODIS raster datasets collect temperature information, minimum and maximum, every eight days throughout the entire year. I downloaded these datasets from NASA's Earth Observing and Data Information System, EOSDIS. Once the raster datasets were downloaded, the temperature information could be viewed, in map form, for each collection day. To collect numerical temperature value I ran the datasets through a computer coding program, Python.

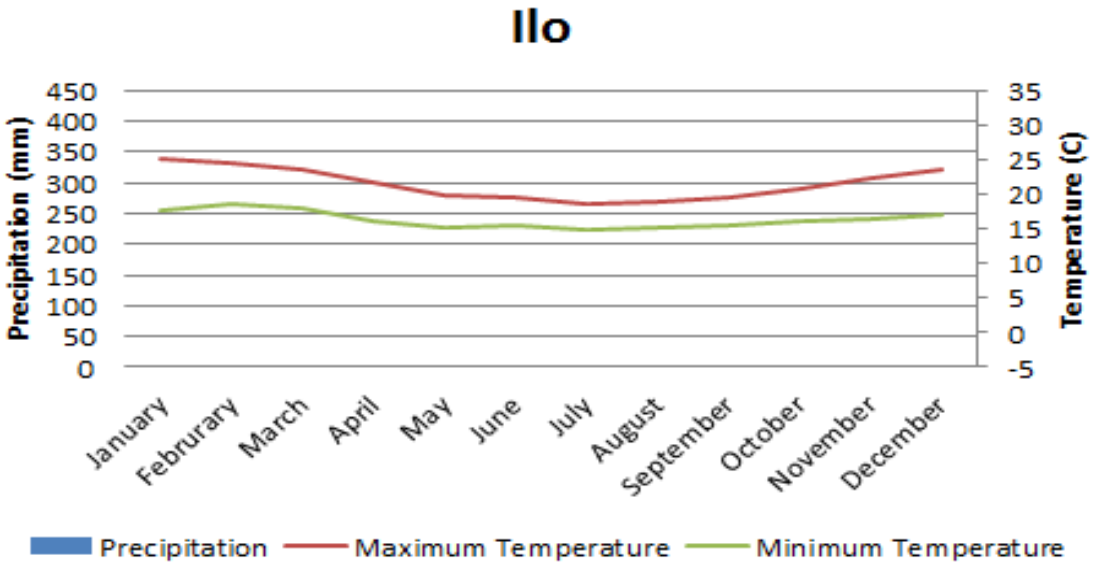
To confirm the MODIS raster data was sufficient, I compared the raster values with temperature data from Senahmi, the national meteorology and hydrology service of Peru. Unlike the MODIS raster data, Senahmi temperature information was taken daily. To compare the Senahmi data with the MODIS raster data, I averaged both the minimum and maximum temperatures of Senahmi data for every eight days for the year of 2006 for each point of interest. When comparing the values, I noted that the values were similar, but not exactly correspondent. I corrected the values by comparing the two data sources' information for both day and night for each point of interest, and computing the numbers through a line of regression from a comparison graph.

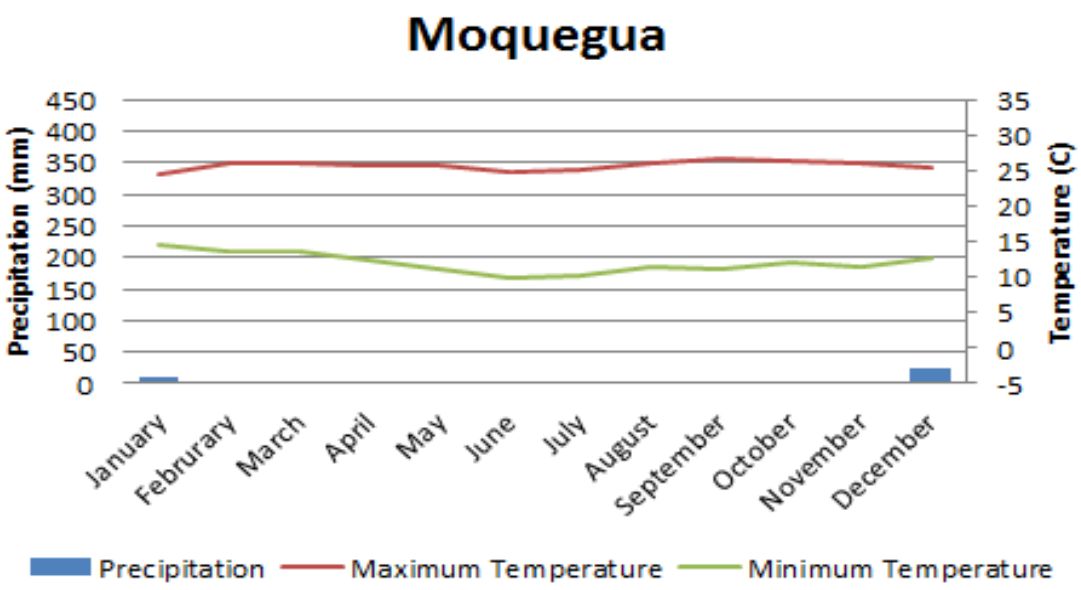
For the next part of my research I analyzed precipitation data for my eight points of interest in Southern Peru. To do so, I used TRMM raster data. TRMM, or the Tropical Rainfall Measuring Mission, is a joint mission between the National Aeronautics and Space Administration (NASA) of the United States and the National Space Development Agency (NASDA) of Japan. The objectives of TRMM are to measure rainfall and energy exchange of tropical and subtropical regions of the world.

