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### Inca Agricultural Systems

Throughout history there have been different technological and scientific advancements that have a huge impact on the present. When looking at the different ancient civilizations it is fascinating to learn about all of the different systems and scientific achievements that were made. One specific civilization that was very established and prosperous was the Inca empire. The Inca empire was massive with the different systems ranging from their widespread agricultural and road systems to their centralized religion. This empire has a dense history and first appeared in 12th century A.D. in what is presently known as southeastern Peru (history.com, 2018). Throughout time they expanded their land under different rulers where the empire reached a peak in the 15th century under the rule of Inca Yupanqui. The capital of the empire Cusco was where different cultural and scientific advancements took place. At its peak the empire consisted of over 12 million inhabitants which is why the well established societal system was important. There was a unique culture and established religion and although there was no written language a quipu knot system was established to keep records. The emperor Inca Yupanqui expanded the fortress around the city and started the massive irrigation system around the city which was then channeled to establish the detailed agricultural terraces. When the Spanish conquered the empire in the 1500s a lot of the agricultural knowledge was lost and the advanced systems were abandoned. It wasn't until recent history where different archaeologists were able to study the empire and fully understand the advanced agricultural techniques of the Inca empire.

As mentioned before the Inca empire was massive and covered a large amount of land throughout southern america. The empire specifically was located in the Andes mountains which has a harsh and diverse climate. The Andes mountains is the longest mountain range in the world at 4500 miles long and also includes some of the tallest mountains (livesscience.com, 2013). The massive length of the mountain range and its geographical location near the Pacific ocean creates a very diverse climate that varies off of different factors such as altitude and latitude. There are many different eco climatic conditions in the high altitude of the Peruvian Andes that are different from the environmental conditions at sea level. To fully understand the climatic diversity in the Andes mountains it is compared to the 104 different ecological life zones established in Holdridge's "Life Zone" classification of the different ecoclimatic systems. Tosi describes, "Thus Peru, with only 0.86% of the world's land area counts with 80% of its zones, has by far the greatest ecoclimatic diversity per unit area of any country in the world" (1978). When looking at the diverse region of the Andes it is important to look at and consider the different factors that impact the fertility of a landscape. These factors include altitude, air humidity, temperature ranges, solar radiation gradients are all important factors in the success of the Inca agricultural systems.

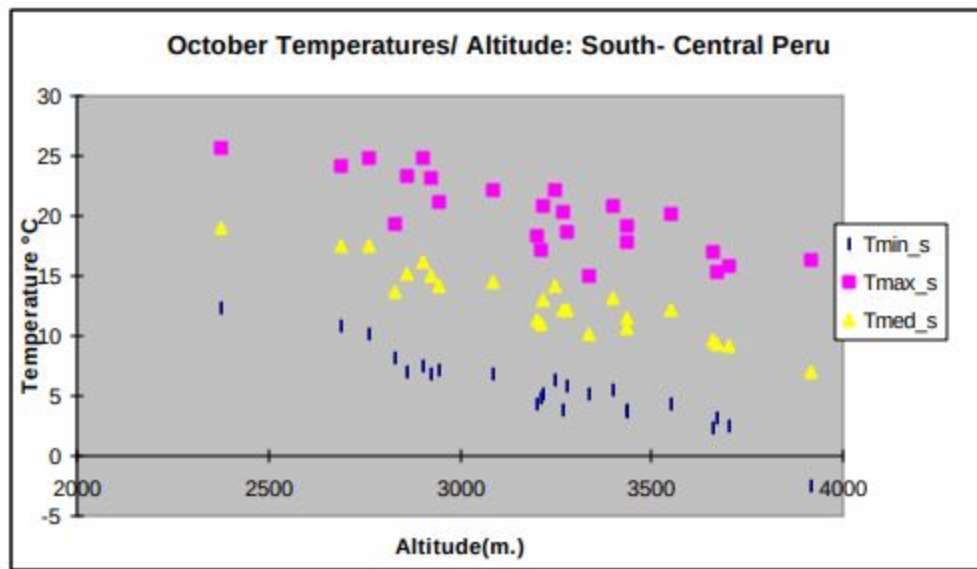


Figure 1: Earls, John. "The character of Inca and Andean agriculture."

