University of Louisville
CEE 590 - 75

ISLP Peru 2025 Report - Project Qoricocha

A Sustainable Future for the Qquencco Community Through Engineering and Indigenous Knowledge

July 28th, 2025 – August 12th, 2025

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Introduction

The Andean Alliance for Sustainable Development (AASD) was founded by three graduate students in 2010 who were committed to understanding why certain agricultural projects failed in Peru. The organization focuses on enacting more responsible and sustainable forms of development in indigenous Andean communities, and has piloted “school greenhouses” that would allow such communities to grow agricultural products that would not normally be available in the climates that they live in.

Campesina Forestal, another non-government organization (NGO), works together with indigenous communities in Peru to restore degraded landscapes, enhance biodiversity, improve water management and increase economic opportunities. Both groups have partnered to provide an experiential learning service that allows student groups to come to Peru and participate in this service work while enriching themselves with deep cultural connections formed while working with these indigenous communities.

Since 2023, the University of Louisville has been working with a community in Qquencco through its International Service-Learning Program (ISLP) to address problems with soil health, water management, and overgrazing. Soil layers at high elevations are often thin and poor in quality, limiting the types of crops that can be grown. These soils are also susceptible to erosion, and this is exacerbated by excessive livestock grazing. As this soil layer loses depth, rainwater becomes difficult to retain through ground infiltration, which is already difficult due to the topography of the Andean terrain. To make matters worse, climate change has led to inconsistent precipitation patterns, accelerated glacier melting, and extreme temperature fluctuations that can kill crops. But most importantly, it has resulted in a consistent drop in the water level of Lake Qoricocha—the community's main water source.

To address these concerns, AASD and Campesina Forestal have partnered with the Qquencco community to enact Project Qoricocha. Over the course of twenty years, the project intends to plant one million trees as a 50/50 mix of Pine trees and native Queuñas. The Pine trees will be harvested to provide a sustainable source of income and building materials for the community, while the Queuñas will play a crucial role in restoring biodiversity to the region. Both types of trees will help anchor the soil to prevent losses due to erosion, as well as act as a “reservoir” to capture rainwater. To date, 20,000 trees have been planted.

Additionally, several new “eyebrow terraces” have been constructed and a new infiltration reservoir, which will aid in soil and water retention. The community is already planning to build new terraces and a reservoir using Geographic Information System (GIS) mapping performed by the university.

Project Summary

Tree Monitoring

A major portion of the afforestation project was the tagging and monitoring of recently planted trees. Trees were divided into several priority areas, but all of them are encompassed by priority area 1, as shown in figure 1 below.

Figure 1: Priority Area 1

The foreign Pines and native Queuñas perform differently based on the location and altitude they are planted in. Through a random sampling across multiple areas and elevations of the mountainside, a rough trend of tree health based on these parameters can be recorded. Given enough data collected over several years, the community can determine whether the current afforestation project is effective. This year, 71 new trees were sampled, and 32 previously tagged trees were revisited. Almost all previously tagged trees exhibited a growth in height between twenty centimeters and one meter, which is indicative of good tree health. Tables 1, 2, and 3 below show the quantitative changes in tree height, circumference, and crown spread respectively. As diameter at breast height was a calculated value and derived from circumference, it is not shown here.

