Testing the insulatory properties of *Ulex europaeus* as a means of protecting *Acacia koa* from frost damage in Humuula, Hawaii

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Abstract

The Department of Hawaiian Homelands (DHHL) is currently working to increase biodiversity and productivity on Mauna Kea (DHHL, 2009). On the Windward slopes, in a place known as Humuula, the land has been dominated by *Ulex europaeus* (gorse), an invasive-thorny shrub capable of surviving sub-freezing temperatures. The DHHL is working towards increasing the Acacia *koa* (Koa) population in these gorse-covered areas on the land that they manage (DHHL, 2009). They are doing this by planting koa in rows, bulldozed into the gorse. A possible concern in this reforestation project is the susceptibility of koa to frost damage (Rose et al., 2020). The objective of this study is to record the temperatures inside of the rows of gorse to see if frost damage will be a concern and to compare these temperatures to previous studies which used conifers to increase temperatures.For the initial planting, five meter wide rows were bulldozed into the gorse field and koa was planted in the middle. In order to test the temperatures, 5 temperature sensors were set up in 4 different rows. Temperature readings will be taken every minute between December-March 2023 & 2024. This data will be extrapolated and turned into figures which clearly show minutes spent below freezing and absolute minimum temperature. I hypothesize that the gorse will provide similar temperatures to the conifers as its high density and height should protect the seedlings from wind and prevent some radiative cooling. Should this be the case, it will show that the risk for frost damage is minimal. If not, then further precautions will need to be taken to prevent frost damage.

Keywords

Invasive species, Native reforestation, seedling survival, climate, Mauna Kea, biocultural restoration

Motivation

In a place known as Humuula, on the windward slopes of Mauna Kea, lies thousands of acres of land which was once a native forest teaming with *Acacia koa* (koa) (Brown, 2016). Now, this same land is dominated by an invasive species known as gorse (Markin et al., 1996). *Ulex europaeus* (gorse) is a thorny shrub which is inedible to most ungulates (Leary, et al., 2006) and is capable of surviving sub-freezing temperatures. These two traits make gorse extremely difficult to remove (Leary, et al., 2006)**.** The Department of Hawaiian Homelands manages some of this gorse dominated landscape (DHHL, 2009). The DHHL is working to increase the productivity of this land to one that has more economic and ecological value (DHHL, 2009). Due to the difficulty to remove gorse, the DHHL started a project which bulldozed rows into the gorse and planted koa (amongst other trees) in these rows. The idea was that rather than removing gorse entirely (which is an immeasurable effort), koa and other conifers could be planted amongst the gorse.

One potential hazard that may hinder this project stems from the fact that Humuula is at the upper limits of where koa can grow; this being at 2000m (Rose et al., 2020). At this elevation, winter nights can get below freezing, leading to frost damage and higher mortality rates in seedlings (Rose et al., 2020). In the past, this has been avoided by planting koa seedlings under the canopy of conifers in order to create a warmer microclimate or creating a physical shaded structure (Rose et al., 2020). In this DHHL gorse row project, the frost damage was avoided by planting the koa seedlings in May. This maximized the amount of time that the seedlings could grow before the cold winter months. The hope was that the koa will be tall enough, and out of the surface level frost zone before it gets below freezing. However, should the

summer be particularly dry, there would be a high risk of mortality in the seedlings due to lack of water. Meaning, it would be extremely beneficial if the seedlings could be kept warm over winter and planted closer to the wetter, winter months.

It has not been studied whether gorse can create a warmer microclimate for the koa and it is unknown what the temperatures look like in this specific plot. Should the gorse hold warmer temperatures and limit the time spent below freezing, it would show that creating the rows in gorse is an effective way to reforest this native vegetation while protecting it from frost damage.

Background

The DHHL was allotted hundreds of thousands of acres of land in order to help the native people of Hawaii (Dinstell, 2000). Some of this land was turned into housing and leased to those with more than 50% Hawaiian ancestry (Dinstell, 2000). However, some land, such as Humuula, is not suitable for development due to its location and elevation (DHHL, 2009). Humuula itself is considered to be extremely sacred to the people of Hawaii and is known to be the land of the gods (Brown, 2016). During most of the 20th century, Humuula was leased to Parker Ranch and other ranchers who cleared out the land and used it for cattle grazing (Tribble, 2020). At the turn of the century, the lease with the cattle ranchers was ended and the land was left to rest (DHHL, 2009). It was during this time that gorse began to dominate this particular area.

Many extermination efforts have been made to remove gorse (Tulang, 1992). This includes crushing using a bulldozer, herbicide, biological control, and out-shanding (DHHL, 2009). Although the first two methods have shown some success, without constant upkeep, they are ineffective and inefficient. In order to out-shade, the DHHL planted *Acacia koa* (koa) amongst gorse to see if it could create a shaded canopy over the gorse. However, the gorse was

able to grow back and now surrounds the koa. This difficulty in removal is one reason why the DHHL has decided to plant koa amongst the gorse, rather than entirely removing it.