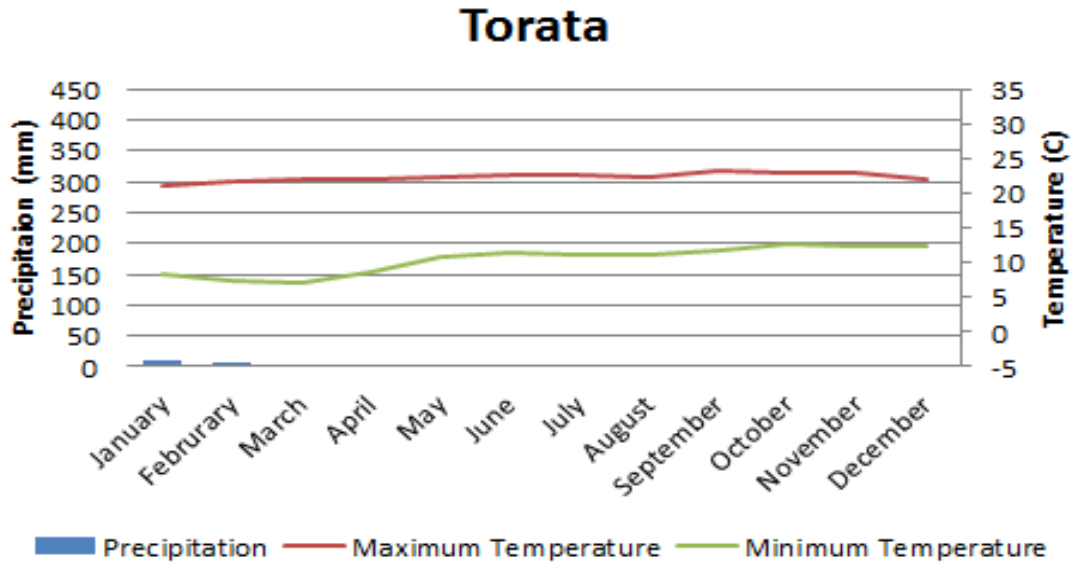
I was given the TRMM raster datasets for the year of 2006 by another team member at CIP. From there, I studied the raster information visually in map form using the ArcGIS program ArcMap. Then, just as with the raster datasets for temperature, I ran the raster datasets for

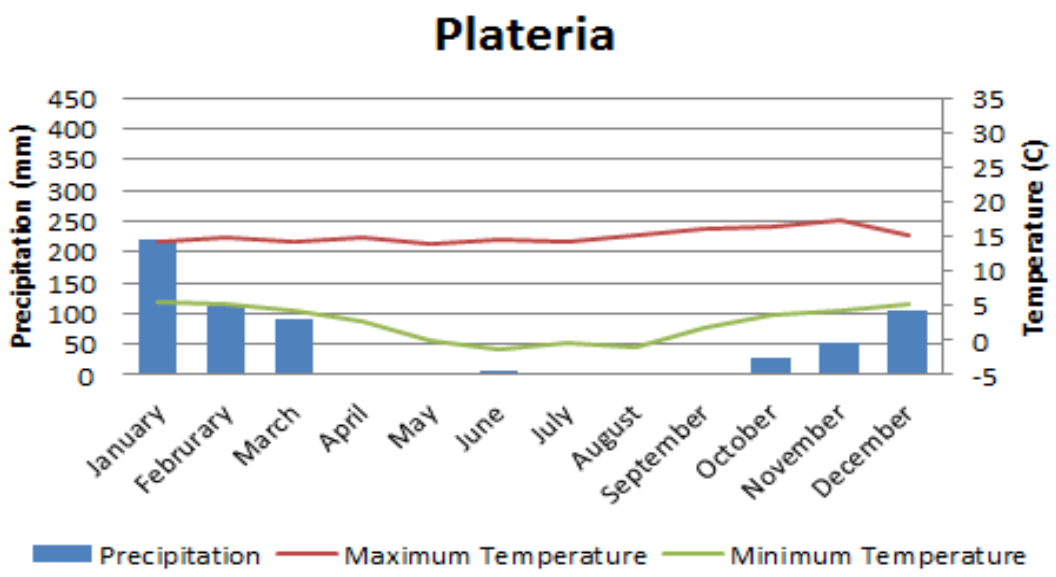
precipitation through the computer coding program Python to accumulate the numerical data for precipitation. Unlike the MODIS temperature raster datasets, the TRMM precipitation raster datasets were collected daily for the entire year rather than every eight days. Because I wanted exact rainfall measurements I decided not to average every eight days. This helped when calculate total rainfall accumulation for each month at each interest point. Again, as I did for temperature, I compared the precipitation values from the TRMM raster datasets with the precipitation values from Senahmi, the national meteorology and hydrology service of Peru. When comparing the two sources I found the data to be similar. So for this, I did not need to correct my TRMM raster values.

