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Moving Monoliths: Easter Island and Environmental Collapse

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The Rapa Nui civilization once thrived on Easter Island, and produced unique statues which became a parable for collapse around the world (Hunt and Lipo, 2011). Several experiments have been conducted to better understand this collapse, specifically surrounding the movement of the islands' largest inhabitants, the *moai* – the large monolithic human figures carved by the Rapa Nui people. Many people surmise that the ultimate downfall of Easter Island is attributed to the movement of the *moai*. Some even believed that the natives placed the creation and movement of these statues above their need to survive.

The following research focused on the environmental impact of moving the *moai* on the island. It has been hypothesised by a variety of scholars, including Jo Anne Van Tilburg and Charles Love (Kamrani, 2012), that these multi-ton stone statues were moved horizontally using palm rollers or sleds. Hunt and Lipo (2011) challenged this idea, arguing that the statues were moved in an upright/vertical position. This follows the narrative that the native Rapa Nui people tell – that the statues "walked" to where they are today. In either scenario, the production and movement of these monoliths would have had an impact on the environment. The goal of this academic research was to decipher the severity of environmental deterioration directly caused by the movement of *moai* in the upright position using ropes.

> “ Working under Hunt and Lipo’s hypothesis that ropes were used to move these monoliths, it was necessary to construct a variety of cordage to understand the environmental impact of this process. To move statues of this magnitude, extremely robust cordage would be necessary. However, there is insufficient remaining cordage from the excavations on the island to determine if a specific technique was implemented.

Background

People first arrived to the island approximately AD 1200, and environmental changes began to occur soon after (Hunt and Lipo, 2011). Island culture consisted of boat houses and lithic gardens scattered across the landscape, but no actual cultural centre was established by the first settlers. They brought critical plants to Polynesian life including taro, breadfruit, coconut, yams, bananas, sugarcane, chickens, and small Polynesian rats (Hunt and Lipo, 2011). After some time, a complex hierarchical chiefdom arose under Hotu Matu’a. This chiefdom had a centralised religion that focused on ancestral worship. As religious and political pressure mounted, the production of *moai* increased (Hunt and Lipo, 2011). Production escalated and statues continued to increase in size. Meanwhile, resources were being collected at an abounding rate. This led to an upsurge in the loss of flora in order to move the statues and sustain hundreds of workers (Hunt and Lipo, 2011). Consequently, as *moai* production increased, so did population and political tension. It is believed that the rapid population growth was the ultimate cause of collapse; the island had exceeded its carrying capacity (Hunt and Lipo, 2011).

Once resources became diminished, *moai* production halted. Statues remained in transport and unfinished at the quarry, where several remain today. Civil war ensued as the population divided into two groups, long and short ears, each faction toppling the statues of the other tribe. The war continued until the last tree was cut (Hunt and Lipo, 2011).

In an attempt to understand these circumstances, scientists from around the world traveled and conducted experiments to determine how the Rapa Nui people made and transported these colossal pieces. In 1919, Katherine Routledge proposed, and then retracted, that the statues were moved upright (Van Tilburg, 1996). In 1955, Thor Heyerdahl set a ten-ton *moai* on a tree trunk to be dragged (Kamrani, 2012); later in 1970 William Mulloy attempted to swing the *moai* forward in steps using an inverted wooden 'V' to hang the statues neck from (Kamrani, 2012). Moving forward to 1986, Pavel Pavel along with Thor Heyerdahl walked a real statue with the assistance of volunteers (Kamrani, 2012). This resulted in damage to the *moai* (Kamrani, 2012). The following year, Charles Love conducted a successful trial using a wooden sledge and rollers, moving the replica 45 meters (Kamrani, 2012). In 1998, using a Polynesian wood ladder and a replica sledge, Jo Anne Van Tilburg and her team successfully moved a *moai* 70 meters (Kamrani, 2012). While some success was found, these experiments lacked a crucial point of view, that of the islanders. The Rapa Nui people have always stated that the statues walked. Taking this into consideration, in 2011 Terry Hunt and Carl Lipo proposed and executed the theory of the statues being walked upright with ropes creating a rocking motion (Kamrani, 2012). Three ropes, three teams of assistants, working in synchronization to move these monoliths.