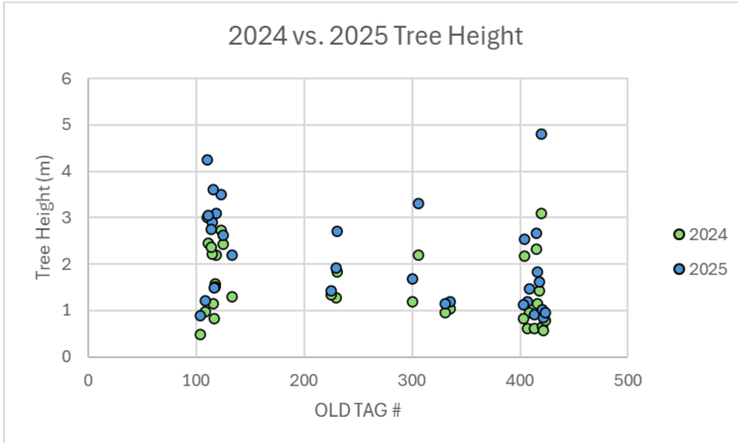


Table 1: 2024 vs. 2025 Tree Height

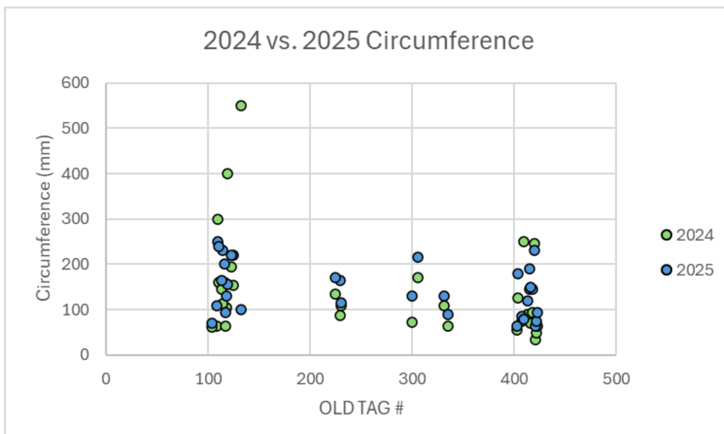


Table 2: 2024 vs. 2025 Circumference

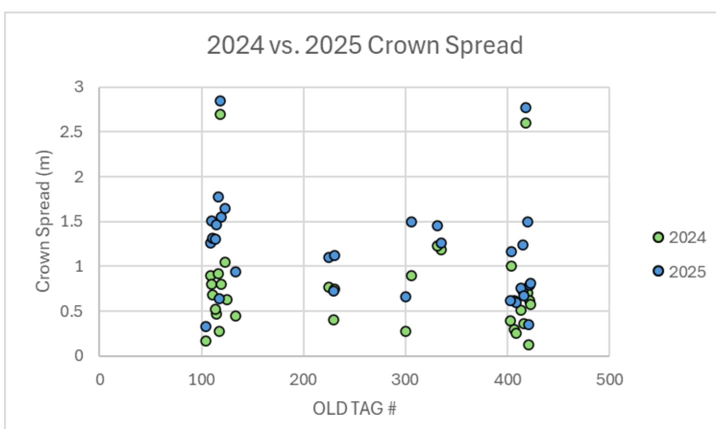


Table 3: 2024 vs. 2025 Crown Spread

Due to a severe frost that occurred last year, some Pines planted at the highest elevations were killed. Future work could involve preventative measures to protect young trees from excessively low temperatures.

Last year trees were tagged using red foam tags affixed to the tree with string. The tag number was hand scribed with sharpie. While versatile, this tagging method made it difficult to locate previously tagged trees, as exposure to the elements rendered most tags illegible. In one case, a previously tagged tree in a group near the lake had lost the branch that was used for tagging, though it was found nearby. No other trees in this group were able to be located. To avoid similar problems this year, pre-numbered bright yellow plastic tags were used. These tags should prove less susceptible to environmental effects and allow future groups to quickly locate them. Additionally, several trees tagged last year had their trunk circumference measured incorrectly. For example, one tree measured last year had a recorded trunk circumference of 550 millimeters, while the measurement taken this year was 100 millimeters. Although we do not know the exact cause for this discrepancy, we believe that in some cases crown diameter was incorrectly recorded as the trunk circumference. To avoid this problem in the future, we recommend a “tree measurement workshop” take place on campus, allowing students to familiarize themselves with the measurement process prior to working in the field. Groups of students were sent out into the priority area and using the transect sampling method to obtain higher quality tree sampling data.