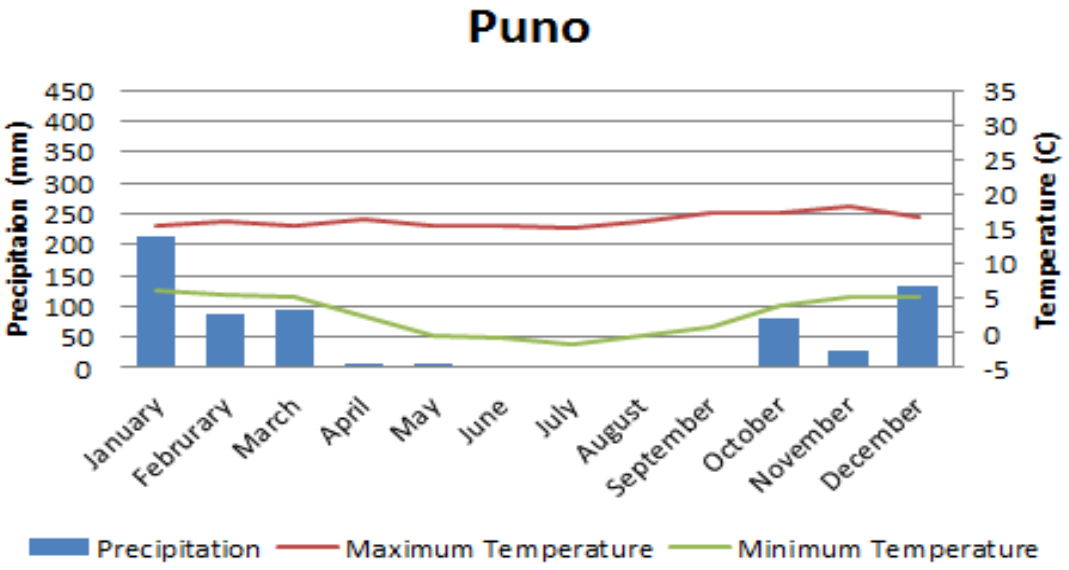
The following graphs highlight minimum and maximum temperatures of each point of interest along with the accumulative monthly precipitation. Starting with the coastal areas of Ilo, Moquegua, and Torata then moving to the highland areas of Plateria, Puno,Taraco, and Putina and then the rainforrest area of San Juan Del Oro.




Moquegua
Precipitation (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
0
35
30
25
20
15
10
5
0
-5
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature


Torata
Precipitaion (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
0
35
30
25
20
15
10
5
0
-5
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature


Plateria
Precipitation (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
0
35
30
25
20
15
10
5
0
-5
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature


Puno
Precipitaion (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
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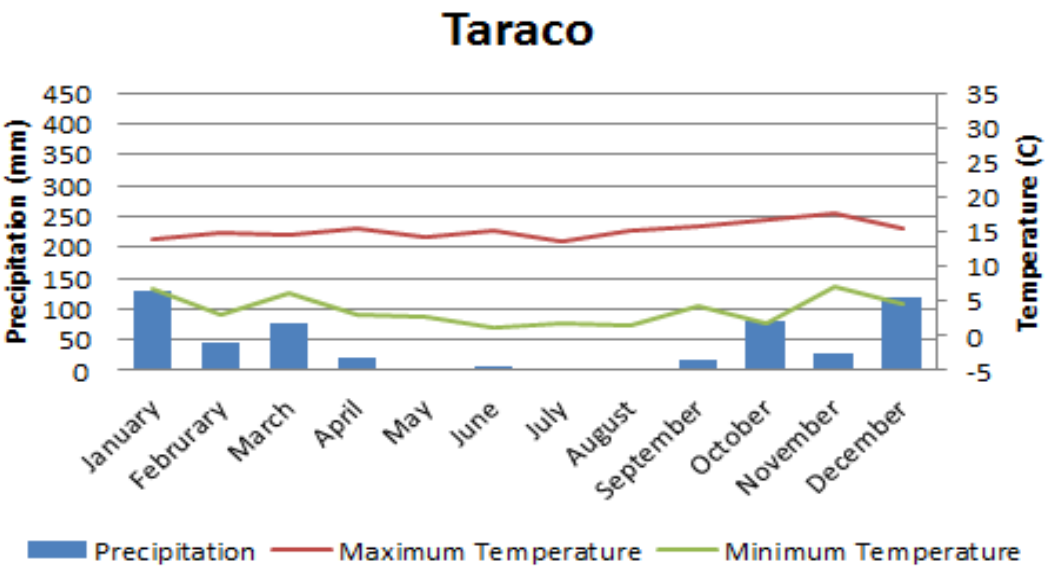
30
25
20
15
10
5
0
-5
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature


Taraco
Precipitation (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
0
35
30
25
20
15
10
5
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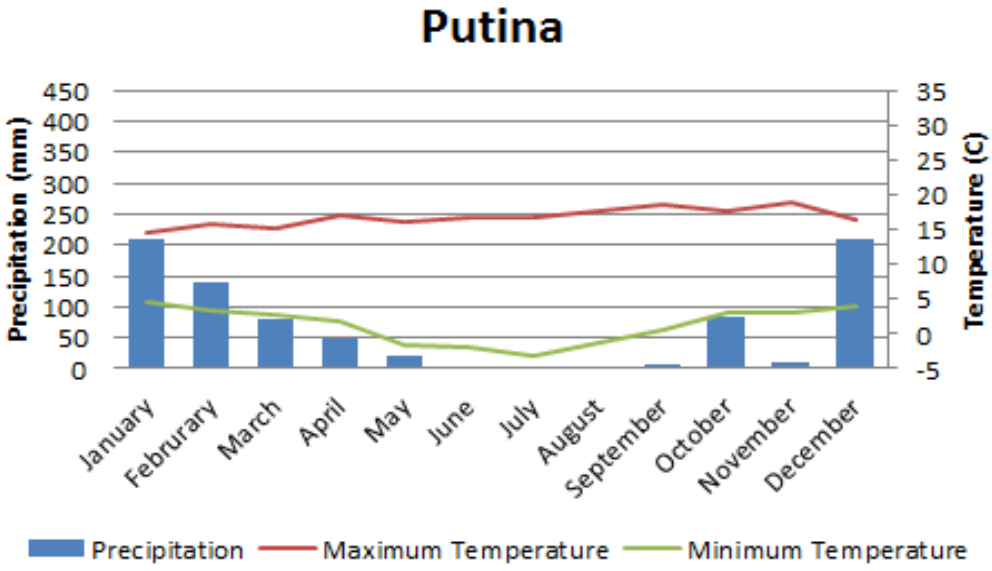
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature


Putina
Precipitation (mm)
Temperature (C)
450
400
350
300
250
200
150
100
50
0
35
30
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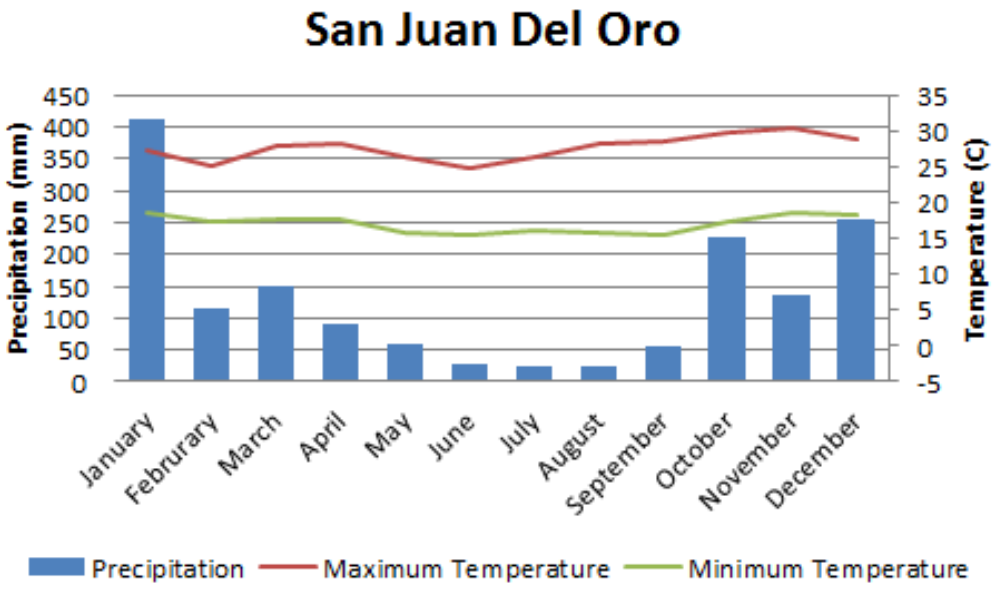
20
15
10
5
0
-5
January
Februrary
March
April
May
June
July
August
September
October
November
December
Precipitation
Maximum Temperature
Minimum Temperature



For my final tasks of my research at CIP, I created 3D landcover and TRMM profiles as well as visual animations. I did so using the ArcScene program in the ArcGIS computer software. I created shapefiles from my TRMM datasets and downloaded elevation and landcover rasters from NASA's Earth Observing and Data Information System, EOSDIS to create my 3D images.

3D Landcover Profile of Southern Peru:

In Image 1 you can see the geographic features at the points of interest in Southern Peru. The coastal areas of Ilo, Moquegua, and Torata are at the bottom of the image, the highland areas of Plateria, Puno, Taraco, and Putina are in the center surrounding Lake Titicaca, and the rainforrest point of San Juan Del Oro is at the top of the image.