The Experiment

Working under Hunt and Lipo's hypothesis that ropes were used to move these monoliths, it was necessary to construct a variety of cordage to understand the environmental impact of this process. To move statues of this magnitude, extremely robust cordage would be necessary. However, there is insufficient remaining cordage from the excavations on the island to determine if a specific technique was implemented.

Before construction could begin, the resources had to be acquired. Without access to materials that existed on Rapa Nui a substitute was determined. Through examination of pollen charts dating to the height of construction and movement of the *moai* (Flenley, 1993), a fibre source was chosen. While a variety of sources were present on the island at this time, *Thespesia populnea* was chosen because of its bast fibres (Orliac, 2000). These fibres are ideal for rope production and therefore would have likely been selected for use. *Tilia americana* is abundant in North-eastern America and was the substitute chosen to carry out this experiment. With the assistance of a farmer in Huevelton, New York and three volunteers, two trees were felled and stripped clean of their bark.

To harvest the inner bark, which possesses the bast fibres, linear cuts were made along the tree using a small knife and wooden barking spuds were used to separate the junction between the bark and phloem (See Figure 1). This layer peeled off effortlessly, creating a smooth, uniform surface. To ensure enough material was harvested, two trees were stripped completely, with an average height of 23.5 meters and 21.75 centimetre base diameter. Once this was done, the removed bark was tied into two bundles and transported to Potsdam, New

York. It was immediately submerged in the Raquette River, weighed down with cinder blocks, and left to soak for 38 days (See Figure 2). The time for this process may vary; although the longer it soaks the easier it becomes to work with the fibres (Whitcombe, 2004). This process, known as retting, is the rotting away of the cellular tissues and pectins that hold the inner and outer bark together (Roberts, 2007). Once this material breaks down, the inner bark can be easily separated from the outer bark, which is then disposed. Retting is not a process required for the use of all fibres. Depending on the type of material used to produce cordage on Easter Island, the Rapa Nui people may or may not have used the retting technique.

After the soaking period ended, the bundles were pulled from the river and the process of cleaning and separating the inner fibres began. This produced approximately 6,000 grams of fibre. The sheets of fibres were then laid outside to dry in the direct sun (See Figure 3).

Using a truncated cone formula, the amount of material each tree provided by volume was calculated and the weight of each tree before construction was averaged. This was done to ensure not only that each rope was made using the same amount of material, but also to understand exactly how much material each tree contributed to the total of 6,000 grams. The first rope constructed was a common two-ply type seen globally and over the course of centuries, but more specifically in the Pacific Northwest, where cedar is abundant (Stewart, 1995). In addition, the Māori in New Zealand implemented this technique, connecting this method with a Polynesian island. A variety of cordage has been found in caves and rock-shelters in Aotearoa, New Zealand (Mckendry, 2017).

The second type is based on a composite technique, which consists of twisting several individual ropes into a larger cable. This is the method used to build the Q'eswachaka Bridge in Peru (See Figure 4), a bridge that has been rebuilt annually for the past 500 years (Stone, Leahy and Rossi, 2015). The common two-ply approach was chosen due to its abundant use cross-culturally whereas, the composite technique was used due to its resilience and its regional geographical proximity to Easter Island.

The two-ply rope segment was constructed first. With the assistance of one other person to keep the mass amount of fibres separate, a rope approximately 4 meters in length was constructed (See Figures 5 and 6). This method requires splicing, as fibres taper off and become thin new fibre is added. This can create weak points in the rope.

The composite rope was next constructed. Ten thin ropes were initially built using the two-ply method with the same amount of material as rope one (1,200 grams). With the assistance of four volunteers the ten ropes were twisted together into a large cable (See Figures 7 and 8). This segment was approximately 2.5 meters in length. The discrepancy in length can be attributed to the differences in the techniques used.

Analysis and Findings

The goal of this research was to determine the extent of environmental deterioration caused by rope construction to move the *moai*. The ropes built in the experiment acted as a swatch that was mathematically scaled-up to determine the amount of rope necessary.