Figure 2: Example of Transect Method

The Transect method used involved students travelling across a priority area while changing elevations in a zig-zag pattern. This allowed data to be collected across different areas and elevations such that data representing the wide range of the various planting areas could be collected. Using the FieldMaps app, a relatively accurate location of each tree was recorded, along with the tag number, circumference, diameter at breast height, tree height, and species.

Students were tasked with collecting three different types of data when they were sent into the field: The tree height, the circumference, and crown spread. While data collection was generally uneventful, some issues were encountered. Collecting tree height proved difficult, as several trees were much taller than the students and required creative solutions and estimations when recording the data. In addition, many trees were not tall enough for the diameter at breast height to be collected. These were issues that had to be resolved and fixed before all the data was able to be collected and processed.

Erosion Monitoring

On the first day, the entire group explored the erosion zone along the reservoir runoff. Of the two stakes embedded last year, both had washed out as the entire bank collapsed due to erosion. One stake was recovered from the bed of the river and re-driven into the bank.

On the second expedition, a group of three students and one Quechan guide went to the small canyon to check the condition of the erosion stakes set up in 2024 by the University of Louisville team. The students used ArcGIS through their mobile phones, which provided GPS data and photos of the old stakes, to find these stakes. The GPS data was accurate up to about 20 feet, so the students depended on the pictures and the knowledge of the guide to find the stakes once they were in the approximate area. All five stake locations were found, but only two stakes were still in place.

Stake #	Exposed Stake Length (mm)	Height off ground (cm)	Slope (degrees)	Precise Location
3	200	45	90	13.414218 °S 71.948255 °W
4	190	149	85	13.414150 °S 71.948227 °W

Table 3: Erosion stake location and initial lengths (2024).

Stake #	Exposed Stake Length (mm)	Height off ground (cm)	Slope (degrees)	Precise Location
3	210	45	90	13.414218 °S 71.948255 °W
4	190	150	85	13.414150 °S 71.948227 °W

Table 4: Erosion stake location and updated lengths (2025).

Ultimately, the change between 2024 and 2025 of the remaining stakes is negligible. It seems that erosion near the stakes is either very strong or next to none, since the other stakes fell out and the environment surrounding them noticeably changed.

Figure _: Before and after images of stake 5 location.

In the figure above, the location of the pictures is slightly different, but it is evident that the stake and the rock marked with the stake number had disappeared.

The problems with finding the stakes were the homogenous environment and the stakes' small profile. Much of the canyon was monochromatic and peppered with identical, dry yellow plants that made it hard to use the background of the 2024 photos as a reference. Additionally, the stakes only pointed out around two feet from the canyon wall, and the stake and canyon colors were quite similar. However, orange paint was used to mark both the stake and a landmark close to the stake to make each area easier to find.

Ironically, the prevailing problem with locating old erosion stakes was erosion. Ultimately, the team was able to find all five areas where the 2024 stakes were planted. However, only two stakes were still in place in the canyon wall. In the other three areas, the team used landmarks in the picture to confirm the areas of the stakes, but much of the soil surrounding the stakes' original location had clearly eroded. Additionally, the stakes and the landmarks marked by the 2024 group were nowhere to be found anywhere in the canyon.

Something which was helpful for finding the erosion stakes was the Quechan guide. He was the most mobile person of the entire group, showing the students how to safely traverse the canyon. The guide also found the first stake in the canyon after being provided the approximate location and a picture of the old stake. Additionally, the stakes being in the bottom of the canyon made finding and walking to them easier.