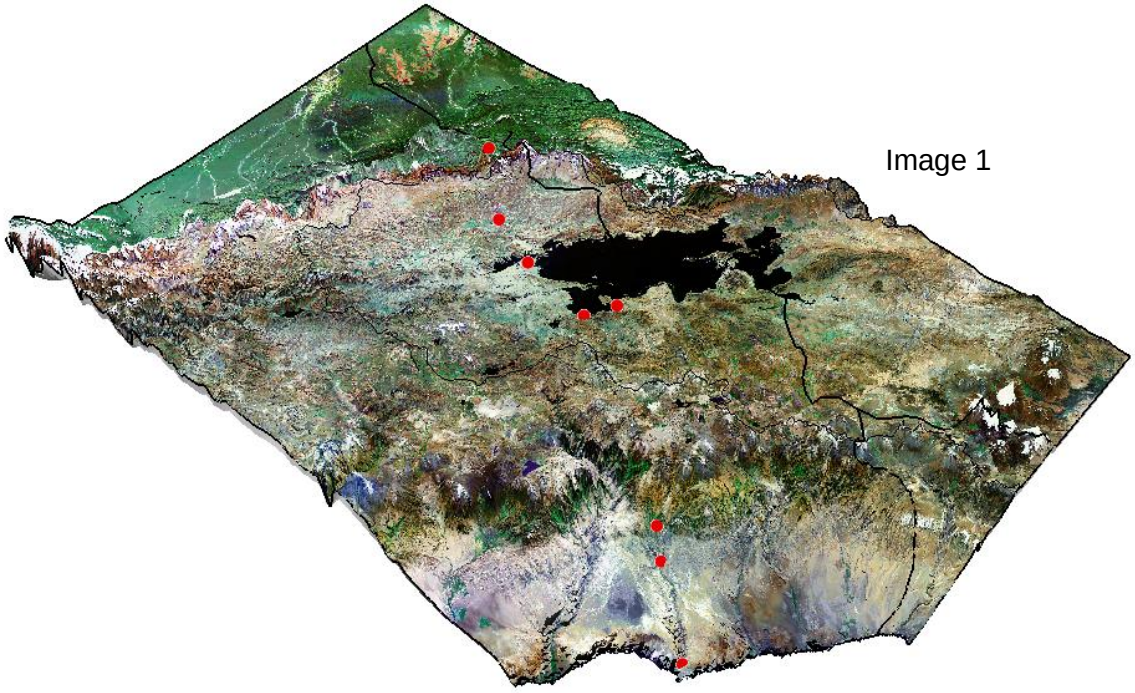
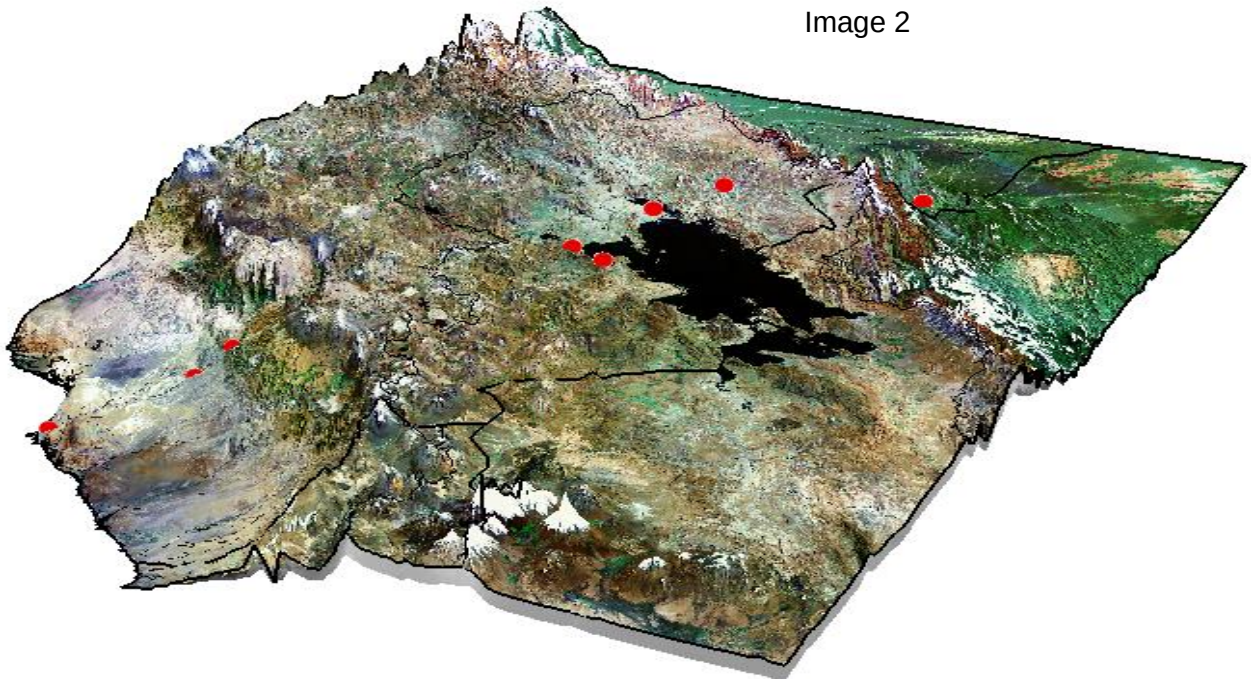


Image 1

In Image 2 you can see the elevation as well as the geographic features of the points of interest in Southern Peru. Farthest right are the coastal areas of Ilo, Moquegua, and Torata. The highland areas of Plateria, Puno, Taraco, and Putina are in the center surrounding Lake Titicaca. The rainforest point of San Juan Del Oro is furthest right in the image.

