Traditional Innovation: A Borrowed Approach to Hawaiian Dryland Agriculture

Is it Possible to Increase Sweet Potato Yields by Introducing a Non-native Intercropped Species When Compared to Traditional Sugarcane?

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ABSTRACT

Discovering a functional relationship between plant species to increase agricultural productivity is a reliable agricultural alternative to conventional monocropping in Hawaii. Due to colonization in the 19th century, Native Hawaiian Traditional Ecological Knowledge (TEK) of farming practices were lost, resulting in a loss of culturally significant food production. Hawaiians historically relied on sweet potatoes for sustenance. Sweet potatoes are a prehistorically introduced crop brought to the Hawaiian Islands by early Polynesian discoverers. Native Hawaiians traditionally intercropped sugarcane and sweet potatoes as this method created a successful agricultural system. This proposal examines mutualistic plant relationships of sweet potatoes by comparing intercropped agricultural methods to increase sweet potatoes yields. Evaluation of sweet potato nutritional profile amongst different agricultural methods will detect if intercropped crops are more nutritionally healthier. The results will create a framework for integrating positive results into Hawaiian agricultural systems. This proposal will contain twelve experimental plots divided into four equal groups: a control group consisting of sweet potatoes only, a traditional plant group consisting of sugarcane/sweet potatoes, a nitrogen-fixing plant group, and a phosphorous-fixing group. Results from statistical analysis using variance analysis will determine if there is a significant difference between the different growing methods of sweet potato yields. The results will likely suggest that a non-native intercropped plant increases sweet potato quality and yields because the intercropping plants would make the soil more nutrient dense. The research is valuable because it proposes a sustainable alternative agricultural practice in Hawai'i by applying the TEK of ancient Hawaiians. This proposal has the potential to revitalize traditional systems to give power back to Indigenous people and combat of climate change issues.

LITERATURE REVIEW

Introduction

The central focus of this proposal is investigating the role of the sweet potatoes on agricultural properties of the Leeward Kohala field system because it was the historically significant staple in ancient Hawaii. The Leeward Kohala field system is an ancient agricultural system built by ancient Hawaiians before European-contact (Lincoln et al., 2018). The practice of *'Aina Malo'o* (Hawaiian dryland agriculture) successfully produced significantly more food than the more well-known form of Hawaiian agriculture *'Aina Wai* (Hawaiian wetland agriculture) (Lincoln et al. 2018). *'Aina Malo'o* is prominent on younger islands like Hawai'i island and Maui (Lincoln et al., 2018). Dryland agriculture made way for a broader range of resource crops such as fiber, timber, and medicine that was later used in establishing an economic base giving power to Hawaii chiefs that inevitably took over the archipelago (Lincoln et al. 2018). Lanikeha sweet potatoes will be used in the experiments. The proposed research explores intercropped crops' mutualistic relationship and distinguishes a correlation between the number of sweet potatoes produced. Furthermore, the research measures the nutritional profile of sweet potatoes to determine how these mutualistic relationships influences the nutritional value of native sweet potatoes. The results of this proposal can be used to introduce a foundation for Native Hawaiian methods of farming and revitalizing traditional foods.

History and TEK of intercropping

Traditional Hawaiian intercropping of sweet potato and sugarcane established entire functioning societies before colonization. Colonization severely impacted the Leeward Kohala field system and the Native Hawaiian population (Kagawa & Vitousek, 2012). Prior to the arrival of early Polynesian discoverers, the Leeward Kohala field system was essentially untouched Hawaiian dryland forest (Ladefoged and Graves, 2008). Around 1100 to 1650 AD, a rapid expansion of Hawaiian dryland agriculture in Leeward areas began (Ladefoged and Graves, 2008). The Leeward Kohala field system was a series of agricultural walls and ditches integrated into a grid-like network of trails leading to residential populations, religious sites, and other agricultural features (Ladefoged and Graves, 2008). Ancient Hawaiians mastered intercropping of ‘Uala (sweet potato) along with Ko (sugarcane), sweet potato being the dominant crop occupying these regimes (Ladefoged and Graves 2008). The sweet potato was an essential staple for ancient Hawaiians. This research brings to light historically significant food sources and contributes to understanding ancient Hawaiian agricultural practices. The methods of TEK could bring food sovereignty to Hawaii communities and establish a healthier food economy.