Eyebrow Terrace Implementation and Waterline Installation Placement

Eyebrow terraces are designed to slow down the runoff of stormwater to decrease soil erosion, and to promote infiltration for improved soil moisture and groundwater recharge. The eyebrow terraces in Qenqo are enhanced by downslope infiltration trenches, allowing for capture of stormwater, further improving the ability of the landscape to maintain a healthy water cycle

We assisted in the planning construction of the terrace system by mapping out contour lines so the Qquencco community would obtain optimal placement for their terraces along level terrain allowing for better water capture. The materials we used to determine the placement and the visual of the contour lines are the Bad Elf to measure precise points, the Bad Elf application to track the data, we used an iPad to capture the points on the Bad Elf software, and powder plaster to mark and label the points connecting the contour lines. The Bad Elf and the iPad were connected through Bluetooth, and they must sustain a certain range to maintain connection.

We had a total of 5 people assisting in the operation of the placement of points: Julio, a Spanish speaking community member who told us what level he wanted the terraces to be and where to start and finish each contour line; Someone to translate between English and Spanish, someone to steadily handle the Bad Elf, someone to operate the bad elf software, and someone to place the plaster point and label.

Figure: Image displaying the process of marking points for the contour lines.

We began the contour line process with Julio pointing us where to start near a boulder. We placed the Bad Elf over the point and on the iPad, we would log it as a name point, giving it an appropriate name. After we captured the point we placed plaster on the point and label it with the "p1" and the elevation that way we know the elevation of all the points without having to go back and measure previous points to recall the elevation. We repeated this process for the remaining of the contour lines.

The intention of the waterline is to carry water from the reservoir that sits at a higher elevation to a new reservoir that is soon to be built on a lower side on the mountain. For the waterline we used the same tools and similar processes to mark a point every 100 meters horizontally and one meter down. In addition to the Bad Elf, Bad Elf Application, The iPad, and the plaster; we also used a large measuring tape that was in inches and feet and was significantly shorter than 100 meters. Due to these challenges we had to convert inches into meters, and we had to measure 50 meters instead and .5 meters down. Which was 164 ft across and 1.64 down. The terrain was uneven forcing us to have a 2 feet margin of error for the horizontal distance and a .02 feet error for the vertical distance.

Reservoir

In efforts to expand the water retention capabilities of Lake Qoricocha, an additional reservoir has been constructed since the University last visited in 2024. The reservoir was constructed to increase the volume of retention water within the watershed of the lake and mitigate erosion in the infiltration ravine. This reservoir serves as an additional water supply for grazing livestock, afforestation effortss, the work lodge, and the community of Qquencco.

This reservoir reached maximum capacity sooner than expected, giving a positive outlook for reservoir expansion. A mapping flight plan was created to capture aerial imagery of the total watershed to document the new reservoir, calculate annual water collection, and possibilities of future expansion. This imagery can also be used as a comparison to previous imagery allowing future data calculations.

GPS was utilized to record spatial data of the dam and to project the location of the future dam expansion, a one-meter increase in elevation. This will help the community of Qquencco to market the idea to the Peruvian government for gaining financial and physical assistance for expansion efforts.