According to a research paper by John Earls the air temperature gradient in south central Andes of Peru will drop off by 6.4 degrees celsius per km altitude during a dry planting season and even more during the wetter months of the year. In figure 1 is a representation of the mean temperatures over a twenty year period in the month of October for twenty four different stations located in the inter Andes. The figure represents the correlation between temperature and altitude. The relationship between altitude and temperature is well researched because it is important to understand why the temperature lowers at higher altitudes. The higher and farther away from the surface of the Earth the thinner the atmosphere becomes therefore it gets cooler because there is less matter and heat present (scientificamerican.com, 2003). At higher altitudes there is more of a variability in climate compared to lower altitudes. Also at higher altitudes there is a lower atmospheric temperature and water vapor density than at sea level. Rudolf Geiger discusses how the ground temperature has a much bigger impact on plant growth than the air temperature. Geriger states "In high mountains with their low temperatures, the plant world can thrive only close to the ground, and the amount by which the ground temperature exceeds the air temperature increases with altitude." At higher altitudes because of the colder air temperatures the ground temperature was more important and had a greater effect on plant cultivation than most of the other factors. The different challenges with the climate made agriculture more difficult in the Andes mountains but also the overall terrain of the mountains. The terrain of these mountains included 9,800 feet in elevation with steep slopes and a variety of rocky plateaus making it extremely difficult to navigate (livesscience.com, 2013). Throughout the many years of the Inca empire they had to adapt therefore they had to create an agricultural system that would work for the harsh terrain and climate of the Andes mountains.

There were many challenges for the Inca empire living in the Andes specifically when it came to farming. The steep and harsh slopes of the Andes mountains made it difficult to find fertile land for agriculture. The mountains were so steep that it was nearly impossible for the Inca people to navigate also because of the steep terrain it was hard to find fertile soil for the plants to prosper. Another challenge with the Andes is controlling the water to go to all the different places in the empire. The entire Inca empire spread out over thousands of miles so being able to have access to water in the towns and in the fields was important for their survival. To compensate for this problem the Incas developed a system of agriculture that would allow them to navigate the steep slopes and farm at high altitudes. This system is called terrace farming where in the hillside they would build walls and fill them with soil to make terraces (westada.org). These terraces would be cut into the hillside and progressively work up from the valleys all the way up the mountain slopes. Alongside the terraces there would also be irrigation canals that would provide water for the different crops that they were growing. There are many different benefits from the terrace system such as it would increase the amount of land that would be used for growing crops compared to the valley. Also the terrace system allowed plants to be exposed to more light because they were growing on the hillside compared to in the valley where there was little light because the high mountains would block the sunlight. Another benefit from building the terrace system was that it would prevent topsoil from washing away down the slopes when it would rain and creating a more secure environment for the plants to grow. There are parts of the Inca empire that are still remaining today which is helpful to scientists and engineers to learn more about how they were able to build this advanced agricultural system. When looking specifically at how the terrace system was created there is a process to making them. One of the first steps in building these terraces was building the stone retaining walls. These walls would be what separated each of the terraces. The walls played an important role in making sure the crops survived, because during the day these massive stone walls would retain and capture the heat from the sun. Then at night when the temperature would drop drastically these walls would release the heat back out which would prevent the crops from freezing. (web.stanford.edu). After the terrace was constructed it was then filled with a combination of different soils and materials that would make the plant growth on those terraces the most productive. Usually these terraces would first be built with medium size gravel near the bottom which would then be topped with a more fine sand and a mixture of more gravel. One of the important steps to help the plants grow would be the addition of topsoil which the farmers would place that would help the seeds of their primary crops would flourish (science.howstuffworks.com). The use of different layers in the terraces combined with the irrigation system also prevented erosion from happening on the hillsides. Another helpful aspect of the terraces was because the stone walls would be very tall there would be steps built in along the walls therefore the farmers would be able to move up the terraces. In figure two there is a diagram showing the process as to how the terrace system was built. In the diagram it shows how the terraces would be cut into the hillside and then large stone walls would be built to support the