Archeologists and soil scientists focus on the Leeward Kohala field system because of the system’s highly productive agricultural properties. Ancient Hawaiians developed this system through calculated manipulations of the environment before European contact. The abandonment of the Leeward Kohala Field system is primarily due to diseases in the Native Hawaiian population and socio-political changes (Aurora K. Kagawa and Peter M Vitousek, 2012). The introduction of cattle and grazing after colonization obliterated the agricultural productivity of these systems (Aurora K. Kagawa and Peter M Vitousek, 2012). Scientists and cultural practitioners are trying to regain the knowledge of traditional agricultural practices that were lost due to colonization. (Aurora K. Kagawa and Peter M Vitousek, 2012). The suggested research contributes to the lack in literature by modifying the Leeward Kohala field system to adapt to climate change, using traditional Hawaiian farming practices. The importance of the research is to restore productivity to these systems for future agriculture use in Hawaii.

This research focuses on utilizing the Leeward Kohala field system to become more resilient against climate change. The purpose of my research is to alter the Leeward Kohala field system to work better for today's environment while utilizing the ancient Hawaiian's agricultural methods. In 2019, an article by *Nature Sustainability* discussed the agricultural potential of restoring ancient Hawaiian food systems and how the restoration of Hawaiian agricultural systems can increase local food production (Kurashima, Fortini, and Ticktin, n.d.). The literature reveals tubers are highly resistant against droughts and high humidity, making sweet potatoes the ideal crop against climate change (Zhu et al., 2011). The significance of the project lies in creating resilient agriculture to combat the effects of climate change. The implication of the research is to propose reliable food production through traditional agricultural methods to implement food sovereignty that will make Hawaii better equipped against climate change.

Intercropping

Intercropping is planting two or more crops together in the same area to facilitate growth (Jurik & Van, 2004). Intercropping has a multitude of agricultural benefits relative to conventional monocropping practices. Many people do not see the value between cultural traditions and agricultural practices; however, the art of intercropping has been passed down through Indigenous communities for centuries (Ngapo et al., 2021). A prominent model of Indigenous intercropping derives from various Native American cultures known as the Three Sisters; involving squash, corn, and beans (Terry et al. 2020). The Three Sisters style of intercropping provides balanced soil chemistry and a nutritionally balanced food supply (Terry et al. 2020).

In some cases, intercropping exhibits higher productivity per unit of land than mono-crop systems and include diverse food production allowing for excellent economic value (Temple, 1976). This effect might occur because of the diverse or similar nutrient resources amongst various crops (Jurik & Van, 2004). Likewise, researchers from Cenderawasih University and Macdonald Campus of Mcgill University compared the pest population of intercropped sweet potatoes and mono-crop sweet potatoes found fewer pests and damage to the intercropped sweet potatoes (Yaku, Hill, and Chiasson, 1992). A substantial component of the research is highlighting the value of Indigenous Hawaiian intercropping practices and elevate appreciation for Indigenous knowledge by proving the applicability in the modern era.

Intercropped food sources share and input nutrients into the soil. Growing food in an intercropped style suggests the likelihood of nutritionally valuable crops. An examination of mixing crops revealed a higher total calorific value amongst intercropped plants (Chinaka and Obiefuna, 2000). Discovered during an intercropping experiment, the mutualistic relationship of maize and sweet potato displayed large amounts of energy production and nutrients producing higher caloric content in crops (Moreno, 2014). The proposal contributes to understanding plant relationships and the probability of generating higher quality produce. The results of my research can propose healthier and locally sourced food options to people in Hawaii.