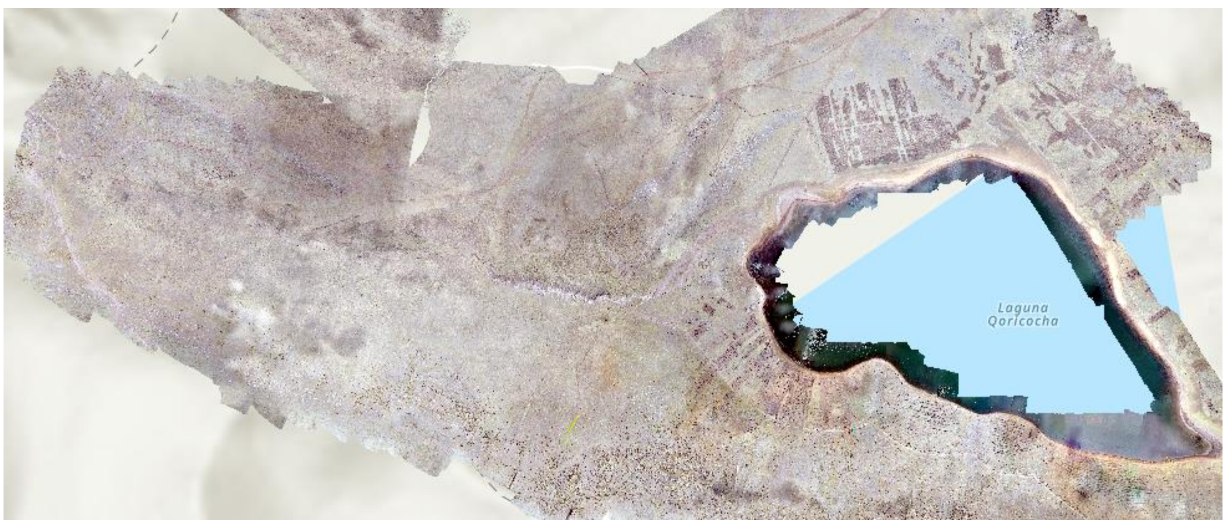
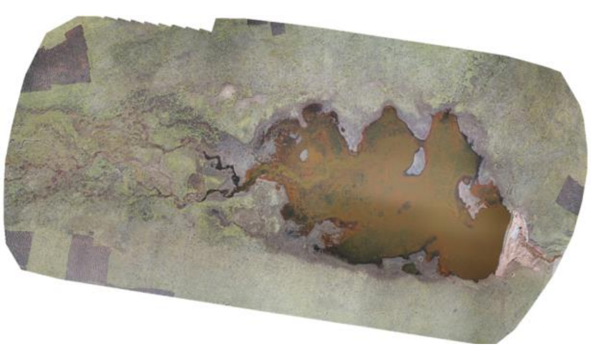


Figure _: Orthomosaic of Lake Qoricocha watershed; 2023



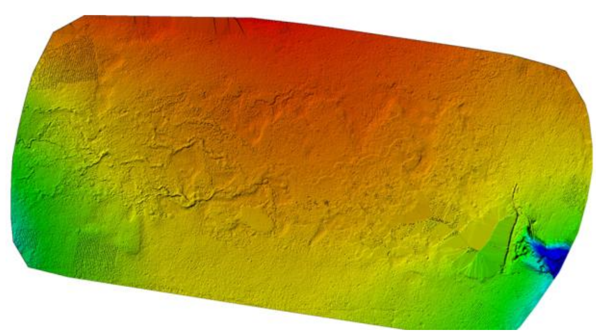


Figure _: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification; 2025.

Project	QenqoReservoir_2025
Processed	2025-08-06 12:45:01
Camera Model Name(s)	L1D-20c_10.3_5472x3648 (RGB)
Average Ground Sampling Distance (GSD)	1.43 cm / 0.56 in
Area Covered	0.073 km^2 / 7.2824 ha / 0.03 sq. mi. / 18.0045 acres
Time for Initial Processing (without report)	01h:16m:02s

Images	median of 67567 keypoints per image
Dataset	311 out of 312 images calibrated (99%), all images enabled
Camera Optimization	22.66% relative difference between initial and optimized internal camera parameters
Matching	median of 45676.6 matches per calibrated image
Georeferencing	yes, no 3D GCP

Figure _: Data summary used in creating Orthomosaic; 2025.