Image 2



3D TRMM Profile of Southern Peru:

In Image 3 you can see the TRMM information for the points of interest in Southern Peru. The coastal areas of Ilo, Moquegua, and Torata are at the bottom of the image, the highland areas of Plateria, Puno, Taraco, and Putina are in the center surrounding Lake Titicaca, and the rainforrest point of San Juan Del Oro is at the top of the image. The areas of red indicate areas with little percipitation and the areas of orange and yellow represent areas of moderate percipitation, and the green areas indicate ares with heavy percipitation.

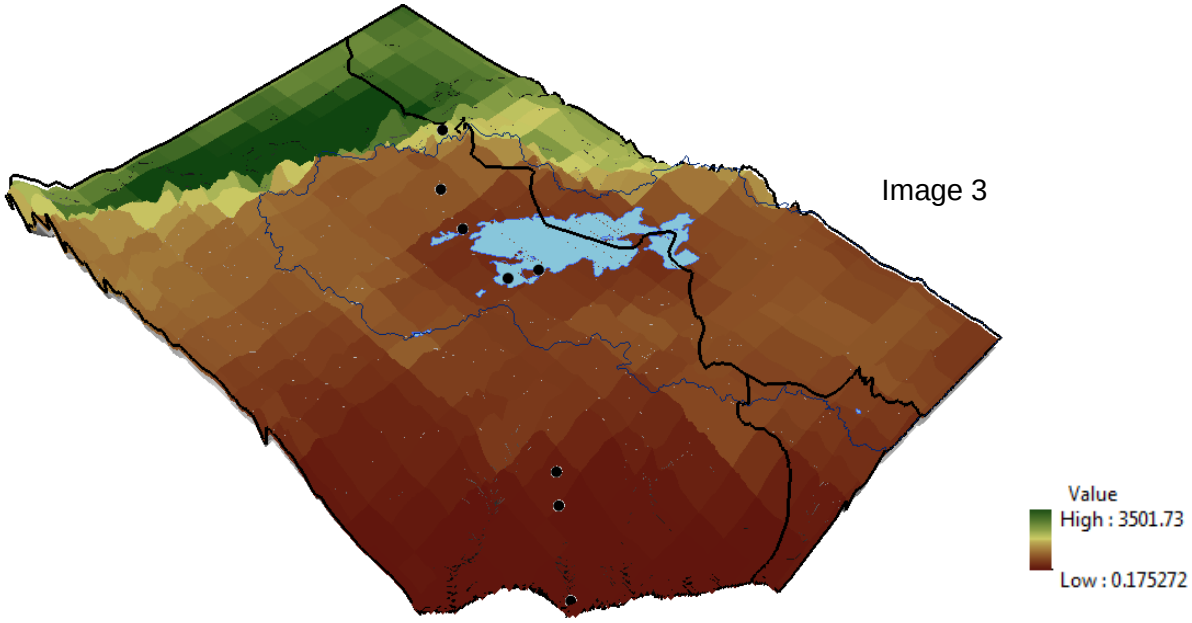
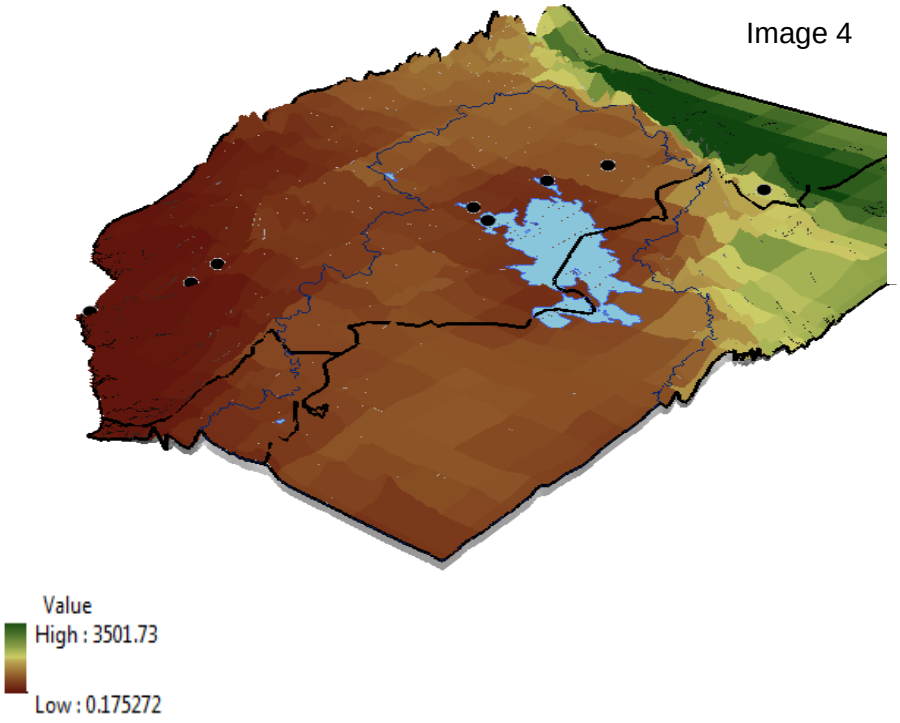