Past sweet potato and sugar cane intercropping

Native Hawaiians discovered the existence of a functional relationship between intercropping sweet potatoes and sugarcane. Traditional agricultural systems on Hawaii island are distinguished by elongated linear hills and stone mound structures (Lincoln et al., 2018). The hills consist of stalky plants such as sugarcane, banana, and ti-leaf, and the ditches in between each hill were carpeted with root crops such as sweet potato, taro, and yams (Lincoln et al., 2018). One of the focuses of the research will be centered around the relationship between sweet potatoes and sugarcane. The University of the Philippines investigated the light interception of mono-crop sugarcane and intercropped sugarcane. The relationship between sweet potatoes and sugarcane demonstrated the earliest time of light interception, collecting greater than 50% of incoming radiation (Mendoza, 1986). Sweet potatoes and sugarcane were the relationship that collected the highest amount sunlight (Mendoza, 1986). Furthermore, when looking into various intercropped varieties of sugarcane amongst several plant species, sweet potato was among the few plants producing higher profits than when sugarcane was grown alone (Parsons 2003). However, both studies concurred the diversity of food products made for better profits but the main plant species being studied did not increase in yields (Mendoza, 1986). My analysis will fill in the gap in research because many of the studies are outdated; the most recent is dated over a decade ago. Agricultural research involving the relationship between sweet potato and sugarcane focused primarily on sugarcane, whereas my research centers around sweet potato yields and effectiveness of the sweet potato and sugarcane relationship. Utilizing an Indigenous farming method in dryland agriculture makes the research unique and specific to Hawaii. Understanding the relationship between sweet potato and sugarcane through an Indigenous lens makes my research unparalleled to other literature.

Nitrogen fixation on tubers

Nitrogen fixation is a critical aspect of plant development. Investigating the role of nitrogen in sweet potato growth will develop a firm understanding of the agricultural productivity of sweet potatoes. A variance analysis found potatoes and cabbage held the highest yields when planted after lupin beans were harvested (Mugo, Obura, and Schulte-Geldermann, n.d.). Leyte State University researchers planted sweet potatoes with inoculated and uninoculated legumes.

The data revealed sweet potatoes increased when planted with inoculated legumes (Quirol, Escalada, and Manatad, 1984). Inoculated legumes were the legumes sprayed with nitrogen fixing bacteria. Inoculated legumes input higher nitrogen concentrations into the soil and created ideal growing conditions for cabbage and sweet potatoes (Quirol, Escalada, and Manatad, 1984).

Additionally, a study by Standford University exploring pre-European Hawaiian agriculture, revealed that nitrogen was deposited into the soil by decomposition of leaf and stalk litter from the sugarcane plants (Lincoln and Vitousek, 2016). Although existing information seems promising, this research contributes to the absence of literature on the effects of nitrogen fixation on tubers. Analyzing the role of different vegetation used in various farming methods can unveil the specific roles of nutrients to sweet potato growth.

Utilization of a Non-native Plant Species

There is a negative attitude towards non-native plants naturalizing in areas where they do not originate. Many individuals associate the introduction of non-native plants with the devastating effects of the influx of invasive species. *Big Island Invasive Species Committee* claims most plants are non-invasive, but a small percentage can cause harm to agriculture, human health, and the health of the environment (Big Island Invasive Species Committee, n.d). For this reason, the proposed research is unique because it involves utilizing a non-native plant that established itself in Hawaii. A study in Papua New Guinea examined the relationships between sweet potatoes yields and fallow species; researchers discovered after two cropping seasons there was a significant decrease in phosphorus in the soil (Hartemink, 2003). If my hypothesis is correct, pairing the sweet potato with a plant that is efficient at breaking down the soil, should increase soil phosphorus levels thus increasing the number of sweet potatoes. The plant for this experiment is *Abelmoschus manihot*. The organization *Plant Pono* is a non-profit Hawaii directory that assesses the risk potential of any non-native plant species in Hawaii (Chimera, n.d.). *Plant Pono*'s mission is to assist Hawaii residents in making educated decisions about introducing non-native plant species to Hawaii. The risk assessment on *Abelmoschus Manihot*, is classified as a low-risk plant, there is little to no severe impact on the environment in Hawaii (Chimera, n.d.)