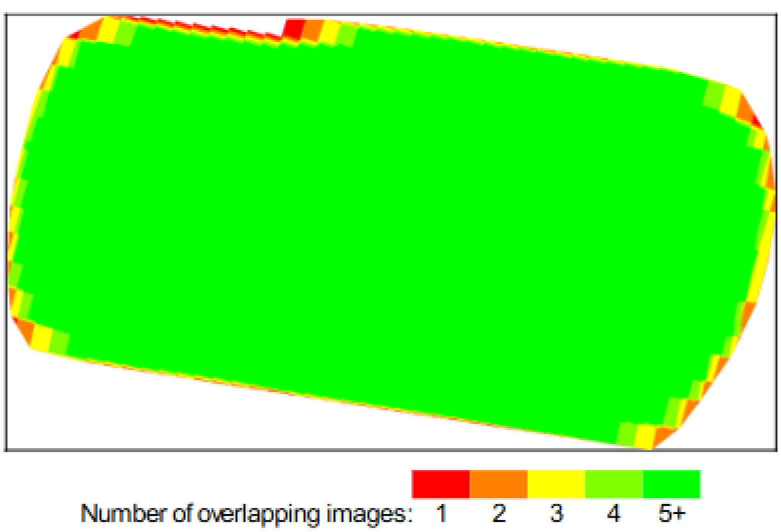


Figure _: Number of overlapping images for each pixel of the orthomosaic; 2025.

Future Work

An opportunity for meaningful future work is water shed volume estimations. This information can build a hydrological map of the area around the reservoir. The map can predict how much land can be serviced by the reservoir. The best methods rely on existing wells or drilling new holes to measure where saturation starts and where the bedrock is. Combined with core samples, an accurate estimate of the watershed volume can be made. This would require a mid-sized auger. Another technique uses a gravimeter to detect changes in gravitational force based on changes in surface density of the earth. This change can be used to estimate the amount of underground water. There is uncertainty because you could detect a change in soil composition. There is a final theoretical technique based on our aerial maps. Based on the elevation, lake volume, soil moisture, and vegetation, a series of assumptions and tables can be used to estimate the watershed. There is significant uncertainty with this technique.

Since five of seven erosion stakes were swept away, future groups should use longer erosion stakes. It is clear that there is significant erosion year to year, so to prevent the stakes from falling out, longer stakes should be adopted.

For tree tagging, time can be saved by using consistent units across all data fields. Since we measure in centimeters, convert all fields to centimeters. Also, as the number of trees grows, future groups should consider which data fields are necessary. It could be beneficial to measure more trees with fewer data points compared to more data points on less trees. For example, the crown spread is not as important since we already take aerial maps of the planting areas and can measure tree coverage. Finaly, we can map out the tagging paths beforehand.

During this trip, the community did not always follow the lines of constant elevation to build the terraces. There were big rocks in the way, so it was easier to follow other lines as opposed to getting a perfectly level terrace. The community already knew how to build terraces properly, so our high-precision instruments weren't necessary. The time working with the terraces could be better spent measuring water retention.

Project Reflection

Nothing in the classroom could have ever properly prepared us for what we were about to experience in Peru whether it be the environmental conditions, culture, language barrier, or even the food. It was a learning experience that we will all be grateful for. Throughout the summer we studied the culture of Peru to fully understand the place we were visiting. We also studied many technologies such as ArcGIS and drones so we could use these tools to help the community in their efforts for environmental sustainability.

When we arrived in Peru, we took it easy the first couple days to get acclimated to the high-altitude conditions. Therefore, when we did work up in Qquencco we would be able to handle the conditions while working. While up in Qquencco, it was incredible how tight-knit the community was. On our last workday we had the honor of working closely with the people of Qquencco to build eyebrow terraces using pickaxes and shovels. Now let me tell you it was hard work for all of us. We were all out of breath after five minutes. However, the community members were chipping away all day like it was nothing. It was incredible to watch their hard work. It was inspiring and made us all work twice as hard. We also presented our work to the community on the last day, which was an incredible experience. We want Quencco to thrive for generations to come, and we hope our work will help do that.

Throughout the trip we toured old Incan ruins, scaled mountains, and interacted with the locals to truly immerse ourselves in the Peruvian culture. Another highlight of the trip was staying with a Peruvian family in Calca. They graciously opened their homes to us offering all of us food and shelter. We all called our homestays our second family and it was just another part of the whole learning experience.