terrace structure. Then they would fill in with different gravels and sand to also help secure the terrace. The farmers would then finish it off by adding a nutrient dense topsoil that would help the terraces prosper.

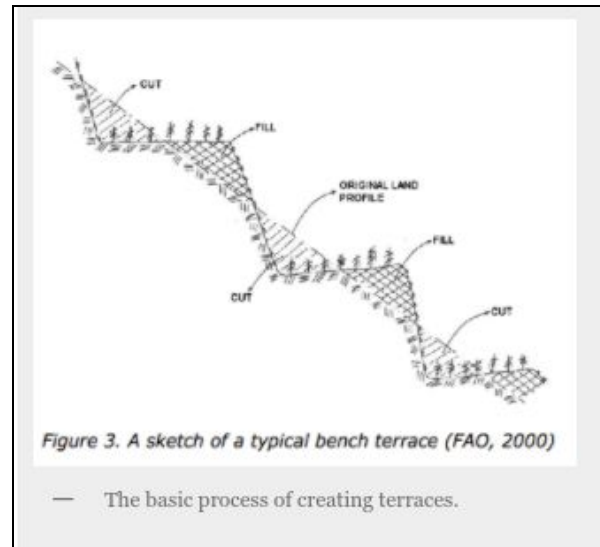


Figure 2: <https://pages.vassar.edu/>

As you can see there was definitely a lot of work that had to be done in order to create this terrace system but ultimately it was worth it because the Inca empire had one of the most advanced agricultural systems at that time in the world. The Inca had many technological and engineering advancements for that time period. They were able to build a vast empire that covered a lot of terrain and their agricultural system was advanced because of the terrace system but another important factor that helped the empire flourish was their irrigation system. The empire covered so much land therefore it was important that they had an irrigation system set up that would be able to reach all parts of the empire. Just like the terraces Pachacuti Inca Yupanqui led the way on creating an irrigation system consistent with aqueducts and canals to provide water to the empire. In order to get the water for the empire they would first have to find a water source that would work based off of their location. They would oftentimes first find their water source such as a river or fresh water springs and then build their city based off of the water location. Ken Wright who is a hydrologist and civil engineer in an interview with PBS discusses the irrigation system at Machu Picchu. In the interview he states, “The location of the spring was fixed, and the Inca engineers figured out the slope of the canal and set it at an average of about three percent, and the length was fixed at about 2,500 feet. These things were determined by nature and by hydraulics” (Wright, 2009). Once they found a water source they would then create the canal system with the help of gravity and other engineering techniques. They would build these canals that would go down the slopes of the mountain past the agricultural terraces and into the urban center where it would disperse among a series of different fountains. Another important aspect of the irrigation system was creating an efficient drainage system which is

where the terraces were also very useful. The terrace structure was also constructed with efficient drainage in mind to combat the problem of erosion. As mentioned before the soil was layered with stones at the bottom, sand and gravel in the middle, then a layer of topsoil which created an efficient structure for drainage. Another aspect of the terraces that helped with drainage was the slope of the terraces directing the water to a series of drainage channels that would then go through the city. Then the force of gravity would continue the runoff water from the agricultural and urban areas away from the city (waterhistory.org). In figure three shows the canals that would run alongside the terraces down the slope of the mountain. It is interesting to point out that a lot of the structures that still remain in present day show that the way they were constructed the first time included all of these benefits. It shows that the Incas thoroughly thought out and planned their city with organization in mind while building these technological structures and that everything is connected.