Calculations were compiled from each *moai* requiring three ropes of approximately 30.5 meters (100 feet) in length to move. As illustrated in Figure 9, once projected on a large scale, the composite rope would require significantly more material to construct enough cordage to move the *moai* on Easter Island. Ultimately, this results in the loss of more trees. Approximately 9 trees or 9,200 grams of fibre are required to construct three ropes approximately 30.5 meters long using the two-ply method. For the same amount of cordage, using the composite technique, it would require approximately 15.6 trees or 15,947 grams of material. The length of 30.5 meters is an estimate based on the necessary clearance for the statue if it were to fall, and individuals to hold the ropes. Calculations can continue to be made adjusting to an increasing or decreasing length for each rope.

With these calculations made, the environmental impact (i.e, the quantity of felled trees required) of rope production could be determined. To do this, the vegetation on Easter Island was examined. Pollen charts show the changes in vegetation through time. The island experienced long-term changes (See Figure 10), where the flora remained relatively stable throughout the Holocene but then there was a dramatic change coinciding with the arrival of humans (blue box, Figure 10). The column on the far right shows the changes in levels of trees and shrubs against the changes in levels of herbs and ferns. The dramatic increase in herbs and ferns occurs once the loss of trees and shrubs begins (Flenley, 1993). To fully understand the deforestation, a timeline of events was added to the pollen chart (See Figure 11). There was a dramatic decrease in *Palmae* and increase in *Graminae* (now known as *Poacea*). This indicates that the canopy was being opened up and removed (through felling of trees) and grasses grew in their place. In addition to *moai* construction and movement, several anthropogenic alterations were being made, including the use of slash and burn agriculture and the construction of shelter and watercraft (Hunt and Lipo, 2011). While slashing and burning the scant resources they had seems foolish to us, it was in an effort to produce more fertile farmland. If the Rapa Nui people were in fact using grasses for cordage production, this method would have destroyed precious material. However, grasses have a rather quick regeneration rate, reoccurring annually. On the contrary, if trees were the source then the regeneration rate is much slower (Folk, 2017).

Discussion & Conclusion

This data was evaluated to determine the environmental impact of the movement of the *moai* on Easter Island. While cordage can be used to aid the movement of extremely heavy objects, a study into the tensile strength and durability of the cordage manufactured for this experiment is required. Providing a rationale for these yet to be determined factors, in order to determine the greatest levels of loss of trees, the final calculation was made based on the production of three new ropes for each statue whether they were transported or not. Accounting for the 961 *moai* on Easter Island and the production of 2,883 ropes (measuring approximately 30.5 meters) to aid in the movement of these monoliths, a loss of 14,992 trees would be necessary for the production of sufficient cordage. This loss is based on the composite technique, as it requires more fibrous material and produces a more substantial rope. It should be noted that many of the ropes might have been reused. Without a study on tensile strength it is undetermined what the weight limit is for these ropes, breakage through transport is possible. If the cordage was in fact reused, even less raw material would be harvested, resulting in a smaller ecological footprint caused by the movement of the *moai*. In addition, the Rapa Nui people may have chosen the two-ply method. In this case, only 8,649 trees would be felled in order to produce sufficient cordage.

This information evaluated in conjunction with the aforementioned pollen chart shows that deforestation as a result of rope production alone would have been highly unlikely. Easter Island was once populated by approximately 16 million palm trees (Bork and Mieth, 2003), thus with the production of ropes in order to move the *moai*, only 0.09% of the canopy would be required for harvesting. This is clearly illustrated in figure 13 whereby the minimal loss is shown along with 70% of the island afforested by 16 million palm trees.