Overall, this project improved our problem-solving capabilities, presentation skills, and pushed us to our limits physically and mentally. In the summer, Adam talked about how it's a struggle for programs like this to benefit the community and the students. However, we all came together as a class and truly put our heart and souls into the project. We hope that the community benefitted as much as we did from our time in Peru. All of us will remember Peru forever and hope to be back to Qquencco soon.

APPENDIX

REVISITED TAGGED TREES										
TREE	2024					2025				
SPECIES	OLD TAG #	CIRCUMFERENCE (mm)	DIA BREAST HEIGHT	CROWN SPREAD (m)	TREE HEIGHT (M)	NEW TAG #	CIRCUMFERENCE (mm)	DIA BREAST HEIGHT	CROWN SPREAD (m)	TREE HEIGHT (m)
Nativo	109	65	N/A	0.9	0.98	44591	110	N/A	1.26	1.2
Piño	230	87	N/A	0.41	1.27	44929	165	52.55	0.73	1.92
Nativo	225	134	N/A	0.77	1.34	44925	170	N/A	1.1	1.42
Piño	231	110	35.03	0.75	1.84	44986	115	36.62	1.12	2.7
Nativo	335	64	N/A	1.19	1.04	44933	90	N/A	1.26	1.18
Piño	300	73	N/A	0.28	1.18	44932	130	41.40	0.66	1.67
Nativo	331	110	N/A	1.23	0.96	44937	130	N/A	1.45	1.14
Piño	110	300	95.54	0.8	3	44974	250	79.62	1.51	4.25
Piño	119	400	127.39	0.8	2.2	44965	155	49.36	1.55	3.1
Piño	133	550	N/A	0.45	1.3	44527	100	31.85	0.94	2.2
Piño	104	62	N/A	0.17	0.48	44528	70	N/A	0.33	0.89
Piño	407	75	N/A	0.296	0.605	44530	85	N/A	0.62	1.18
Piño	409	250	N/A	0.26	0.95		80	N/A	0.6	1.46
Piño	420	245	78.03	0.7	3.1	44977	230	73.25	1.5	4.8
Nativo	413	90	N/A	0.514	0.6	44582	120	N/A	0.76	0.91
Piño	421	35	N/A	0.125	0.645	44978	65	N/A	0.35	1.01
Nativo	403	55	N/A	0.39	0.83	44987	65	N/A	0.62	1.13
Nativo	422	50	N/A	0.62	0.56	44981	75	N/A	0.79	0.85
Nativo	423	64	N/A	0.58	0.775	44982	95	N/A	0.81	0.95
Piño	125	153	48.73	0.63	2.44	44955	220	70.06		2.63
Nativo	418	95	N/A	2.6	1.43	44952	145	46.18	2.77	1.62
Piño	306	170	54.14	0.9	2.2	44958	215	68.47	1.5	3.3
Piño	123	195	62.10	1.05	2.73	44956	220	70.06	1.65	3.5
Piño	118	105	33.44	2.7	1.58	44957	130	N/A	2.85	1.5
Piño	116	160	N/A	0.92	1.15	44942	200	63.69	1.77	3.6
Piño	117	65	N/A	0.28	0.825	44951	95	N/A	0.64	1.48
Piño	115	113	35.99	0.47	2.21	44967	230	73.25	1.47	2.9
Piño	111	160	50.96	0.68	2.46	44923	240	76.43	1.31	3.05
Piño	114	145	46.18	0.52	2.36	44941	165	52.55	1.3	2.75
Piño	416	70	N/A	0.36	1.14	44989	150	47.77	0.67	1.82
Piño	415	145	46.18	0.73	2.32	44953	190	60.51	1.24	2.67
Piño	404	125	39.81	1	2.17	44954	180	57.32	1.16	2.53