Image 3

In Image 4 you can see the elevation as well as TRMM information for the points of interest in Southern Peru. Farthest right are the coastal areas of Ilo, Moquegua, and Torata. The highland areas of Plateria, Puno, Taraco, and Putina are in the center surrounding Lake Titicaca. The rainforest point of San Juan Del Oro is furthest right in the image. Again, the areas of red indicate areas with little percipitation and the areas of orange and yellow represent areas of moderate percipitation, and the green areas indicate ares with heavy percipitation.

Image 4



From my observations I could conclude that there was clear evidence that the higher the altitude, the lower the temperature. I can also conclude that with precipitation, the farther away the points were from the coast, more precipitation occurred. I also noted that there was not a clear comparison between MODIS data and data from the weather stations using Senahmi for temperature data. Another realization was that not all information is reliable and to maintain a reliable data source, many comparisons need to be made with local and global sources.

The Integrated Crop and Systems Research division at CIP will use my research to continue further investigation in carbon stocks research in Southern Peru and to compare my data from the year of 2006 with years from 2000 to 2008 to study the climate change occurring in this region. This research is extremely prevalent, especially for the farmers in the Antiplano region. The Antiplano is one of the poorest areas in Peru. Farmers do as much as they can to provide for their families and make a living. In doing so, they are moving their farms into higher elevations. This causes more amounts of carbon to be released into the air from the soil. These carbons will then become trapped in the atmosphere by greenhouse gasses and contribute to the Global Warming epidemic.

CIP Experience Outside of Lima

During the third week of my internship at CIP, I was given the opportunity to go collect research material with another department. I went with Wilmer Perez, a specialist in Late Blight research at CIP to collect host plants infected with a certain fungus that is similar to the fungus that caused the Irish Potato Famine. The host plants were in two different regions of Peru. One type of plant was indigenous to the humid subtropics; the other belonged to the highlands. To collect the hosts we traveled through some of the roughest and most beautiful areas of Peru. Using a shovel and an impressive weed-whacker we collected the hosts and repotted them for the return journey to CIP.

Late Blight research is an extremely pressing issue, especially in developing countries, such as Peru, where many people depend on potato crops for their income. If the farmers' crops are exposed to Late Blight pathogens their crops could be entirely wiped out or even destroyed. With increasing temperatures caused by global warming, the fungus is quickly spreading. If temperatures continue to increase, the fungus could spread into other countries and other continents, effecting millions of farmers around the world.

During this excursion outside of Lima, I was able to experience another sector or CIP's research. Being able to see another factor gave insight to CIP's mission through another field of research. Also, I was exposed to the three regions of Peru—the coast, the highlands, and the jungle. It also exposed me to beautiful scenery of the mountains and the diversity of the jungle, both completely unique and a totally different atmosphere from Lima, which sits directly on the coast. This helped me put my research of climate data from each of the three regions of Peru into perspective. As we were twisting and turning our way through the highlands, I was exposed to the poverty of Peru. People living in shacks at the top of the Andes to have easy access to their potato farms were among many images that will never leave my memory. I realized that in Lima I was very sheltered. The people in Lima are more privileged to have a sturdy home and even a car while the people in the highlands that are dealing with poverty struggle to survive. While living in Lima I questioned why Peru was considered to be a developing country, but in the highlands I was able to see the real Peru--not clouded by skyscrapers, combis, and endless Chifa restaurants.

Personal Reflections

Before arriving in Peru, I read the essays of previous CIP interns to familiarize myself with CIP and the type of research I would be conducting. I also contacted a few of the interns to ask questions about what to expect of Peru and CIP. Each paper and intern shared an experience that was uniquely their own. No matter how many papers and travel books I read, nothing could prepare me for my eight week endeavor in Peru.

As soon as the driver and I left the Jorge Chavez International Airport and made our way through the nightlife of Lima, I realized this was not small-town Iowa. Seeing endless adjacent houses covered with graffiti as the driver skillfully maneuvered through the traffic was an immediate difference. As I would soon learn, the constant sound of horns honking and dogs barking did not cease to occur, even at night. At first I felt completely out of my element. Crowds of people at every corner and in every bus were something very intimidating, especially after the many warnings from my host mother, Liliam, that I could not trust anyone.