There are several additional factors that must be considered when examining this case. There was a great deal of tension between the tribes on the island. As religious and political pressures mounted, the production of *moai* increased (Hunt and Lipo, 2011). Production escalated, and the monolith statues continued to increase in size. Meanwhile, resources were being collected at an abounding rate. This led to an upsurge in the loss of flora to move the statues and sustain hundreds of workers (Hunt and Lipo, 2011). Slash and burn agriculture would have been an incredibly important farming technique, providing nutrients for the soils, but it would have depleted the forest. Canoes would have also played a critical role in everyday life. The surrounding ocean provided abundant sources of protein and other nutrients. Once the trees were gone, canoes were no longer built and the ocean's bounty became less accessible. Further, the island itself is geologically young. Easter Island was formed less than one million years ago by three seafloor volcanoes (Hunt and Lipo, 2011). This implies that the soils are relatively shallow and do not have the rich nutrients that the older landforms do. For this reason, it is challenging to farm on the island due to the paucity of a fertile soil layer. The Rapa Nui people used a variety of techniques to combat this, including lithic mulching: a method that covered the soil with mineral rich rocks (Hunt and Lipo, 2011). The minerals seep out and provide nutrients for plants such as banana and taro.

Agriculture necessitates deforestation. The large palms that once populated the landscape have an extremely slow regeneration rate, as it takes nearly one hundred years to reach their full height and several decades to produce seed-bearing fruit. Further, the introduction of the Polynesian rat meant that the seeds dropped by these massive trees were consumed and the trees were unable to regenerate (Hunt and Lipo, 2011). These facts, in conjunction with the data generated throughout this experiment, demonstrate that the removal of vegetation was not done solely to transport the monoliths (Folk, 2017).

Though this technology relied on cutting the forest trees for raw materials, this research highlights the fact that complex processes, such as ecological change, rarely result from singular causes, they are in fact multifaceted. Instead, this work illuminates the importance of examining the intersections between broader social and cultural dynamics and environmental change. Today, Easter Island remains an example of how internal conflict, both social and political, contributed to the destruction of a society (Folk, 2017).

Keywords bark
rope
megalith
ancient technology

Country Easter Island

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Gallery Image

FIG 1. MAUREEN FOLK USES HOMEMADE WOODEN BARKING SPUDS TO SEPARATE THE INNER AND OUTER BARK FROM ONE FELLED BASSWOOD TREE.

FIG 2. DR. TIMOTHY MESSNER SUBMERGES BARK BUNDLES INTO THE RAQUETTE RIVER TO SOAK FOR SEVERAL WEEKS.

FIG 3. SHEETS OF BASSWOOD FIBRE SPREAD OUT TO DRY BEFORE THEY CAN BE TWISTED INTO ROPE.

FIG 4. THE Q'ESWACHAKA BRIDGE IN PERU, HAND WOVEN ANNUALLY BY THE NEIGHBORING VILLAGERS.
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FIG 5. MAUREEN FOLK AND ASSISTANT, STANLY MERRITT, PRODUCE THE TWO-PLY ROPE.

FIG 6. THE COMPLETED TWO-PLY ROPE WITH SCALE.

FIG 7. VOLUNTEERS STANLEY MERRITT, TRAVIS HANSON, RACHAEL HOWARD, AND JOANNA HOLDEN ASSIST IN BUILDING THE COMPOSITE ROPE.

FIG 8. THE COMPLETED COMPOSITE ROPE WITH SCALE.