As mentioned previously, Humuula is located at 2000m of elevation (Rose et al., 2020). This is the upper range that koa can be found naturally (Rose et al., 2020). This is because koa, and many other native tree seedlings, will suffer from frost damage when exposed to sub freezing temperatures (Rose et al., 2020). A few ways to protect koa from frost damage include creating a physical structure surrounding the seedling or using a nurse species.

Using a nurse species to help seedlings grow is very common (Yelenik et al., 2017). In most cases, nurse plants are used to help underpopulated species re-establish themselves (Yelenik et al., 2017). Nurse plants can be used to help with sunlight, temperature, nutrients, or out-competing other invasive species (Yelenik et al., 2017). Using nurse trees for koa has also been tested and proved useful in Humuula (Rose et al., 2020). A study done in 2020 by Purdue University dealt with frost damage by planting *Cryptomeria japonica* (sugi pine) alongside the koa (Rose et al. 2020). This created microclimates and reduced frost damage in the seedlings (Rose et al. 2020).

This project was also done alongside the DHHL to help increase productivity in Humuula (Rose et al. 2020). In the end, koa was less likely to develop frost damage when planted with more cover from the sugi pine (Rose et al. 2020). Now, koa is commonly found planted alongside sugi pine and patches of sugi pine can be found all over Humuula. One issue with this is that sugi pine is not native, it is from Japan (Rose et al. 2020). Although it is not considered to be an invasive tree (Hawaii Invasive Species Council, 2023), it still takes time and resources to plant. Along with this, sugi pine takes

up surface area where koa can be grown. It would be interesting to test if the gorse, that is already present, could take the place of sugi pine and serve as a nurse plant to the koa.

There has not been a study done which specifically uses gorse as a nurse plant for insulation. The closest research to this was the previously mentioned Rose et al. paper coming from Purdue University. It was well documented in the Rose et al study that koa suffers from frost damage in Humuula. Rose also found that when planted with sugi pine, the koa seedlings are protected from the cold (Rose et al., 2020). Although this method worked, there has not been any research done on using an invasive species to protect koa seedlings from frost. Along with this, the technique of creating rows in the gorse and planting koa throughout the wind rows has not been done in Humuula. This research will show exactly how cold the rows get in comparison to the sugi pine and how far from the gorse the trees need to be planted to stay the warmest.

Objectives

The reforestation of koa is extremely important to the DHHL. This study will help this effort in a few ways. The main objective is to test a technique to keep koa seedlings insulated over the wintertime. Observing different temperatures throughout the rows of gorse will show how effective this rowing technique will be. This data can also be compared to the Rose paper to show whether sugi pine or gorse is a better insulator.

Approach

In May 2022, the Department of Hawaiian Homelands (DHHL) crushed 8 rows, each 150m long and approximately 5m wide. This was done using a bulldozer to crush and plow through the gorse. After this was done, half of the rows were treated with

herbicide to see if it would reduce regrowth. The hope is that the rows of gorse will give the koa seedlings enough time to take root and grow before the gorse regrows. Inside of the rows, Koa (*Acacia koa),* Sugi Pine (*Cryptomeria japonica),* and redwood (*Sequoia sempervirens*) were planted in varying distances and combinations. In order to gauge the temperatures inside of the row, we will start by using Hobo MX2202 temperature gauges. These sensors are used in many different applications and studies requiring rugged, outdoor sensors running for long periods of time (Tutton et al., 2021). They are also able to sense light which helps temperature differentiations due to light energy. These sensors will take a temperature reading every minute. Five Hobo sensors will be placed per row. One outside of the row as a control, one in the middle of the row, one 1 meter and 1.5 from the center sensor (to align with where the seedlings are planted and the edge of gorse), and one 3 meters into the gorse row. This will be repeated 4 times for a total of 20 sensors. Data will be taken over the two winters (December to April) during 2022-2023 and 2023-2024. After the data is collected, the approximate 6 million temperature readings will be analyzed using an "R" package which will display the average minimum temperature at each sensor location in the gorse as well as the minutes spent below freezing.

Outputs

The outputs of this study are crucial as they will show the DHHL whether the gorse row technique is worth their time, money and whether it is a capable insulator. In order to show temperature, the first output will be a map showing exactly where in the gorse the temperature sensors will be placed. I will also create another map showing the

land in Humuula managed by Humuula and highlighting where the plot is. On this map, elevation will be shown in order to give an idea of what land in this region is a candidate for gorse rows. Lastly, I will create two figures, one for minimum temperature and one for minutes below freezing, using the "R" package. This analysis will also be compared to the results of the sugi pine study to show which technique creates warmer environments for the koa. These outputs will all be made with visual aids (either maps or figures) to simplify the results for any project manager to read.

Outcomes

Should this gorse produce warmer temperatures, the DHHL, specifically our contact Kualii Camara, and the people of Hawaii will gain multiple positive outcomes. The first being a new technique/method to reforesting koa using gorse that is resistant to frost damage. This method would also allow koa to be planted during more months out of the year and closer to wetter winter months. If this were to be the case, these koa-gorse rows could be implemented on a larger scale across the thousands of acres that make up Humuula. Using the already existing gorse to insulate koa would make it simpler to massively increase the koa population. Increasing the biodiversity and potential economic productivity (lumber) of the land.