The *Abelmoschus Manihot* grows well in loamy soil and full sun, indicative of the Leeward Kohala field system ("Abelmoschus Manihot," n.d.). The *Abelmoschus Manihot* grows in grasslands and near ditches. *Abelmoschus Manihot* is predicted to work in the Leeward Kohala field system due to ditches and extensive grassland (Luan et al. 2020). The height of the plant is expected to grow from four to six feet. If this is true, the *Abelmoschus Manihot* can mimic the function of the sugarcane in the traditional style of intercropping (Luan et al. 2020). Additionally, the leaves and flowers on *Abelmoschus Manihot* are edible, doubling as a secondary food plant alongside sweet potatoes (Luan et al. 2020). According to the risk assessment, the *Abelmoschus Manihot* has a long history of domestication, justifying using the plant in a controlled environment (Chimera, n.d.). Investigating non-native plants in agriculture can fill the gap in the literature on the study of non-native plant advantages. The importance of my research is to begin looking into the benefits of introduced species instead of eliminating their potential.

Environmental Interactions with the Leeward Koahala field System

Environmental effects of the Leeward Kohala field system include the fluctuation of precipitation, soil composition, and temperature contributing to the overall agricultural productivity. Studies are decoding the environmental interaction of the Leeward Kohala field system and how this system was successful in producing tremendous amounts of food. A rain gauge located nearest the Leeward Kohala field system displayed a constant increase in precipitation within the past decade ("USGS Current Conditions for USGS 200518155405801 185.7 Kawainui Rain Gage near Kamuela, HI" n.d.). A study done by the University of Hawaii at Manoa displays extreme weather events and the increase in common storms on Hawaii island during the study's timeframe (Chen and Chu, 2014). Hawaii responded to these concerns with the development of Hawaii's Climate Change Adaptation Plan and recognizes the impending issues of climate change ("Adapting to Climate Change" n.d.). According to Hawaii's Climate Change Adaptation Plan, as climate variability increases, the demand for adaptations for Hawaii farmers will be difficult heading into the future ("Adapting to Climate Change" n.d., p.2-13). As climate change in Hawaii is evident, Hawaii farmers and politicians must find an effective response to emerging issues.

RESEARCH DESIGN

Restorative agricultural methods worked in areas experiencing similar climate change conditions to develop a resilient agricultural system. For example, a region with identical climate conditions is Zimbabwe, Zimbabwean farmers experimented and found success in intercropping food crops to increase agricultural productivity to adapt to climate change (Zhu et al., 2011). The Agricultural Productivity Index (API) will track the agricultural productivity of the Leeward Kohala field system (Dharmasiri, 2009). The API will calculate the agricultural potential of the system. The agricultural productivity index will include the inputs of the system such as soil composition, precipitation, and temperature and calculate outputs such as the weight of sweet potato yields and quality of sweet potato yields. This data will answer the research question because the information will systematically determine the agricultural potential for each experimental plot by recording each yields nutrient content and weight.

Data collection for my research project will involve experimental gardens within the Leeward Kohala field system. The experimental garden will be grown as the system intended, with one plant species grown on the little hills and the sweet potatoes grown in between each hill. The system is grown horizontally, parallel to the ocean. There will be twelve plots in the experimental garden; three plots will be the control group, nothing will be paired with the sweet potatoes, three plots will have traditional sugarcane, three plots will have nitrogen fixing plants, and three plots will have a pioneer plant to increase phosphorus. The plots will be staggered, and no plot will be next to the same kind of plot as itself. *Sri Lanka Journal of Advanced Social Studies* used the API in an analysis evaluating the crop per harvested areas for ten food crops including sweet potatoes (Dharmasiri, 2009). The API is an ideal method because it allows for a simple comparison between the growth rate of each plot amongst one another, confidently determining which plant relationships increased the number of sweet potatoes.