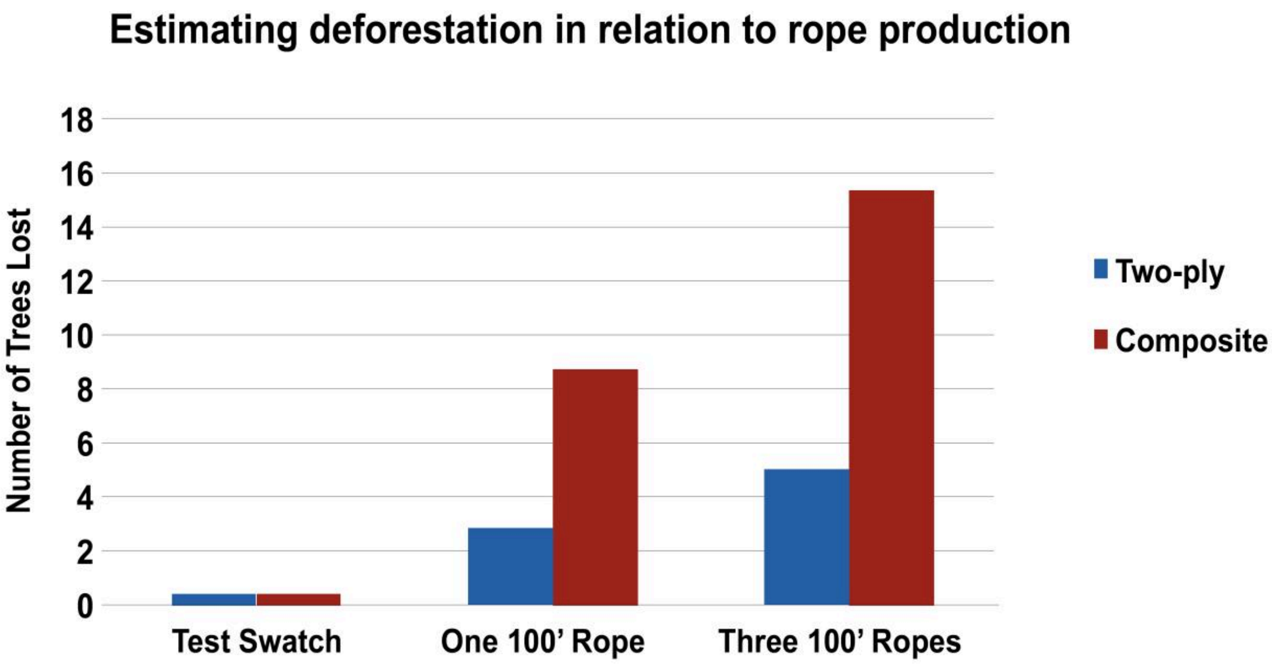
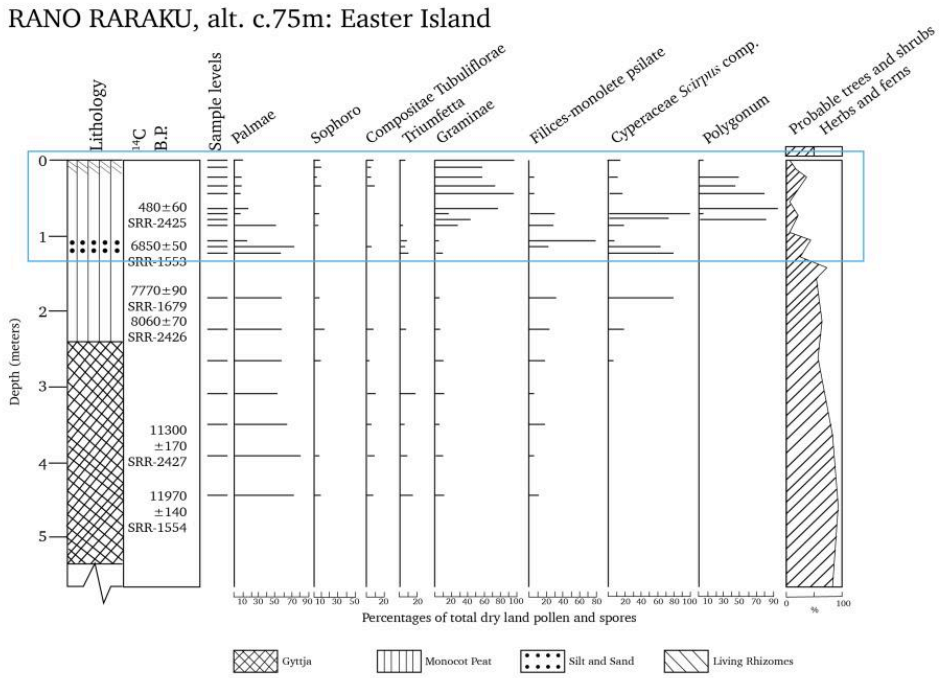