Timeline

The rows were bulldozed into the gorse, herbicide sprayed, and seedlings were planted in May 2022. The sensors were set up and planted in December of 2022. Data will be taken between January and March for both 2023 and 2024 winters. Once a month,

data will need to be downloaded from the sensors. Once this happens, the temperature readings can start to be synthesized. After March 2024, all data will have been taken and the analysis can be written. By May 2024, a final paper and capstone project will be completed, turned in, and shared amongst stakeholders. Most important stakeholder being the DHHL.

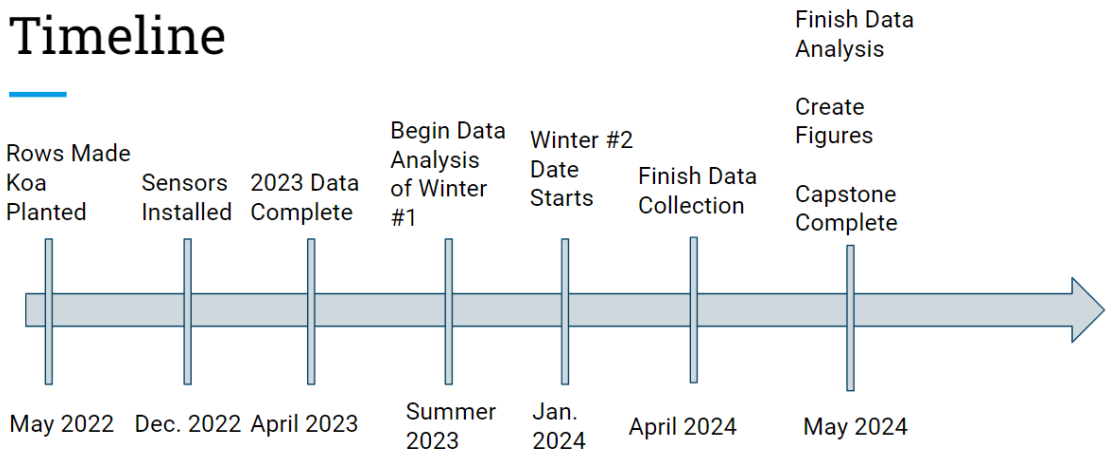

Figure 1: Timeline

Resources Needed

20 Hobo MX 2022 sensors are the most expensive, important resource for this study. JB Friday and the College of Tropical Agriculture and Human Resources (CTAHR) have already helped and pitched in for 15 of these sensors. For the mounting of the sensors, zip ties, fence posts, and a funnel for sun shade are also needed. Along with this, transportation to and from Honolulu to Mauna Kea once a month will need to be arranged including airfare between HNL and ITO as well as use of the NREM truck located in Hilo. Access to the plot is provided by the

partnership between DHHL and CTAHR however the permitting to do so will need continually updating. Finally, a computer capable of running large “R” algorithms and an iPad to download the data via bluetooth from the sensors will need to be purchased along with the required software. I would like to thank my capstone Panel Dr. Douglass Jacobs, Dr. Travis Idol, and Dr. JB Friday for their help with this project. Along with them, Kualii Camara is the manager of this region through the DHHL and the work would not be possible without him. All resources have been acquired through the generosity of the Hauoli Mau Loa Foundation, Dr. JB Friday, Dr. Travis Idol, and Kualii Camara.

References

Brown, Marie Alohalani. "Mauna Kea: Ho'omana Hawai'i and Protecting the Sacred." *Journal for the Study of Religion, Nature & Culture* 10.2 (2016).

DHHL. “Aina Mauna Legacy.” *Ho’okuleana.* (2009)

Hawaii Invasive Species Council. “Invasive Species Profiles.” *DLNR.* (2023).

Leary, J. K., et al. "The major features of an infestation by the invasive weed legume gorse (Ulex europaeus) on volcanic soils in Hawaii." *Biology and Fertility of Soils* 42.3 (2006): 215-223.

Markin, George P., Ernest R. Yoshioka, and Conant, Patrick. "Biological control of gorse in Hawaii." *Proceedings of the IX International Symposium on Biological Control of Weeds*. University of Cape Town Stellenbosch, South Africa, (1996).

Rose, Kyle ME, et al. "Canopy openness affects microclimate and performance of underplanted trees in restoration of high-elevation tropical pasturelands." *Agricultural and Forest Meteorology* 292 (2020): 108105.

Tribble, Sarah. "Assessing Land Cover Dynamics and Evaluating Potential Management Implications of Gorse on Mauna Kea, Hawaii." (2020).

Tutton, Rosamond J., and Way, Roberts. "A low-cost method for monitoring snow characteristics at remote field sites." *The Cryosphere* 15.1 (2021): 1-15.

Yelenik, Stephanie G. "Linking dominant Hawaiian tree species to understory development in recovering pastures via impacts on soils and litter." *Restoration Ecology* 25.1 (2017): 42-52.