All the plots will be planted with the Lanikeha, a Hawaiian variety of sweet potatoes. Four Lanikeha sweet potatoes of the same variety will be chosen from each plot yield within two growing seasons. After each yield, samples will be collected. Samples will be prepared in two ways. Two of the four samples of each plot yield will contain the flesh and skin of the sweet potatoes while the other two samples will have the flesh but not the skin (Terry, Pearson, and Holder, 2020, p.103). The raw samples will be separated and cooked in a conventional oven at 350 degrees Fahrenheit for 30 minutes (Terry, Pearson, and Holder, 2020, p.103). Sweet potato samples will be submitted to a lab and undergo a macronutrient and micronutrient analysis. The macronutrient analysis will determine the number of calories, carbohydrates, fiber, and protein for each plot yield. The micronutrient analysis will detect the number of vitamins and minerals for each yield of sweet potato. An additional four Lanikeha sweet potatoes will be selected from each experimental plot. The samples will undergo a dehydration process and be measured for their dry weight.

Once the data is collected, the next step will be inputting the value of each plot into the agricultural productivity index to confirm the productivity of each plot. Upon the results of the agricultural productivity index, there will be a comparison of each plot against one another to understand which plots generate the higher quality sweet potatoes and the most significant yield of sweet potatoes. The quality of the sweet potato yields will be measured by the levels of nutrients from different yields and the weight of each yield. The results will be implemented into a graph revealing the nutrient content of the sweet potatoes from each plot to visualize the uptake and return levels of nutrients. This research design works because the design will help visualize the plants' relationship.

ACADEMIC PREPARATION

My experiences with the Kupu Hawaii Youth Conservation Americorp internship and majoring in environmental science has developed a strong understanding of ecological problems and food insecurity issues in Hawaii. The potential for large agricultural systems has become of great interest to individuals looking for a change in sustainable farming. I also have worked intimately with the Leeward Kohala field system. As a Hawaii resident, I thoroughly understand the functions of the environment through an Indigenous perspective and the need for better agricultural practices. When I worked in the conservation industry in Hawaii, it aided my decision making about the species of plant that I will choose to implement in my research. Unfortunately, Hawaii has many historical incidents where species were introduced and devastated the environment, so I will be sure to not introduce a plant species that will harm the environment. Ideally, I intend to plant a non-native plant that is already established in Hawaii.

The plant species applied to the Leeward Kohala field system will be deliberately planned to avoid harm to the environment and increase agricultural production.

My studies as an environmental science major have equipped me with the abilities to execute my research project. Within this past year, I wrote an environmental assessment. The assignment was to create a hypothetical project while abiding by the criteria of the Hawaii Environmental Policy Act (HEPA) rules as if it were an official government document. My environmental assessment project has refined my writing and sharpened my critical thinking skills. Simultaneously, I wrote a sustainable agricultural business plan. From a business standpoint, my research into the agriculture industry correlated with my experiences as an Americorp intern carrying out emergency food distribution in 2020. The opportunity to actively feed my community gave me profound insight into the alarming inadequacy of Hawaii's agricultural resources and dependance on imported food.

CONCLUSION

Thoroughly understanding the interaction between plant species incite profound knowledge that will benefit the greater well-being. Investigating the results of this proposal can reclaim culturally significant Hawaiian agricultural systems in Hawaii. The results of this proposal can be a starting point to developing a framework to integrate healthier, locally sourced, and historically significant foods to the people of Hawaii. This project is intended to be presented at a University of Kansas undergraduate poster presentation. This proposal will be submitted to the annual American Indian Science and Engineering Society (AISES) committee to apply to the AISES conference in 2021.

The ultimate success of this project is to introduce the idea to the agriculture industry in Hawaii. The purpose of this proposal is to develop a resilient and reliable food resource. Hawaii was once an independent and sustainable kingdom. The aspiration for this project is to help Hawaii become less dependent upon imported foods, eventually revolutionizing Hawaii's economy. There is hope that we can build cultural sovereignty by integrating cultural values and practices into our daily lives.

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