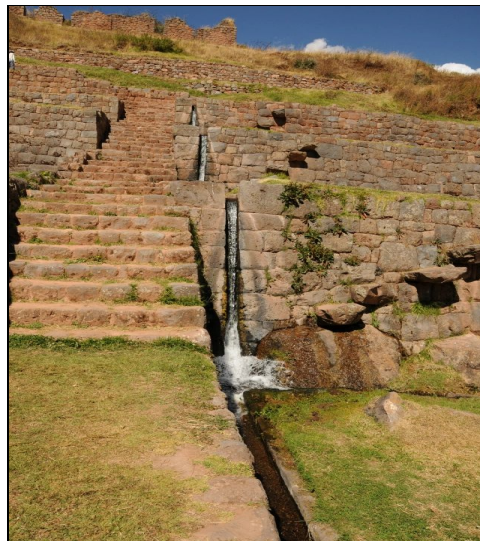


Figure 3: [www.waterhistory.org](http://www.waterhistory.org)

After analyzing the different structures and systems that the Inca empire was able to build it is very obvious that they were a well functioning society. They had a lot of knowledge and the ability to build great cities and engineer different structures that helped support the society. Being able to build the terrace agriculture structures and combine that with their well functioning irrigation system made food production very efficient for them especially based off of the environment they were living in. The next piece of the puzzle to figure out now that they have the structures in place to support their food production is how did they know what plants would survive at such high altitudes in such harsh terrain. Some of the staple crops cultivated throughout the Inca empire include maize, beans, potatoes, quinoa, and squash (ancient.eu, 2015). Other crops that were cultivated based on the season and climate include tomatoes, avocados, and peanuts. The Inca farmers were intelligent and ambitious; they understood how to



Some other researchers believe that it was more of an exact process such as what is being shown in Figure four. This figure depicts these circular terraces that are found in the city of Moray outside of Cuzco. As you can see in the image the terraces look like giant bowls and there are staircases on the side of the stone walls that build the terraces so people can walk from the bottom to the top. The design of these terraces is very unique because it creates an interesting environment for different crops to grow in. An interesting fact about these circular terraces is that the bottom circle never floods no matter how much rainwater is captured (interestingengineering.com, 2016). It is said that because of the drainage system set up underground with very porous rocks that is the reason why it never floods. Another interesting fact about this circular terrace system is that there is about a 15 degree celsius temperature difference between the bottom circular terraces and the upper circular terraces. This drastic temperature change in these terraces creates two very different environments at the bottom and at the top. A lot of researchers believe that these circular terraces were used by Inca scientists to test different crops at different altitudes and temperatures to determine what climate a crop survives in best. Then once the best altitude was determined that kind of crop would be grown at that certain altitude and climate throughout the Inca empire. This system was also used to assimilate crops to different altitudes, “As they conquered the different countries and regions, they brought back different fruits and vegetables which grew at different altitudes and in different climates. For these to slowly adapt to their local climate, they would then plant them in the center, i.e., in the lowest and warmest level. Little by little they would move them up a level, and another, and another until the plant was thus completely adapted to its new environment” (interestingengineering.com, 2016). By establishing different temperatures at each terrace they were able to control what the temperature and altitude would be making it easier to test crops at different terraces. Overall the Inca terrace system was very advanced and useful to help provide food throughout the entire empire. Unfortunately the Inca empire fell around 1572 when the Spanish came and conquered the people. The main reason why the empire collapsed is because a lot of the people were wiped out by the introduction of smallpox from the Spanish (livescience.com, 2018). Luckily a lot of these places were constructed so well and throughout that a lot of the ruins still remain intact today. Many scientists still study the Inca agricultural techniques such as archaeologist Ann Kendall who has been studying the Cusco region in Peru in hopes of being able to use and bring back some of these ancient agricultural practices (smithsonianmag.com, 2011). The different advanced technologies and structures is what makes the Inca empire stand out in history and why they still have an important impact on the world today.

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