The area where I lived in Lima, La Molina, has a saying that I found to be very true for me--*Disfrutando a mi hogar.* This translates to "enjoying my home." I fell in love with every aspect of Peruvian culture while living in Lima. The people were very welcoming, especially at CIP. Whenever I needed help with my research or anything in general, my team members were

more than willing to help. They also wanted to make sure I learned as much about Peruvian culture as possible. They introduced me to the traditional music and dances of Peru as well as helped me navigate my way through restaurants by pointing out the best Peruvian dishes to order and which to avoid.

My experience in Peru and at CIP is something that has constructed a new way of life for me. Apart from the now dependence on strong coffee to get me though a tough day I have learned many things from the people I met in Peru. The most influential person is Rubi Raymundo, my direct supervisor at CIP. I remember walking into her office on my first day at CIP and seeing this short woman practically jump out from behind the door to greet me. She hurried to explain my project and get me accustomed to the office and CIP. She made sure that I got the "true" Peruvian experience by bringing various treats into the office for me to try and giving me traditional music to listen to and even took me to *El Museo de Oro,* Peru's Gold Museam, to learn about the history of Peru. Through our many chats I learned how dedicated and intelligent Rubi is. She is a single mother that was working a full time research career and supporting her young son and currently, she is working on her doctorate in Agronomy at the University of Florida. Rubi is someone that I hope to model my life after and her wisdom will influence many of my decisions in the future. I remember conversing with her about my plans for after high school and she gave me one piece of advice that will remain with me forever, "Education is constant, Sarita[1]. You do not need to worry about how long it will be or where you will go, everything will work out. If not now, you have your whole life to learn."

Rubi was not the only woman to influence my experience at CIP. My department was, in majority, made up of women. These women are some of the smartest and most entertaining people I will ever meet. Whether teaching me Spanish, enjoying afternoon coffee, attending Tae-Bo classes or just asking questions about research these women were always there to help. Most of them are continuing their education, writing a thesis, or in training to continue work at CIP and they were all wonderful role models of women in research that will continue to inspire and motivate my future endeavors.

While in Lima I lived with a host family. Liliam Gutarra worked at CIP in a department researching bacterial wilt on potato plants. Her husband, Daniel is a retired professor of plant physiology and their grandson, Danielito, lives with them as well. I enjoyed living with such a caring family. I must admit, I learned most of my Spanish while playing videogames with

[1] In Spanish, the ending –ita or -ito is given to show sign of affection.

Danielito and having conversations with the family at dinner. They introduced me to some of the more exotic foods and I helped them with their English. Each member of the family will hold a special place in my heart for different reasons and occasions. Going to church with Lilliam, Daniel bringing my alfajores for dessert everyday and going to movies and having popcorn with Danielito on Sundays will be some of my fondest memories. They will always be a part of my family. *Mi familia Peruano.*

Final Reflection

During my second week at CIP, my supervisor gave me some of my most treasured advice I received while in Lima. “Sometimes we cannot avoid that which we struggle with. But, in situations where the end result gives great meaning behind the little triumphs that come during the journey, success is most rewarding.” He reminded me of what my research would be accomplishing and how much of an impact on the lives of so many Peruvians it would produce. This came at the opportune time for motivating me and reminded myself of my purpose at CIP and as a Borlaug-Ruan Intern. I gave my all, working endlessly to produce a project that I was proud to call my own. During my last day at CIP and after my final presentation, my supervisor asked how I felt about my research. I told him how sad I was to leave and hand my project over to someone else and he told me what I had actually learned in Lima. I learned that to get to the big picture perseverance, determination, and dedication are needed to accomplish all the little triumphs that are on the journey to the finish.

My internship at The International Potato Center changed my life in many ways. It has nourished my love for learning and research as well as my passion for history, culture and travel. More than anything, it has reassured me of what I want to pursue in the future, helping others. I realized through my research that this can be done in so many ways, whether indirectly or hands on. In the case of my observations, my project provided background information to a team of scientists that conducted an extensive research project together as a team. This taught me how each aspect of a project come together in an intricate web to focus of one investigation. The basis of my project can be paralleled with my aspiring future; all of the small accomplishments experienced as a Borlaug-Ruan Intern and throughout my high school career are leading up to a life full of new discoveries, challenges and a life rich with helping others on a global scale.

Acknowledgements

I owe my deepest appreciation to the World Food Prize Foundation for such a remarkable experience, to Dr. Norman Borlaug for sparking my passion for food security, to Ambassador Ken Quinn and Mr. John Ruan, and of course Lisa Fleming for her constant support and encouragement. And to the people at CIP, Dr. Quiroz, Rubi Raymundo, Mariella Carbajal, Yessica Martinez, Haline Heindinger, Wendy Yactayo Gabriel, and Mercedes Suito. Words cannot express how thankful I am to have met and learned from such wonderful and influential people. Thank you for everything you have taught and shared with me. *Este gringita se aprecian las experiencias y recuerdos para siempre.*