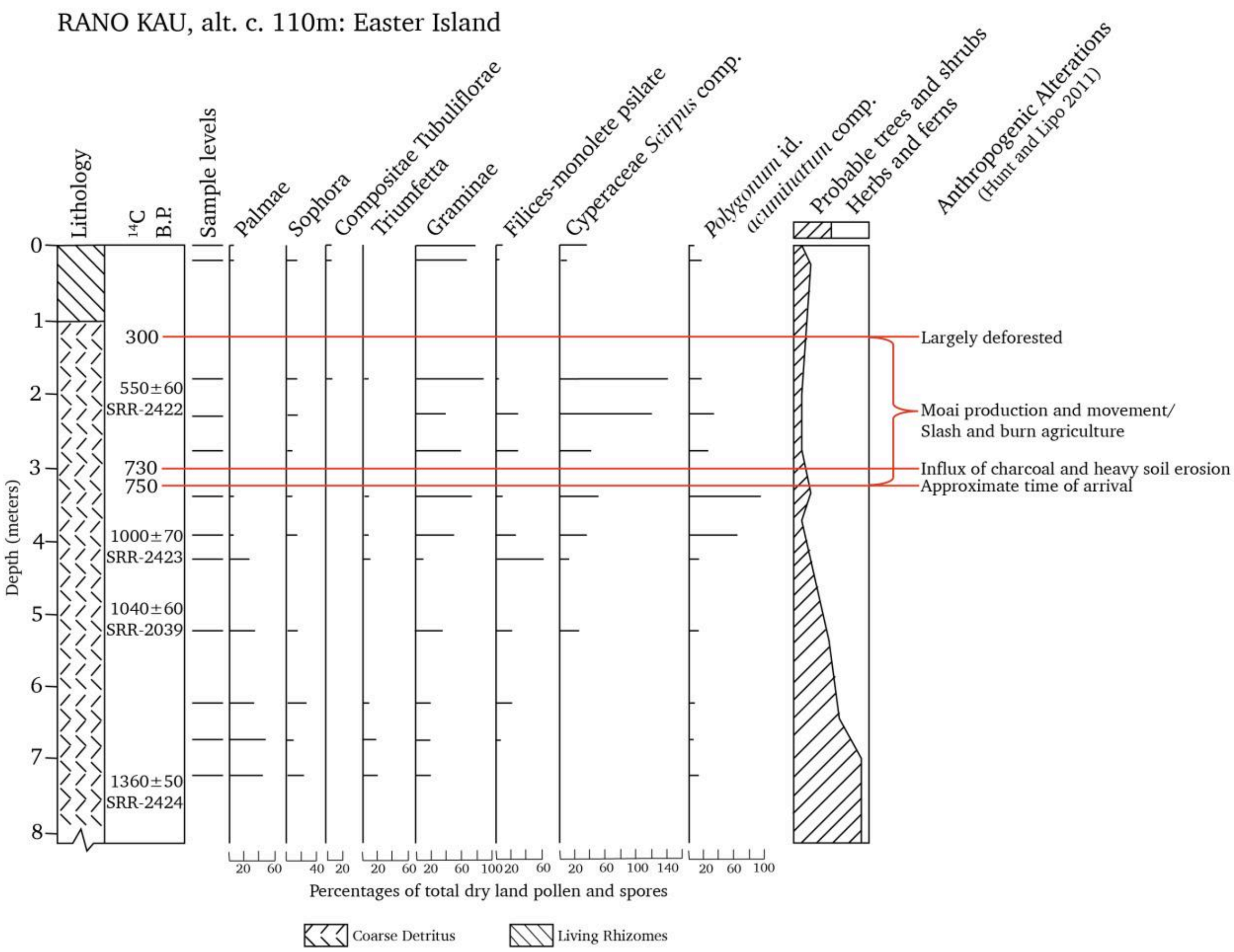


FIG 9. THE CHART DEMONSTRATES THE NUMBER OF TREES NECESSARY TO PRODUCE SUFFICIENT CORDAGE TO MOVE ONE MOAI FOR THE TWO-PLY AND COMPOSITE TECHNIQUES.



Pollen diagram for core RRA 3. Values are percentages of total dry land pollen and spores. Only selected taxa shown. (Modified after Flenley et al. 1991)

FIG 10. RECONSTRUCTED POLLEN CHART BASED ON THE WORK OF JOHN FLENLEY (1993), THE BLUE BOX HIGHLIGHTS THE RAPID LOSS OF TREES.



Pollen diagram for core KAU 1. Values are percentages of total dry land pollen and spores. (Modified after Flenley et al. 1991)

FIG 11. RECONSTRUCTED POLLEN CHART BASED ON THE WORK OF JOHN FLENLEY (1993), IT IS OVERLAIN WITH A TIMELINE TO HIGHLIGHT THE FLORAL CHANGES THAT COINCIDE WITH HUMAN ACTIVITY.

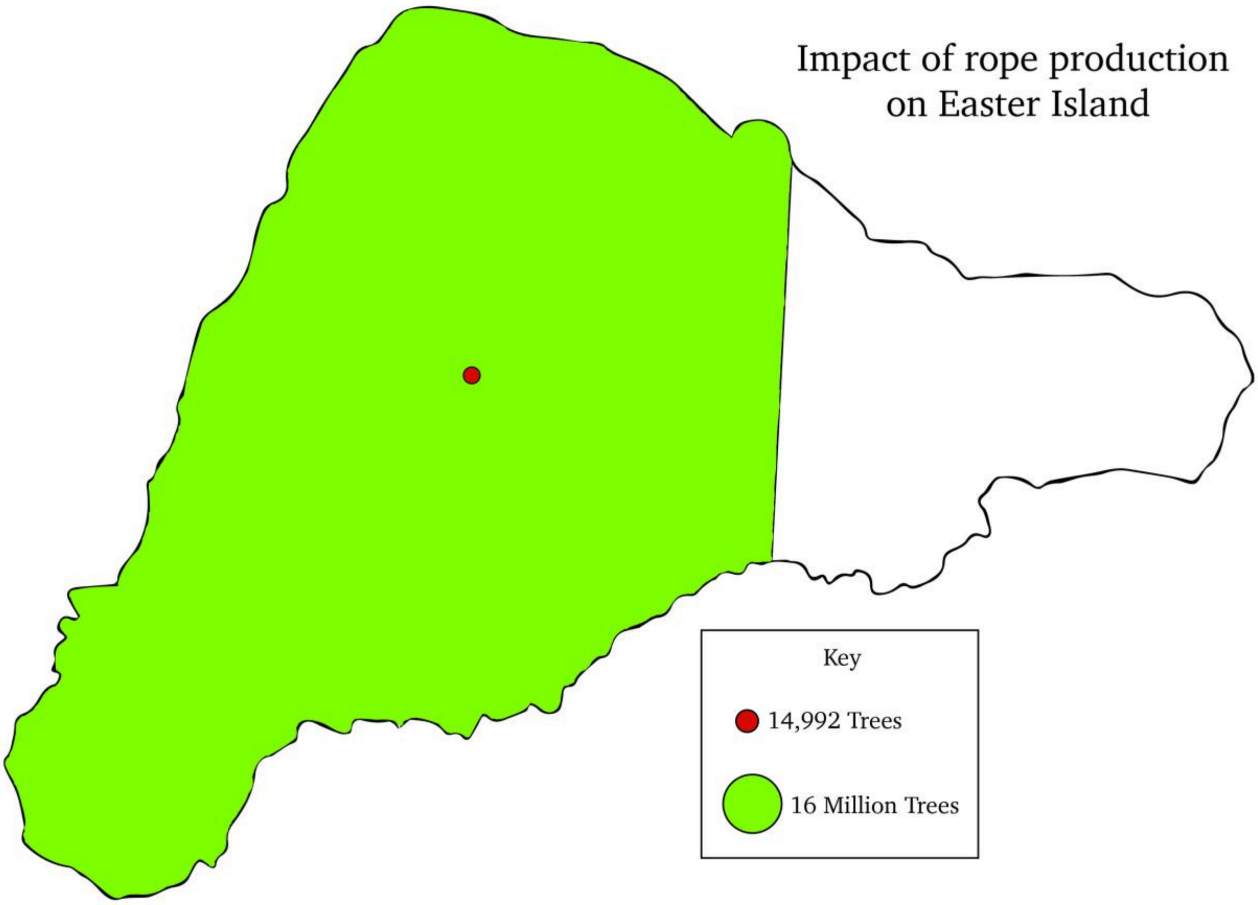


FIG 12. AN APPROXIMATE VISUALIZATION OF THE LOSS OF TREES IN COMPARISON TO THE POPULATION OF PALMS ON EASTER ISLAND.